

# HM DCC



*This Reference Manual is continually under revision. If you have downloaded this manual in the past, please ensure that you have downloaded or are viewing the latest version. We are open to any suggestions re the manual content or what might be missing within the context of the manual. The date of this revision is within the file name.. e.g. "HM7000 Series Decoder Reference Manual - DDMMYY" and also appears on each page footer. There is also a version reference number... RX.X*

## HM7000 SERIES LOCOMOTIVE DECODERS

Sound and Non-Sound Bi-Mode DCC BLE types

Manual Version 1.3 ... Decoder Version 1.3

### FULL REFERENCE MANUAL

Kenn Wards & Chris Reilly

#### **Please Read this first!**

The HM7000 decoder is a delicate piece of electronic equipment. Some individual components on the circuit board are minute and are easily damaged. Therefore, we recommend some caution when handling the decoder. In the case of the 21-pin type decoder, do not use a screwdriver or other pointed tool to prise the decoder from its mounting in the locomotive. Always, ease the decoder from its mounting by gripping the edges of the decoder circuit board.

While the decoders are reasonably resilient to electrostatic discharge through general handling, it does not hurt to discharge yourself before handling the decoder. A convenient way to do this, is to touch one of the fascia plate screws on a standard mains wall socket. These screws are always tied to earth. Please note this might apply to the UK only... check your local mains wiring regulations for earthing standards regarding mains outlets.



# Contents Decoder Firmware Version 1.3.0 Manual 1.3.0

<b>What's In the box?</b>	<b>12</b>
<b>Sound Decoders..... First time use of a decoder... do this!</b>	<b>13</b>
First things...	13
If you do not have the APP... get it!	13
Setup APP procedure...	14
Linking your new decoder to the APP.	14
Set Address and Locomotive name and Mode of control.. e.g., Bluetooth, DC or DCC.	14
Download and install the desired Sound Profile.	14
<b>About this reference manual... Scope...</b>	<b>16</b>
Function and hardware naming...Conventions...	16
Definition: OTA...	16
<b>HM7000 Series Decoders... What are they???</b>	<b>17</b>
What?	17
Summary	17
Bluetooth advantages...	18
We do not recommend DC operation ... Why?	18
<b>HM7000 Decoders... the basic features... an outline.</b>	<b>19</b>
<b>HM7000... Meet the Family...</b>	<b>21</b>
Introduction...	21
<b>Sound Decoder Types and Connection</b>	<b>22</b>
21 Pin BLE Decoder ... HM7000-21TXS ... R7322.....	22
Mounting 21MTC Decoders... There are two modes of mounting: "Compact" and "Rotated" ...	24
Compact variant	24
Rotated variant	24
8 Pin BLE Decoder ... HM7000-8TXS ... R7336.....	25

Next 18-S Pin BLE Decoder ... HM7000-N18TXS ... R7345.....	27
<b>Non-Sound Decoder Types and Connection</b>	<b>29</b>
8 Pin BLE Decoder ... HM7000-8 ... R7335.....	30
6 Pin BLE Decoder ... HM7000-6 ... R7321.....	32
<b>Decoder Function Lists and Function Description.</b>	<b>35</b>
General...	35
Sound Decoders... Functions range	35
Non-Sound Decoders... Function range	35
Electro-Diesel Sound Decoders... Features and Functions	36
Diesel Sound Decoders... Features and Functions	37
Electric Sound Decoders... Features and Functions	38
Steam Sound Decoders... Features and Functions	39
Non-Sound Decoders... Features and Functions	40
<b>Decoder Firmware Description, User Updates, Sound Profiles, and getting help.</b>	<b>41</b>
OTA updates	41
Decoder Updates and firmware structure... Sound Decoders	42
Structure Notes... and updates	42
General Description of the decoder internal firmware structure...	42
APROM ... the Control Code	42
SPIROM ... the Sound Code etc	42
Firmware Version Numbers	43
Decoder Updates and firmware structure... Non-Sound Decoders	43
<b>HM7000 Bluetooth Mesh operations ... System Overview</b>	<b>44</b>
<b>The Common CVs...</b>	<b>45</b>
General Description	45
CV1... Primary Address	45
CV2... Vstart	45

CV3... Acceleration Rate	45
CV4... Deceleration Rate	46
CV6... Vmid	46
CV7... Manufacturer Version number	46
CV8... Manufacturers ID and <b>RESET</b> decoder.	47
CV10... Back-EMF Feedback Cut-out Speed Step	47
CV12... Decoder Control mode select... DCC/BLE/DC... Sound Decoders Only.	47
CV17 and CV18... Storing Long Addresses	48
CV19... Consist setup... Decoder based consist set up.	49
CV27... Asymmetric DCC (ADCC) Configuration... (ABC operation) ... rail select.	51
CV29... Decoder Configuration ... general explanation	52
CV29 ... Examination of each bit and its function...	53
bit0 ... Reverse Motor Direction ... EQD = 1 (Equivalent in Decimal.)	53
bit1 ... Headlight/rear light direction control... FL ... EQD =2.	53
bit2 ... Power Conversion mode ... EQD = 4	53
bit3 ... RailCom enable ... EQD = 8...	54
bit4 ... Speed Table Select ... EQD = 16	54
bit5 ... Address Selection... “short” or “long” address mode ... EQD = 32	55
bit6 ... Reserved...	55
bit7 ... decoder type select...	55
<b>CV47, CV48 and CV49... Control Processor Firmware Version... APROM</b>	<b>56</b>
<b>CV51 to CV58... Lighting Configuration description...</b>	<b>57</b>
General Description	57
Summary... Hi-Level Outputs	57
Setting Lighting Effects and Brightness...	58
<b>CV59 to CV66... Auto Function Control (AFC)</b>	<b>59</b>
<b>CV67 to CV94... Complex Speed Table Configuration</b>	<b>60</b>

<b>CV119... Function Mask Select for multi decoder locomotives...</b>	<b>61</b>
<b>Special Decoder Functions... F25/28 Sound Decoders ... F5/F8 Non-Sound Decoders... configured by CV120 to CV124</b>	<b>63</b>
General Description	63
F25... Shunting mode... CV120	63
F26... “Creep” mode... Coupling Assist CV121-122	64
“Creep Mode usage suggestions...	64
“Creep” ... carrying out precise coupling procedures etc.	64
“Creep” used with trackside uncouplers ... uncouple/coupling operation.	64
F27... Manual Application of Brake during normal deceleration... CV123	65
CV125 to CV127... ABC/ADCC Actions...	65
See Appendix 4... Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)	65
<b>F28... Enable/Disable Auto Function Control (AFC) of Spot Sound Play ... CV59 – CV66</b>	<b>66</b>
Programming explanations...	67
Sound Selection... help...	67
Working out CV values to enable specific sounds...	68
Notes re Selecting sounds for AFC control... Please read this.	68
F8... “Push Button” operation, set speed... CV??? This feature applies only to non-sound decoders.	69
<b>Sound Decoders... adjusting sound volumes etc.</b>	<b>70</b>
Steam Locomotives...	70
Diesel Locomotives... Electric Locomotives etc.	70
CV159... Volume of F0 (re Sound Only Projects... Does Not Apply to Locomotive decoders.)	71
CV160... ELECTRIC motors volume	71
CV161... Steam/Diesel engine volume on Acceleration and Deceleration	71
CV162 to CV180... Set individual volumes of Spot Sounds F2 to F20	72
Spot sound by F#... “Volume configuration” CV table...	72
CV200 to CV203... Sound IDs and Versions... SPIROM	73
<b>Horn and Whistle Selection re F2 and F3... Configuration... CV205 to CV208...</b>	<b>74</b>

Programming tips...	75
<b>DIESEL LOCOMOTIVES Engine Running Sound Playback... 3 Notch and 4 Notch Systems.</b>	<b>76</b>
3 Notch Diesel... Configuration... CV210 to CV215	76
4 Notch Diesel... Configuration... CV210 to CV217	76
Diesel Sound... How it works... 3 or 4 notches... Detail...	77
Diesel... Examples of operation	78
CV225... Start delay after Brake release ... Diesel Locomotives Only	79
<b>ELECTRIC LOCOMOTIVES... Engine Running Sound Playback...</b>	<b>81</b>
Explanation and Configuration... CV218 to CV222	81
<b>ELECTRO-DIESEL LOCOMOTIVES... Engine Running Sound Playback...</b>	<b>83</b>
Explanation and Configuration... CV210 to CV222	83
The DIESEL part...	83
The ELECTRIC part...	83
Examples of transition...	84
<b>STEAM LOCOMOTIVES... Non-Synchronised Wheel/Chuff system... Explanation and Configuration...</b>	<b>85</b>
Steam locomotive specific Complex Speed Curve...	85
<b>STEAM LOCOMOTIVES... "Piston Sync" Puff/Chuff system... Explanation and Configuration...</b>	<b>86</b>
<b>STEAM LOCOMOTIVES... Turbomotive ... Explanation and Configuration...</b>	<b>87</b>
Turbomotive: Operation Modes...	87
Turbomotive unique CV settings...	88
Steam Locomotives... Automatic Wheel slip behaviour simulation ... CV213 and CV216	89
Manual Mode...	89
Automatic Mode...	89

<b>Appendix 1: CVs... what are they?? What do they do? And dealing with binary, if you really want too...</b>	<b>90</b>
Bytes and bits.... and nibbles...	90
Convert a Decimal number to binary...	90
Convert a binary number to Decimal?	91
<b>Appendix 2: How Decoder addressing works...</b>	<b>92</b>
Definitions...	92
General Description...	92
Address selection... Long or Short?	92
How a Short Address is stored...	93
How a Long Address is stored...	93
Calculating values for CV17 and CV18	93
The Hexadecimal way... this the way programmers will calculate the values ... and it is convoluted!!!	93
Long Address Example...	93
This is easier... Binary only... no mention of hexadecimal!!	94
The default addresses set in the decoder are...	94
Short Address...	94
Long Address...	94
Controllers old and new and programming Addresses.	95
Older controllers...	95
More recent Controllers...	95
<b>Appendix 3: Using AUX Outputs... i.e., the Hardware Function Outputs... (HFOs)</b>	<b>96</b>
Introduction...	96
Load Type.. LEDs	97
LED Current Draw...	97
Connecting LEDS to 8 pin, 21 pi and Nex18 decoders.	99
Connecting LEDS to 6 pin decoders.	100
Bi-Colour LED Types...	102

LED types and sizes...	103
LEDs... Web further references...	104
Load type... Filament Bulbs/Incandescent lamps etc. ...	105
The Last Word... Resistors and power dissipation. IMPORTANT	105
Load Type... RELAYS	106
Example of typical DPDT relay...	107
Relays and Fly Back Diodes!!!! IMPORTANT	108
Fly Back... What's going on?!?	108
<b>Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)</b>	<b>109</b>
IMPORTANT... definitions... which is the right rail? Which is the left rail?	109
Introduction to ADCC/ABC	109
ADCC Explanation... how it works	110
Simple Diodes Matrix...	111
Which Orientation should the Diode Matrix be?	112
Build idea for the Diode Matrix...	113
Programming the ABC system...	114
CV27... Asymmetric DCC (ADCC) Configuration... rail select etc.	114
A Final Note re CV27.... This is a warning	116
A Final Note re "Bypass Switches" and use with ADCC track sections...	117
Some Ideas.. ADCC using a single Diode Matrix... that is, using one Diode Matrix to feed multiple track sections	119
Note re Diode Matrix bypass switches on One Diode Matrix configurations.	119
CV125 – CV127... Configuring the automatic action when ADCC is detected. (Asymmetrical DCC Operation) "ABC Control"	120
CV126... Stop Duration... Further operational notes.	120
CV126... More information re Constant Brake Distances (CBD)	121
Examples of CBD test data...	122
<b>Appendix 5: Reserved.</b>	<b>123</b>
<b>Appendix 6: All about Motor Control and Tuning... Speed Curves. PIDs and Things... ... CV143 to CV155</b>	<b>124</b>



Introduction	124
About Speed Curves	125
Evolution of Speed Step Curves...	125
HM7000 Decoders... implementation of the Basic and Complex Speed Curve system.	126
Explanation of the Speed Step Curve Graphs.	126
The BASIC Speed Curve... applies to all locomotives.	127
CV2 Vstart	127
CV6 Vmid ... this is the motor voltage when the SS = 72	127
CV5 Vhigh ... this the motor voltage wen SS = 255	127
COMPLEX Speed Curve... Diesel/Diesel Electric/Electric Locomotives.	128
COMPLEX Speed Curves... Steam Locomotives types...	129
Tuning the Motor Control Algorithms...	131
What is a Motor Control Algorithm?	131
Introduction...	131
Motor Control Algorithm specific to HM7000 Decoders... tuning...	132
Brief... The 3 Methods of algorithm tuning/adjustment in detail.	132
Stage 1... Auto Calibration	132
Stage 2... Further adjustment of the effectiveness of Auto Calibration parameters	132
Stage 3... Manual PID Calibration.	132
1, Stage One Control Algorithm... CV149 = 2 ***	133
Stage 1 ... Motor Control Algorithm base CVs: initial state and function.	134
2, Stage Two ... adding the PA Control factors... CV149 = 2	135
PA Motor Control algorithm further adjustment: initial state of CVs and Function.	135
3, Stage 3 ...PID Control Algorithm... (Manual Tuning) CV149 = 1	136
Introduction....	136
PID Motor Control algorithm: initial state of CVs and Function.	136
So... what's PID Motor Control Algorithm... how does it work?	137

Proportional... CV153	137
Integral... CV154	137
Derivative... CV155	137
<b>Appendix 7: Power Bank... Hornby “Stay Alive” Implementation.... And alternative” Stay Alive” arrangements.</b>	<b>139</b>
Hornby R7377 Power Bank...	139
Physical...	139
Smart Charging...	139
Special Note: Power Bank fitted decoder... Resetting/Rebooting the decoder... i.e. during decoder updates etc.	140
WARNING re use of Power Banks and “EMERGENCY STOP.”	140
Non-Hornby Stay Alive systems...	141
<b>Appendix 8: Complete CV list for all decoders.</b>	<b>142</b>
Common CVs to all sound decoder types.	142
Diesel Locomotives... Running Sound set up. Uniquely allocated CVs.	147
Steam Locomotives... Running Sounds set up. Uniquely allocated CVs.	148
Electric Locomotives... Running Sounds set up. Uniquely allocated CVs.	148
<b>Appendix 9: Decoder Operational, Electrical and Physical Specifications</b>	<b>149</b>
Sound Decoders Specification.	149
Non-Sound Decoders Specifications	150
<b>Appendix 10: Speakers.... Sugar Cubes and the rest...</b>	<b>151</b>
TT Locomotives... with factory fitted speaker.	151
00 Locomotives... with factory fitted speaker box/sugar cube.	152
DIY... Sugar Cube Speakers	153
Assembling the Sugar Cube kit...	154
Speaker Driver Installation...	154
Connecting the Speaker Driver to the decoder...	155
Supplied Speaker Driver and Audio Amplifier Specification...	155
What is speaker “Impedance?”	156

Using other speaker types with your HM7000 decoder...	156
Two speakers???	156
More than two speakers???	157
Some basic rules re calculating Impedance in arrays with multiple speakers...	158
For Speakers in series...	158
For Speakers in Parallel...	158
Speaker Arrays.... Going Further...	158
Speaker Polarities...	159
<b>Appendix 11: Recommended Power Supplies for HM7000 Decoders</b>	<b>160</b>
Introduction... the recommended power supplies...	160
Recommended Power Supplies in detail...	160
P9000W...	160
P9100W...	161
R7337/P9300W...	161
Notes...	161
WARNING... Other Power Sources... Laptop Type Power Bricks and Batteries etc...	162
Additional Overload Protection...	162
Analogue “Train Controllers” set to maximum output???	Not recommended!!!!
Special Note: Using HM6000 Circuit Outputs for BLE.	164
DC-Controllers not recommended.	164
<b>Appendix 12: Need Help?</b>	<b>165</b>
<b>Appendix 13: This Manual - Revisions and Changes</b>	<b>166</b>

## What's In the box?

If you have bought a boxed decoder (i.e., not preinstalled in a loco) the box will contain...

- The decoder (clearly!)
- A Speaker Driver with wire and plug assembled.
- A plastic sprue with a set of injection moulded speaker enclosures.
- Instruction Leaflet

The speaker components are designed to work together to enable you to create a “sugar cube” speaker to suit your target loco.

Note: A “sugar cube speaker is actually made up of two components i.e., the speaker driver and an enclosure/box.

See [Appendix 10: Speakers.... Sugar Cubes and the rest...](#) for more details re HM7000 decoders and speakers.

## Sound Decoders..... First time use of a decoder... [do this!](#)

### First things...

After you have installed the decoder in your target locomotive, you can place the locomotive on a normal DCC layout and control it immediately under DCC mode. This is the decoder's default configuration. It is now possible to take control using the APP.

If using a DC powered track you will need to take control of the locomotive when setting up the locomotive up in the APP...

The sound played may not be correct for the locomotive that you fitted the decoder to. The sounds can be changed to suit via a free download. \*\*\* When running on a DC track you will need to use the APP to control the loco.

The decoder/locomotive will be controllable via DCC/Bluetooth in the usual way. The decoder may be read back if required using Bluetooth or the controller's service track/programming track connection. Operational mode is also supported.

By changing CV12 to the value 2, you now have switched control to Bluetooth operation. However, you will require the Hornby HM7000 APP for your mobile device in order to take control..... you will now need the APP!!

If you do not have the APP... [get it!](#)



Scan the QR code with your IOS or Android device. You will be directed to the HM|DCC APP in your APP store. (Alternatively go to your APP store and search for the APP.) Carry out the installation procedure i.e., touch "Get" if using an IOS device or "Install" if using an Android device. The APP will download and install on your device.

## Setup APP procedure...

Make sure Bluetooth is enabled on your device.

Open the APP and follow the initial setup routine. Ensure the APP has all permissions granted as directed.

You will be required to login to the APP using your Hornby account.

*If you do not have a Hornby account press the “Register New Account” button to be taken to the Hornby website. Create an account and wait for the verification email. Verify your account. Alternatively go directly to the Hornby website and set up your account.... <https://uk.hornby.com/>*

Once your new Hornby Account has been verified. Now open the APP or close and re-Open the APP... login.

## Linking your new decoder to the APP.

Once you have logged into your Hornby account from the APP you will be taken to the “Settings” page.

Tap “Link Device”

Tap “Start Scan”

The scan will take about 10 seconds and will then display the decoder ID (something like “HM7000\_abcd”) under the words “Ready to Link”.

Press the square containing the decoder ID to start linking the decoder.

You will then be taken to the Locomotive Settings page... the decoder is now linked.

## Set Address and Locomotive name and Mode of control.. e.g., Bluetooth, DC or DCC.

In the “Basic Information” panel on the “Locomotive settings” page you will now see...

Loco Address = 3

Name.. “New Loco”

At this point it is advised that you give the decoder a new address and a name. e.g., “Flying Scotsman, Mallard, Prince of Wales or maybe a running number e.g. 4472.... Etc.” This will make the locomotive easier to find in later pages of the APP.

In the “Control Mode” panel on the “Locomotive Settings page” press the setting you desire... i.e., Bluetooth, or DCC.. in this case we assume you want to use the APP you will find that “Bluetooth” mode is set by default.

Note: If you scroll down the Locomotive “Settings” page you will find other aspects of the decoder that you can preset. e.g., Acceleration/Deceleration/Global Sound Volume, Import/Export Function Set up and most importantly Locomotive Profiles. There is a browse “Profiles” button.

## Download and install the desired Sound Profile.

Now tap the “Browse Profiles” button, you are taken to the Sound Profiles page. Here you will find a complete list of all available Locomotive Profiles. The list is presented in “tiles.”

Scroll through the list and tap the locomotive profile you desire.

You are taken to the “Manage Profile” screen.

Here you will find details of the profile you selected.. Tap the “Install Locomotive Profile” button.... The APP will update the decoder APROM and SPIROM ... this can take about 10 - 15 minutes. A progress bar will appear on screen along with a time estimate to completion.

Once completed... you will receive a completed message... now tap the dismiss button to exit back to the previous “Manage Profile” screen.

Now... scroll down the screen until you see the “Import Function Map & Running Profile” Button.... Tap this button. The CVs set is now installed into the decoder. Also, the Function information is now installed into the APP... You will be taken back to the “Manage Profile” screen.

You now need to check the Locomotive is present in the Control Screen.

Tap the “Joystick” icon at the bottom left of the screen to be taken to the “Control” Screen.

Control Screen... Your installed Locomotives will appear in a horizontal list at the top of the screen... Tap your new Locomotive to bring it to focus.

Scroll the screen down to view pre-set Function Buttons.

Now PLAY WITH YOUR LOCO!!!!

## About this reference manual...

### Scope...

This manual is designed to be “universal” i.e., Configuration Variables (CV) listings are universal and cover all decoders in the system.

We have indicated where a CV only applies to a particular type of locomotive... i.e., Steam, Diesel, Electric, Electro-Diesel, Non-Sound... etc.

The structure of the manual is split into sections dealing with the common CVs of all decoders with other sections dedicated to different sound loco types i.e., electric, steam, diesel etc... full CV details for each type. Some CV numbering is shared between the different sound locomotive type, please refer to appropriate section regarding the sound type your locomotive has. Other sections are for general references and apply to any DCC decoder/layout... these sections are for your guidance. Please check the contents list/index for more detail...

### Function and hardware naming...Conventions...

When referring to decoder function outputs there are several ways that users refer to them.

Please check the table below to understand how the naming conventions relate to each other. For some practices it easier to refer to an HFO when talking about the electrical connection. The term HFO is short for “Hardware Function Output,” this refers to the physical electronic connection on the decoder.

The term AUX refers to any HFO other than the ones allocated to head light/rear light functionality. Finally, F numbers usually refer to controller based “buttons.” E.g., it is accepted that F0 is usually headlight/rear light control, but other F# designations may apply above F0. i.e., they are not fixed.

**The first 6 hardware outputs.... Some decoders will have more function output support but will follow the convention in the table below.**

Actual Hardware	General Term	Controller Function #	Output Level	Typical Current Limit
HFO1		F0 Forward Direction	Analogue 14VDC	100mA
HFO2		F0 Reverse Direction	Analogue 14VDC	100mA
HFO3	AUX1	F1	Analogue 14VDC	100mA
HFO4	AUX2	F2	Analogue 14VDC	100mA
HFOd5	AUX3	F3	Digital Level 3.3V	Low
HFOd6	AUX4	F4	Digital Level 3.3V	Low

There are two main types of decoders i.e., sound, and non-sound types available with different connectors. i.e., 21pin, 8pin, Next18 and 6 pin.

See [HM7000... Meet the Family...](#)

### Definition: OTA...

This is jargon/acronym for “over the air” which refers to update process that involves Bluetooth communication to a target decoder.



## HM7000 Series Decoders... What are they???

What?

The HM7000 series locomotive decoders are unique in that they offer different modes of operation i.e., DCC or APP control under Bluetooth (BLE).

Control from an analogue controller i.e. a (varying voltage source) is possible for testing locomotives etc. We do not recommend DC operation for general locomotive operations.

The Hornby APP is available for Android and IOS.

Decoders can have control handed back and forth between DCC and BLE/APP control modes on the fly...

Decoders, while under BLE mode can be handed over to DCC control mode via the APP.

Decoders, while under DCC mode, the APP can force take over i.e. take control in BLE mode.

The BLE/APP mode has many advantages over DCC control methods in that programming and readback of the decoder via the APP is almost instantaneous. The APP GUI allows easy access to programming etc. Locomotives fitted with BLE decoders can operate on any 15VDC powered track \*\*\* under BLE control only if no DCC controller is available. The decoders, as previously mentioned, also operate on a standard NMRA DCC track allowing both BLE and DCC control modes.

\*\*\* Hornby offer suitable power supplies rated at 1Amp and 4 Amps... which are suitable for DC only operation. See next.

### Summary

The decoder may be controlled/programmed by either DCC NMRA signals received via the track in the conventional way, or by Bluetooth signals transmitted from an IOS or Android Phone/Tablet running the Hornby HM7000 train control APP. The APP can be downloaded for free from the Apple Store or from the Google Play Store.

The decoder can be operated on an analogue DC layout e.g., **for running in purposes**. However, no decoder features will be available. i.e., only motor control will be available. We do not recommend this method for normal operation as unpredictable running behaviour is likely.

The APP can control all aspects of your model railway if the railway has Hornby HM7000 series components. e.g., accessory decoders (see separate dedicated manual) etc, as well as locomotives fitted with HM7000 series locomotive BLE decoders. Legacy decoders (i.e., non HM7000 range Hornby BLE decoders, or any other manufacturers DCC decoder) may still be controlled in normal DCC mode via the APP by using the HM7040 XpressNet to BLE adapter plugged into either an Elite or Select controller.

## Bluetooth advantages...

Using the BLE APP for control has many advantages over the conventional DCC control system. i.e., CV changes and readback are almost instantaneous and there is no need to put the locomotive on a “Service/Programming” track for readback support. The decoder also supports conventional manipulation of CV values i.e., DCC programming operation via a conventional DCC controller. In DCC mode you will need to put the locomotive on a “service/programming” track to carry out both programming and readback in the same session. This readback process is very slow compared to Bluetooth mode. The decoder also supports DCC “operational” mode (OPS) programming in addition to “service mode” programming. Often referred to as POM – Programming on the Main or possibly “OPS Mode.” It is not possible to readback the decoder when using “POM/OPS mode” mode i.e., the decoders do not support RailCom readback.

The APP offers a more visual method of carrying out control and programming of your locomotives etc which can be simpler to understand at a glance....

The “mode” of decoder control is set by CV12. **The default setting is for DCC operation.** This has been chosen to allow users to use the decoder immediately on a conventional DCC layout. When a Bluetooth signal is used to pair the decoder with the control device, CV12 will be automatically switched to Bluetooth mode. The decoder can be switched back (“handed over”) to the DCC controller at any time and so on. However, in some cases a user may choose to have a dedicated Bluetooth controlled layout i.e., no DCC controllers etc. In this case, the user may be using DCC or DC power on the tracks. When linking a locomotive with the APP, they will need to programme CV12 = 2 i.e., setting the decoder to BLE operation mode. They will not be able to drive the locomotive until this is done.

The APP makes setting the control mode for a decoder very straight forward i.e. you can select the control mode by tapping a button on the APP display, no need for CV programming.

## We do not recommend DC operation ... Why?

*We stated earlier that the decoder is capable of supporting DC only (analogue) operation and that we do not recommend this method of operation. No DCC decoder can guarantee consistent operation from a variable DC power source as there is a minimum threshold voltage at which the decoder will boot. Also, it is known that some analogue controllers out here can provide harmful voltage spikes when a locomotive derails etc.*

*We would only suggest using this method of control for steady voltage “running in” a loco on a separate DC analogue track if really required to do so. Never use DC mode for general locomotive operations as this mode can result in unpredictable operation of the decoder. If you intend to run the locomotive on a DC analogue layout for an extended time, please remove the decoder and replace it with a “Blanking Plug.”*

DC operation is also configured via CV12.. [CV12... Decoder Control mode select... DCC/BLE/DC...](#) Note: it is also necessary to turn on DC operation in CV29 by enabling bit2, Power Conversion. (If, programming a decoder with CV29 set to a default value (=2) add 4 to this value... CV29 = 6)

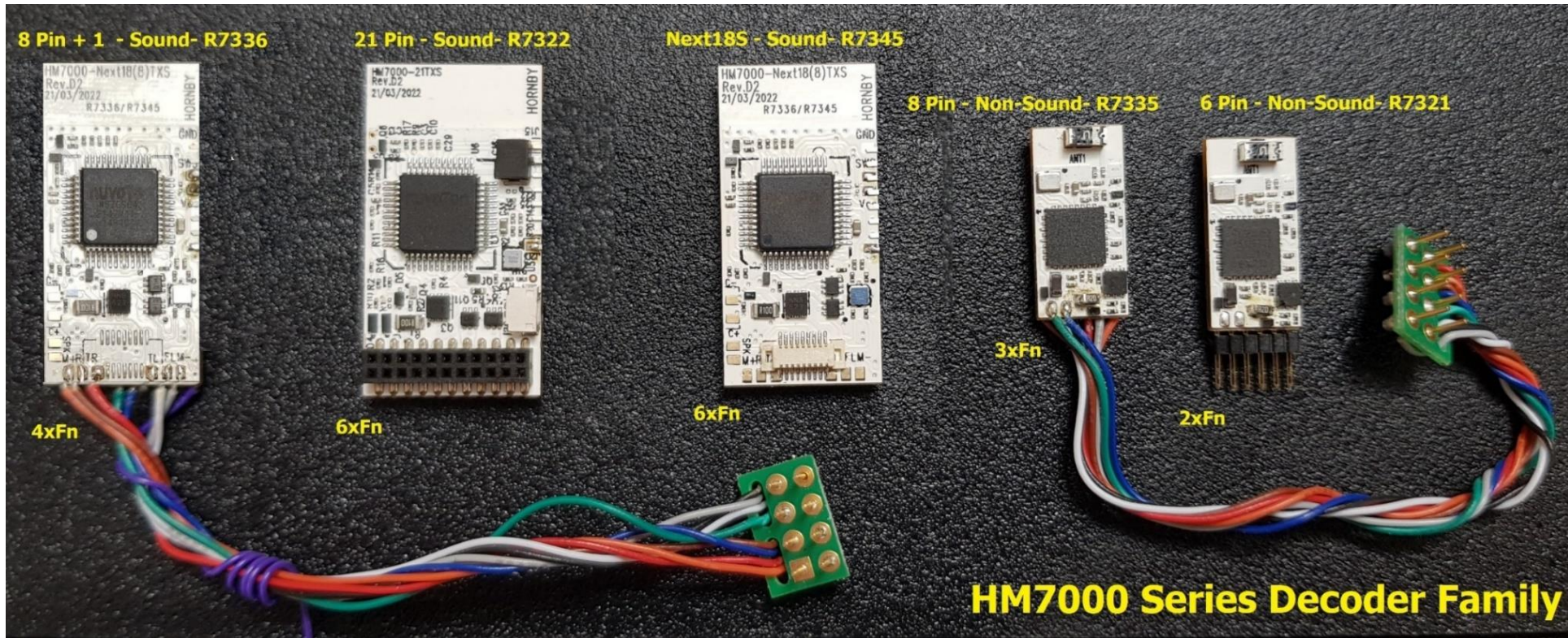
## HM7000 Decoders... the basic features... an outline.

Note some features listed are not supported in all decoders... as indicated.

- *Full Bluetooth wireless control via APP based control interface or standard DCC operation.*
- *Full CV programming and Read-back via APP interface.*
- *Full Support of DCC operations.*
- *Full support for Service Mode Programming (Programming Track) and Operational Mode Programming (Programming On the Main... POM)*
- *Supports Short and Long decoder addresses.*
- *Supports basic speed curve with configuration for Start, Mid and Max voltage configuration.*
- *Supports complex user defined speed curve.*
- *Adjustable Acceleration and Deceleration*
- *Back EMF Load Compensation*
- *Motor control algorithm can be set up via Auto-Calibration routine.*
- *Motor control algorithm can be further adjusted after Auto-Calibration.*
- *Sound decoders have three sound channels allowing for simultaneous play of multiple sounds including... engine/steam/spot sounds e.g., Horns, Whistles, Brakes, Coal Shovelling, Wheel Slip, Injectors etc.*
- *Support for Diesel, Electric, Electro-Diesel and Steam sound.*
- *When a steam locomotive is cruising at constant speed there is a switchable option to either have "Steam exhaust" sounds (i.e., chuffing) or the sound of the loco "Coasting" under its own momentum. Thus, giving added realism to the sounds the loco makes in action.*
- *Steam Locomotives have driving wheel slip sound simulation feature – this can be set up as automatic or selected manually. If too much throttle is applied when a locomotive is stationary wheel slip sounds are played the locomotive will not move... If the locomotive is moving wheel slip sounds are played and the locomotive will not accelerate.*

- *It is possible to alter the volume of each sound through an individual dedicated CV. i.e., there is effectively a simple volume mixer on board the decoder. Volume may be adjusted in 256 steps, 0 – 255 there is also a master volume to set all sounds to the same level.*
- *The decoder supports HFO 1 and HFO 2 (Front and Rear Light operation); this function is controlled by F0 on the controller.*
- *The decoder supports HFO 3 and HFO 4; i.e., these are function outputs controlled by F21 and F22 on the controller (sound decoders.) (F1 and F2 non-sound types.)*
- *The decoder supports HFO 5 and HFO 6 (These HFOs are low level digital level outputs.) These are function outputs controlled by F23 and F24 on the controller (sound decoder.) (F3 and F4 on non-sound types.) Note: HFO5 and HFO 6 are only available on 21-pin and Next 18S decoders*
- *Shunting mode.... Accessed by F25 on Sound locos. (F5 on non-sound types.)*
- *“Creep” mode ... Preset Ultra slow speeds... can be used for Coupling assistance .... The locomotive can be set to “creep” continuously at a preset speed set by a CV or, it can be configured to creep for a short time at the preset speed... time duration is configured via another. Enabled by F26 (Sound locos.) F6 (non-sound types.)*
- *Manual Braking ..... Accessed by F27 on Sound locos. (F7 on non-sound types.) Braking rate is user configurable.*
- *Automatic Function Control (AFC) ...allows random spot sound play in either static or on the move scenarios... configurable by the user. Can be enabled/disabled via F28 on the controller...*
- *Non-Sound Decoders... Single push button motor control at pre-set speed and acceleration/deceleration... Accessed by F8*
- *OTA update support. This feature supports decoder code updates via Bluetooth and the possibility of changing the decoder “sound set” on sound decoders is supported... Different loco types “sound sets” are available for free download from the Hornby web-site via the APP.*
- *OTA software update and support... bug fixes and feature enhancements are applied automatically.*
- *ADCC Support for Automatic Braking Functionality. (Require additional hardware i.e., simple trackside diode packs etc. (Applies to Sound Decoders only).*
- *Hornby Steam System support (Locomotives with ASU – Atomising Steam Unit.)*
- *Support Hornby “Stay Alive System” with “Smart Charging.” Power Bank. R7377. **Please be aware that locomotives fitted with a Power Bank may stop instantly when track power is cut due to an emergency STOP scenario.***
- **IMPORTANT. Sound decoders do not support sound under DC operation. Sounds can only be played under DCC/BLE operation.**
- **HM7000 decoders do not support function number remapping.**

## HM7000... Meet the Family...



### Introduction...

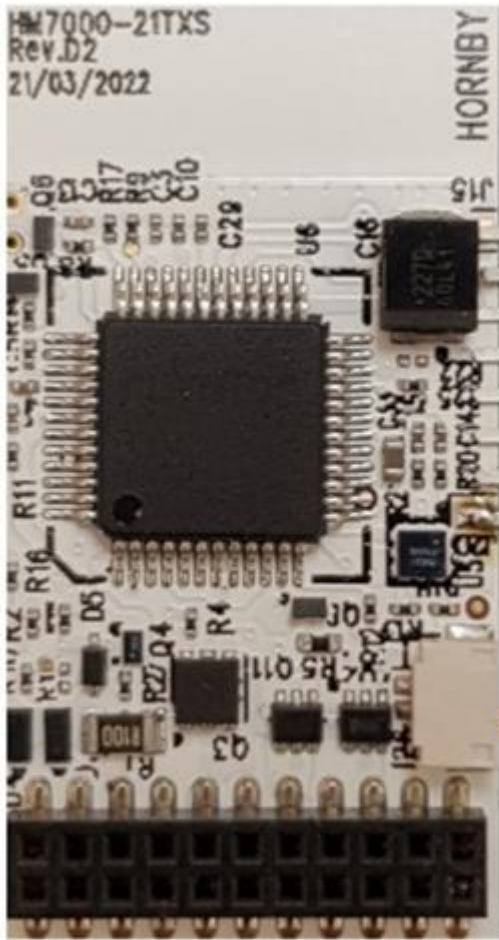
Generally, DCC decoders have connections for the locomotive pickups (power,) the locomotive motor, and hardware function outputs (HFO,) that are used for the connection of lighting etc. however, they may also have other connections present for loudspeaker and “stay alive” components. (In the case of the HM7000 series this will be an external “Pack.” Part number R7377... see [Appendix 7: Power Bank... Hornby “Stay Alive” Connection and Implementation](#))

HM7000 8pin and Next18 sound have provision for connecting a loudspeaker on the decoder pcb in the form of solder pads and a two-pin socket. HM7000 with 21 pin connectors do not have free solder pads for speaker connection... speaker connection is made through the 21 pin socket in the usual way or via the dedicated decoder speaker socket.

**When talking about decoder hardware please refer to the table re reference conventions... see [Function and hardware naming...Conventions...](#)**

# Sound Decoder Types and Connection

21 Pin BLE Decoder ... HM7000-21TXS ... R7322.....



Speaker Connection



Power Pack Connection

Dimensions	15.5mm x 29.5mm x 4.9mm
Termination	21MTC

Pin #	Name	Function	Colour
1	AUX7	Logic output/input HFO9d... <i>Controlled by BLE MCU</i>	
2	AUX8	Logic output/input HFO10d... <i>Controlled by BLE MCU</i>	
3	AUX 6	Logic output/input HFO8d... <i>Controlled by BLE MCU</i>	
4	AUX 4	Logic output/input HFO6d... <i>Controlled by BLE MCU</i>	
5	N/C	No Connection	
6	ZBDATA/AUX10	SWS Prog/Debug of BLE MCU ... alternate AUX10d... <i>Controlled by BLE MCU</i>	
7	F0r	HFO2...	Yellow
8	F0f	HFO1...	White
9	LS/A	Loudspeaker	Brown
10	LS/B	Loudspeaker	Brown
11	N/C	No Connection/Alignment Pin, not used	
12	3.3V	Decoder Internal CPU Voltage	
13	AUX 3	Logic output/input HFO5d... <i>Controlled by BLE MCU</i>	
14	AUX 2	HFO4...	Violet
15	AUX 1	HFO3...	Green
16	V+	Decoder Positive ( <b>HFO Common</b> )	Blue
17	AUX 5	Logic output/input HFO7d... Digital Output <i>Controlled by BLE MCU</i>	
18	MTR -	Motor Left/negative	Grey
19	MTR +	Motor Right/Positive	Orange
20	Ground -	Decoder Ground, tapped at internal rectifier	
21	Power	Left Rail pickup	Black
22	Power	Right Rail pickup	Red



Note: This socket actually has 22 connector positions. Only 20 pins are electrically active, pin position 11 is “blank” and used for alignment. Pin 5 has no connection.

Note: In the design of the decoder there are two MCUs i.e., the NMRA part and the Bluetooth (BLE) part. HFOs are split over the two MCUs. HFOs served by the BLE MCU are digital only types. [\(In Blue\)](#)

Note: This type of connector comprises of a socket on the decoder pcb that plugs into the corresponding plug pins mounted on a pcb fitted in the locomotive.

Note: Speaker connection is made by either the 2-pin socket mounted on the decoder pcb or via the locomotive pcb via pins 9 and 10 on the decoder socket.

Note: R7377, the Power Bank (“Stay Alive”) connection is made by a 3-pin socket mounted on the pcb.

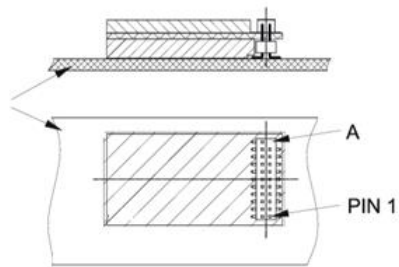
Mounting 21MTC Decoders... There are two modes of mounting: “Compact” and “Rotated” ...

According to the NMRA there are two ways the 21 pin decoder may be mounted to the locomotive motherboard... i.e. **“Compact or Rotated”** ... This means the decoder may be mounted either way up. For more information: [https://www.nmra.org/sites/default/files/standards/sandrp/pdf/s-9.1.1.3\\_21mtc\\_decoder\\_interface\\_2.pdf](https://www.nmra.org/sites/default/files/standards/sandrp/pdf/s-9.1.1.3_21mtc_decoder_interface_2.pdf)

The decoder has a “Top” and “Underside” ... the “top” is defined as the side of the decoder that has the plastic socket strip.

#### Compact variant

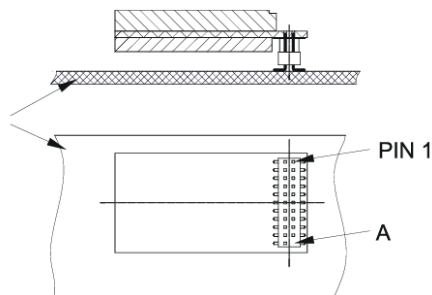
This variant results in the lowest possible overall height. Here the decoder is inserted with the socket facing up. i.e. “top” upwards. The pins of the connector are inserted through the board of the decoder. **The decoder sits on the board in the vehicle. On the circuit board in the vehicle, the area of the decoder - apart from the pin header - must be kept free of components and be electrically isolated.**



“A” indicated the “blanked” or “missing” pin position of the socket.

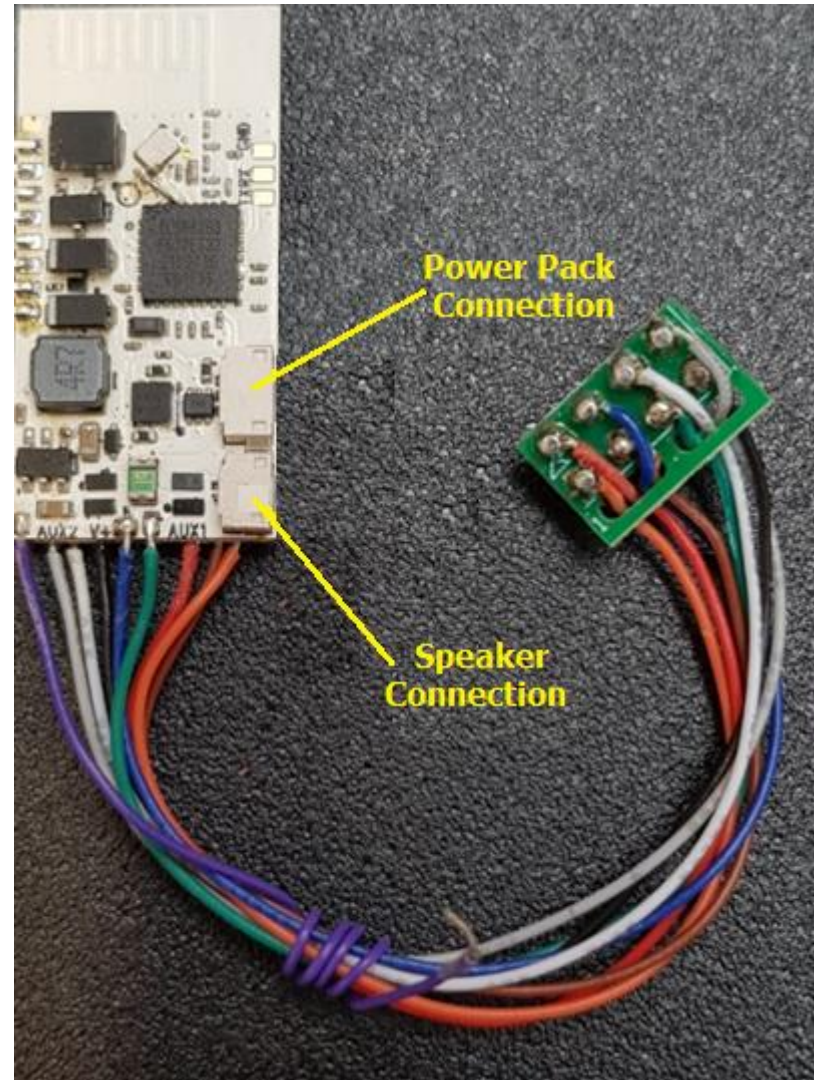
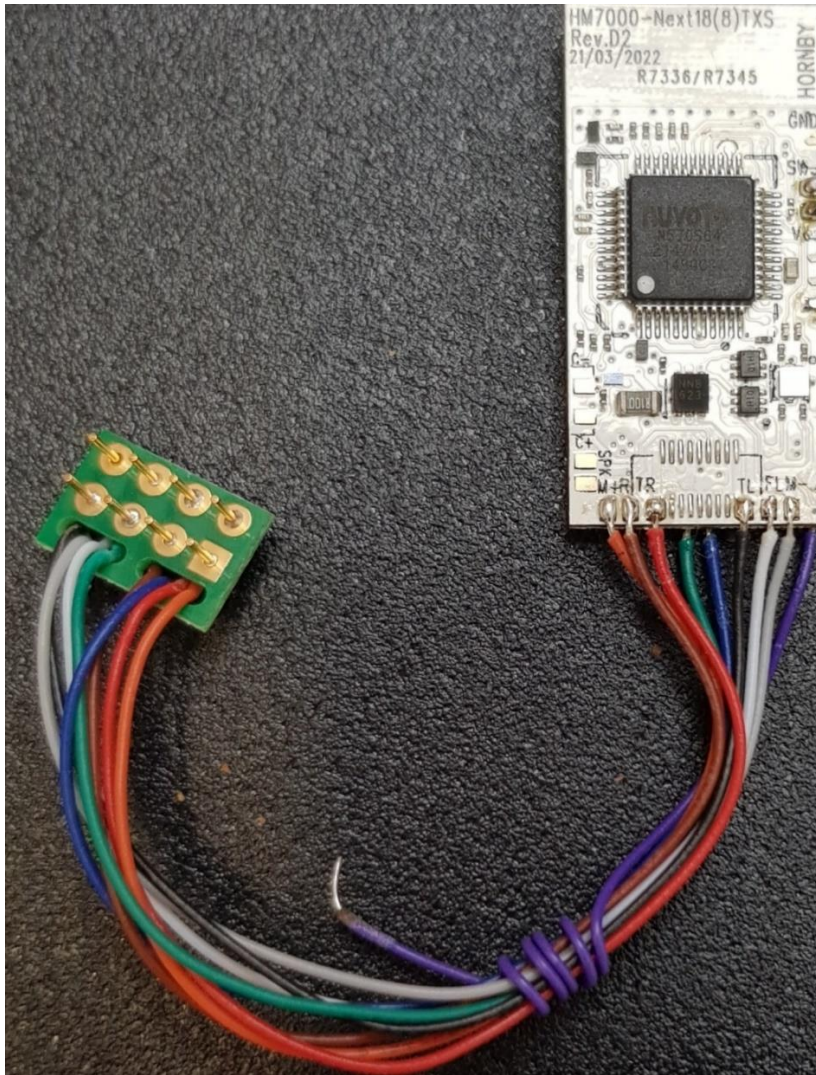
#### Rotated variant

If there is enough height, but no space for the free space on the vehicle board, the vehicle manufacturer can use the rotated variant. The decoder is plugged in with the socket facing downwards (towards the vehicle circuit board) i.e. “underside” upwards.. The assignment of the connector on the vehicle circuit board must be mirrored in the axis of pin 6/17. **The decoder sits “high” and allows some motherboard components/wiring/connections to be present underneath the decoders position... however, great care has to be made to ensure nothing can foul the decoder.**



“A” indicated the “blanked” or “missing” pin position of the socket.

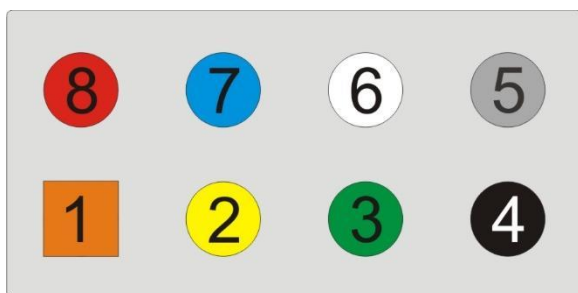




Dimensions	14mm x 28.5mm x 4.9mm
Termination	NEM 652 8 pin + flying lead

Pin #	Name	Function	Colour
-------	------	----------	--------

1	MTR +	Motor Right/Positive	Orange
2	F0r	HFO2...	Yellow
3	AUX1	HFO3...	Green
4	Power	Left Rail pickup	Black
5	MTR -	Motor Left/negative	Grey
6	F0f	HFO1...	White
7	V+	Decoder Positive ( <b>HFO Common</b> )	Blue
8	Power	Right Rail pickup	Red
<b>Flying wire</b>	AUX2	HFO4...	Purple



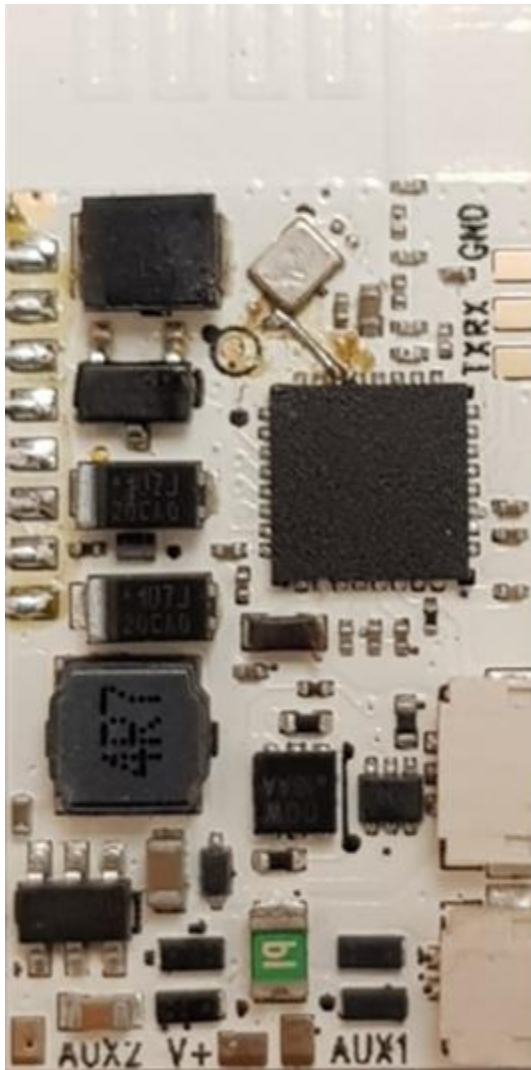
View looking down at the locomotive decoder socket  
Pin 1 may be designated by a star, a square or spot printed on the locomotive pcb.

Note: HM7000-8 non-sound decoder supports 3 HFO outputs i.e., there is no HFO4 (purple flying wire.)

Note: HM7000-8TXS sound decoder supports 4 HFO outputs i.e., there is a flying wire (purple) attached to the decoder pcb. The extra “wire” provides connection for HFO4.

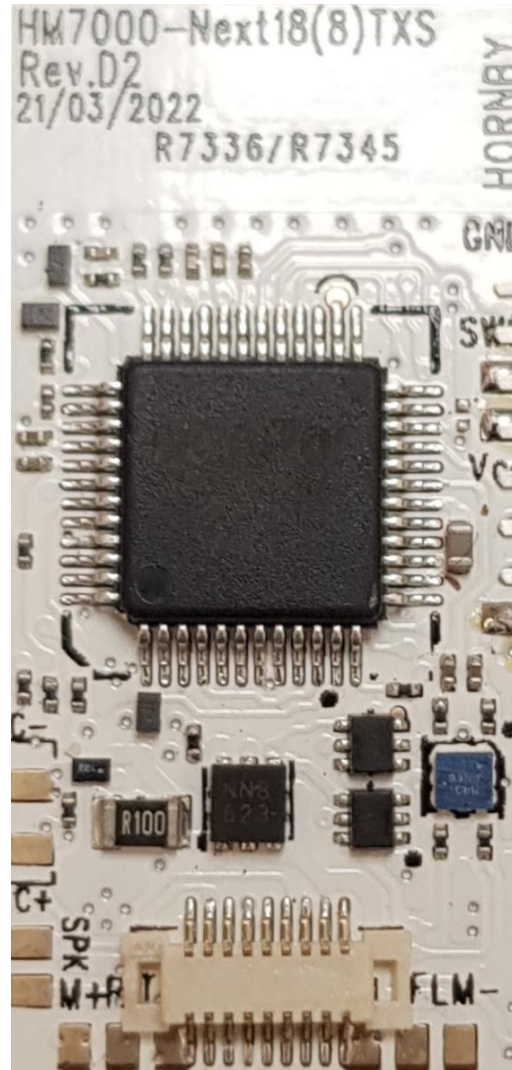
Note: On Sound Decoders... Speaker connection is made by a 2-pin socket mounted on the pcb.

Note: R7377, the Power Bank (“*Stay Alive*”) connection is made by a 3-pin socket mounted on the pcb.



Power Pack Connection

Speaker Connection



Dimensions	14mm x 28.5mm x 4.9mm
Termination	Next18-S

PIN	Name	Description
-----	------	-------------

1	Power	Right Rail Pickup Common with pin18
2	MTR +	Motor Right/Positive
3	AUX1	HFO3...
4	AUX3	HFO5d... Digital Output... <i>Controlled by BLE MCU</i>
5	Ground -	Decoder Ground, tapped at internal rectifier. Common with pin14
6	V+	Decoder Positive <b>(HFO Common) Electrically</b> Common with pin15
7	LS/B	Loudspeaker
8	F0f	HFO1...
9	Power	Left Rail Pickup Common with pin10
10	Power	Left Rail Pickup Common with pin9
11	MTR -	Motor Left/negative
12	AUX2	HFO4
13	AUX4	Logic Output/Input HFO6d... Digital Output... <i>Controlled by BLE MCU</i>
14	Ground -	Decoder Ground, tapped at internal rectifier. Common with pin5
15	V+	Decoder Positive <b>(HFO Common) Electrically</b> common with pin6
16	LS/A	Loudspeaker
17	F0r	HFO2...
18	Power	Right Rail Pickup Common with pin1

Note: Next-18-S connector consists of a plug mounted directly on the decoder pcb.

Note: This type of the plug, plugs directly into the socket on the locomotive pcb.

Note: The locomotive pcb socket is designed so that the decoder can only plugged in one orientation.

Note: On Sound Decoders... Speaker connection is made by a 2-pin socket mounted on the pcb.

Note: R7377, the Power Bank ("*Stay Alive*") connection is made by a 3-pin socket mounted on the pcb.

## Non-Sound Decoder Types and Connection

### Non-Sound Decoders... Operational limitations – Notes

Non-Sound decoder types have a different processor architecture from the Sound decoder types. This means that some features are not supported, and other features require different operational procedure.

..

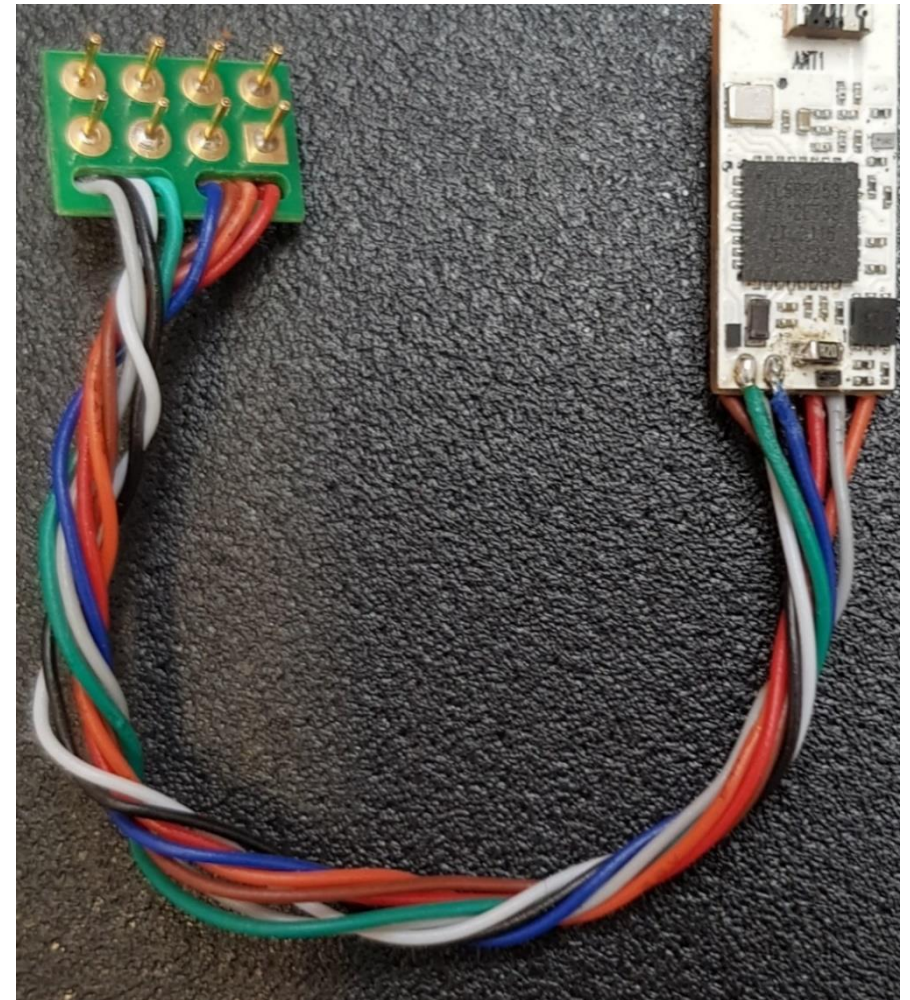
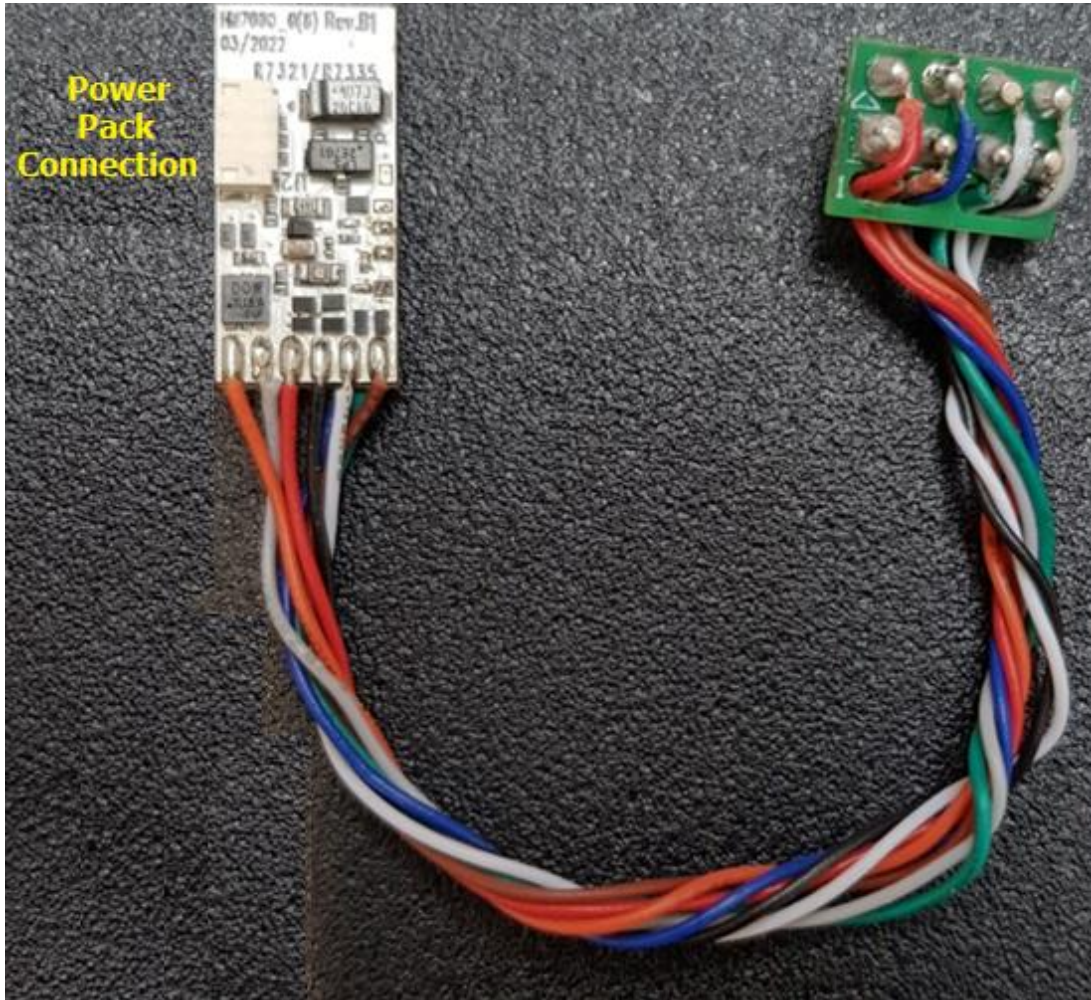
Non-Sound Decoders do not at this time support ABC i.e., ADCC operation (See ABC- ADCC later in this manual.)

..

The decoder selects Bluetooth or DCC depending on track power type. i.e., if straight DC is detected the decoder operates on BLE mode only. If DCC type power is detected the decoder will set itself for DCC mode operation.

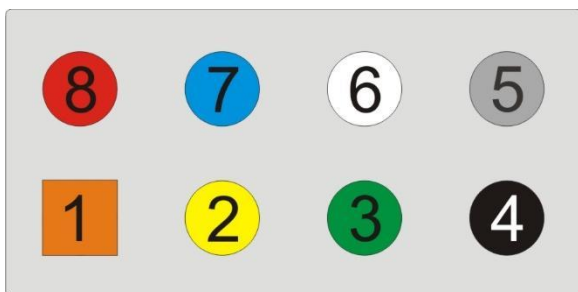
If a DCC user wishes to use the APP to control the decoder, he will require the HM7040 unit to receive the APP Bluetooth signal and translate it to DCC commands... i.e. the decoder is already automatically set to DCC mode and does not respond to BLE signals.

These decoders do not currently support CV12... i.e., mode switching.



Dimensions	8mm x 21.5mm x4 mm
Termination	NEM 652 8 pin

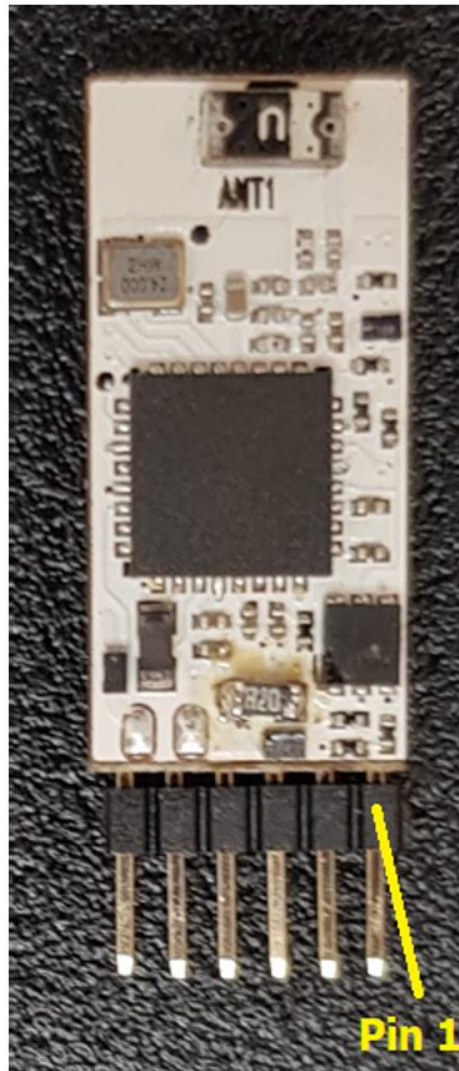
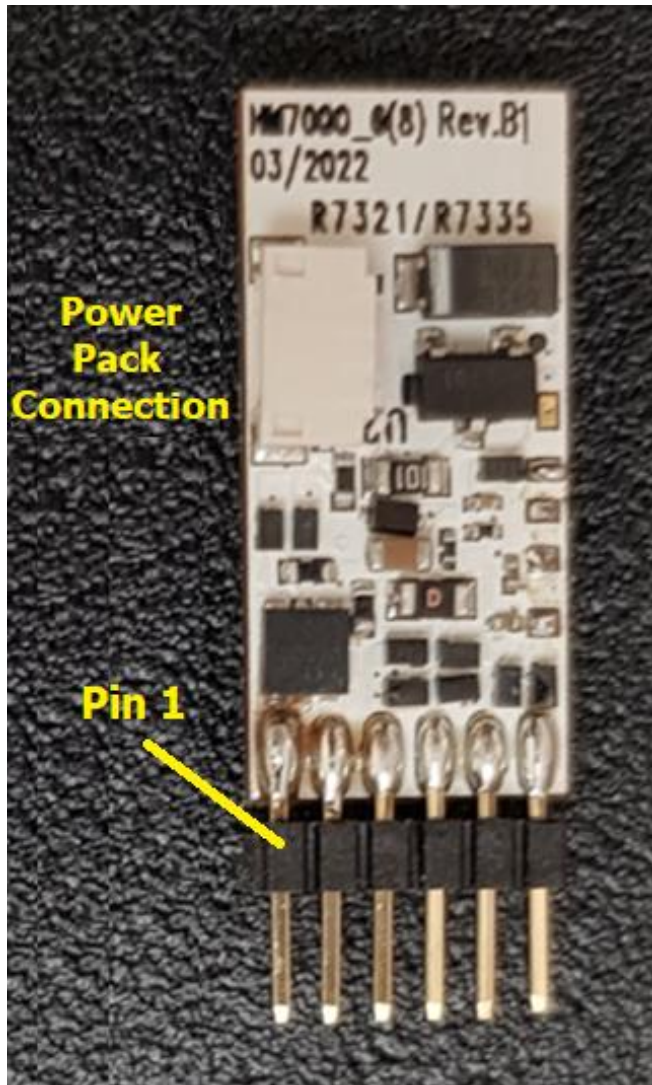
Pin #	Name	Function	Colour
1	MTR +	Motor Right/Positive	Orange
2	F0r	HFO2...	Yellow
3	AUX1	HFO3...	Green
4	Power	Left Rail pickup	Black
5	MTR -	Motor Left/negative	Grey
6	F0f	HFO1...	White
7	V+	Decoder Positive ( <b>HFO Common</b> )	Blue
8	Power	Right Rail pickup	Red



View looking down at the locomotive decoder socket Pin 1 may be designated by a star, a square or spot printed on the locomotive pcb.

Note: HM7000-8 non-sound decoder supports 3 HFO outputs i.e., there is no HFO4 (purple flying wire.)

Note: R7377, the Power Bank ("*Stay Alive*") connection is made by a 3-pin socket mounted on the pcb.



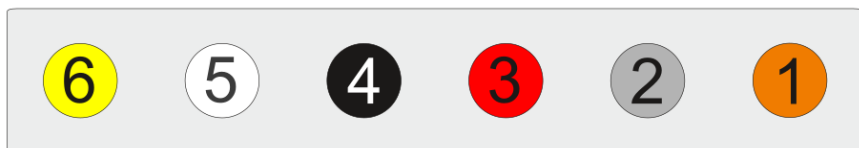
Dimensions	8mm x 22.5mm*** x 4mm *** including pin length, pcb length is 17mm
Termination	NEM651n 6 pin



Pin #	Name	Function	Colour
1	MTR +	Motor Right/Positive	Orange
2	MTR -	Motor Left/negative	Grey
3	Power	Right Rail Pickup	Red
4	Power	Left Rail Pickup	Black
5	F0f	HFO2...	White
6	F0r	HFO1...	Yellow

This type of connection is made up of pins on the decoder and a socket fitted on the loco pcb.

Note: If the locomotive has a socket with a wiring harness it should use the wire colours correspond to the table below.



Decoder pins viewed end on. Check the position of Pin 1 on the socket. It may be designated by a star or spot printed on the locomotive pcb or decoder socket...

Note: HM7000-6 non-sound decoder supports 2 HFO outputs i.e., there is no HFO3 or HFO4 (purple flying wire.)

Note: Any lighting arrangements i.e., forward light/reverse light arrangement will use the left or right rails as the ground reference for the HFO loads... i.e., LEDs or incandescent lamps. See below for more info re connecting LEDs to a 6-pin decoder.

[Connecting LEDs to 6 pin decoders. Click link for more information](#)

Note: R7377, the Power Bank (*"Stay Alive"*) connection is made by a 3-pin socket mounted on the pcb.

**Reserved Page.**

No information is currently available re....

- HM7000-18 R7401 ... Next18 Non-Sound Decoder
- HM7000-21 R7402 ... 21pin Non-Sound Decoder

## Decoder Function Lists and Function Description.

### General...

Please note the information below is a general summary. An outline description/list of functions is given on a locomotive type basis. While there is some commonality between the functions of locomotives of the same type, it is possible that there could be some differences per specific Locomotive.

Please check your locomotive sound profile documentation for full details of the sounds available and F# mapping for your locomotive/decoder sound profile. Function lists for each profile will be available for download from the Hornby website. <https://uk.hornby.com/hm7000/hm-dcc-guides>

Scroll down until you find the “Profile Function Maps”

..

*When you download a locomotive sound profile. On installation, part of the process will configure the APP Control Screen for that locomotive. i.e., it will show the appropriate buttons and icons for the specific functions/sounds for your locomotive.*

Certain locomotive models may have dedicated functions unique to that locomotive... icons for these buttons can also be configured manually within the APP to suit. All decoders have the capability of supporting up to 29 functions dependent on locomotive/decoder type. However, non-sound decoders currently only support up to 9 functions.

### Sound Decoders... Functions range

Steam Engine Functions... F1 to F19 are all sounds.... Function F0 and F20 to F28 are all physical functions i.e., lighting or trigger physical actions in the behaviour of decoder operation.

Diesel/Electro Functions... F1 to F20 are all sounds.... Function F0 and F21 to F28 are all physical functions i.e., lighting or trigger physical actions in the behaviour of decoder operation.

### Non-Sound Decoders... Function range

Functions are all physical types e.g., brake, shunt etc, and range from F0 to F8... These functions will control lighting or trigger physical actions in the behaviour of decoder operation. Function control could be expanded in future releases of the non-sound decoder firmware.

### General Notes...

Note – 6 pin non-Sound decoders only support F0, headlight/rear light functionality.

Special Decoder Features include shunting mode, creep mode, Auto Function Control etc are discussed later in this guide...

[Special Decoder Functions... F25/28 Sound Decoders ... F5/F8 Non-Sound Decoders. configured by CV120 to CV124](#)

## Electro-Diesel Sound Decoders... Features and Functions

The function allocated to each F# is fixed. Remapping of Function numbers is not supported.

- F0... Directional Lighting (HFO1 and HFO2) – (if installed.)
- F1... Engine running sounds enable.
- F2... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F3... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F4... Brake sound.
- F5... Engine Modes... Force Transition between electric and diesel modes.
- F6... Spot Sound
- F7... Spot Sound
- F8... Spot Sound (unique to steam, electric and electro-diesels locos)
- F9... Diesel Cold Start Select...

Diesel locomotives are equipped with one of two types of “cold start” operations. Some diesels will crank over for many minutes i.e., an “extended cold start,” while other more modern locos will “start on the button” with little “cranking.” ... the appropriate cold start type will be set in the sound set for the diesel type...

Cold start... if this F9 is enabled before F1 is enabled.... the loco will run through a cold start sequence and start normally.

- 
- F10 – F20... Various Spot Sounds
- F21... Aux 1 (High level function output typically used for controlling LED lighting etc.) HFO3
- F22... Aux 2 (High level function output typically used for controlling LED lighting etc.) HFO4
- F23... Aux 3 (Low level digital function output for controlling other electronics within the loco.) HFO5
- F24... Aux 4 (Low level digital function output for controlling other electronics within the loco.) HFO6
- F25... Activate Shunt mode. Shunt mode percentage speed drop is configurable by CV.
- F26... Activate “Creep Mode” ... Coupling assistance. Creep speed and duration are configurable by CVs.
- F27... Apply Brake action (overrides current deceleration level.) Brake deceleration rate is configurable by CV.
- F28... Enables Automatic Spot Sound Play. Choice of spot sounds is configurable by CVs.

## Diesel Sound Decoders... Features and Functions

- F0... Directional Lighting (HFO1 and HFO2) – (if installed.)
- F1... Engine running sounds enable.
- F2... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F3... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F4... Brake sound.
- F5... Notch Engine Up... Transition.
- F6... Notch Engine Down... Transition.
- F7... Return to Idle.
- F8... Thrash.
- F9... Diesel Cold Start Select...

Diesel locomotives are equipped with one of two types of “cold start” operations. Some diesels will crank over for many minutes i.e., an “extended cold start,” while other more modern locos will “start on the button” with little “cranking.” ... the appropriate cold start type will be set in the sound set for the diesel type...

Cold start... if this F9 is enabled before F1 is enabled.... the loco will run through a cold start sequence and start normally.

Extended Cold Start... if this F9 is enabled before F1 is enabled the loco will be locked into a continuous cold start cranking cycle until F9 is disabled; at which point the loco will start.

- F10 – F20... Various Spot Sounds
- F21... Aux 1 (High level function output typically used for controlling LED lighting etc.) HFO3
- F22... Aux 2 (High level function output typically used for controlling LED lighting etc.) HFO4
- F23... Aux 3 (Low level digital function output for controlling other electronics within the loco.) HFO5
- F24... Aux 4 (Low level digital function output for controlling other electronics within the loco.) HFO6
- F25... Activate Shunt mode. Shunt mode percentage speed drop is configurable by CV.
- F26... Activate “Creep Mode” Coupling assistance ... Creep speed and duration are configurable by CVs.
- F27... Apply Brake action (overrides current deceleration level.) Brake deceleration rate is configurable by CV.
- F28... Enables Automatic Spot Sound Play. Choice of spot sounds is configurable by CVs.

## Electric Sound Decoders... Features and Functions

- F0... Directional Lighting (HFO1 and HFO2) – (if installed.)
- F1... Engine running sounds enable.
- F2... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F3... Horns play. Different horns will be played on each press of the F# on the controller. Horns are selected sequentially or randomly. Configurable by CV.
- F4... Brake sound.
- F5 – F20... Various Spot Sounds
- F21... Aux 1 (High level function output typically used for controlling LED lighting etc.) HFO3
- F22... Aux 2 (High level function output typically used for controlling LED lighting etc.) HFO4
- F23... Aux 3 (Low level digital function output for controlling other electronics within the loco.) HFO5
- F24... Aux 4 (Low level digital function output for controlling other electronics within the loco.) HFO6
- F25... Activate Shunt mode. Shunt mode percentage speed drop is configurable by CV.
- F26... Activate “Creep Mode” ... Coupling assistance. Creep speed and duration are configurable by CVs.
- F27... Apply Brake action (overrides current deceleration level.) Brake deceleration rate is configurable by CV.
- F28... Enables Automatic Spot Sound Play. Choice of spot sounds is configurable by CVs.

## Steam Sound Decoders... Features and Functions

- F0... Directional Lighting (HFO1 and HFO2) – (if installed)
- F1... Engine background steam and running sounds enable.
- F2... Whistle play. Different whistles will be played on each press of the F# on the controller. Whistles are selected sequentially or randomly. Configurable by CV.
- F3... Whistle play. Different whistles will be played on each press of the F# on the controller. Whistles are selected sequentially or randomly. Configurable by CV.
- F4 – F5.... Various spot sounds
- F6... Wheel Slip function ... see... [Automatic Wheel slip behaviour simulation ... CV213 and CV216](#)
- F7 – F19... Various Spot Sounds
- F20 – Chuff/Coast enable/disable.
- F21... Aux 1 (High level function output typically used for controlling LED lighting etc.) HFO3
- F22... Aux 2 (High level function output typically used for controlling LED lighting etc.) HFO4
- F23... Aux 3 (Low level digital function output for controlling other electronics within the loco.) HFO5
- F24... Aux 4 (Low level digital function output for controlling other electronics within the loco.) HFO6
- F25... Activate Shunt mode. Shunt mode percentage speed drop is configurable by CV.
- F26... Activate “Creep Mode” Coupling assistance. Creep speed and duration are configurable by CVs.
- F27... Apply Brake action (overrides current deceleration level.) Brake deceleration rate is configurable by CV.
- F28... Enables Automatic Spot Sound Play. Choice of spot sounds is configurable by CVs.

## Non-Sound Decoders... Features and Functions

Non-sound decoders currently support 6 functions. See below.

The function allocated to each F# is fixed. Remapping of Function numbers is not supported.

Only 3 HFO connections are available... i.e HFO1 – HFO3

- F0... Headlight/Rear light... HFO1 and HFO2 – (if installed.)
- F1... Aux 1 (High level function output typically used for controlling LED lighting etc.) HFO3
- F2... Not available....
- F3... Not available....
- F4... Not available....
- F5... Activate Shunt mode... Speed is configurable by CV.
- F6... Activate “Creep Mode” ... Coupling assistance. speed, continuous or preset duration is configurable by CV.
- F7... Apply Brake action (overrides current deceleration level.) Brake deceleration is configurable by CV.
- F8... Simple push button control of pre-set motor speed. (Speed set by CV124. Acceleration and Deceleration set by CV3 and CV4.)



## Decoder Firmware Description, User Updates, Sound Profiles, and getting help.

All of the HM7000 family of decoders use Bluetooth Low Energy communications to communicate with a dedicated control APP running on a mobile device. This is referred to as “BLE Communications” BLE is used for control/programming/update of the decoders.

### OTA updates

All decoders can be updated “over the air” (OTA.) by using the Hornby HM7000 APP. i.e. The APP has built in support for downloading and carrying out the OTA update. Updates consist of...

- Any fixes for discovered issues in operation... (i.e., an “undocumented feature” or bug?) If you find anything you think is not working as expected please contact us. We can then respond to the issues and offer a possible fix ASAP via the OTA update process.
- Feature Enhancements re decoder operation.
- Changing/Updating or enhancing the sound set of the decoder.

Updates specifically for Sound Locomotives...

- Out of the box a new decoder will be preloaded with the sound of an A1/A3 locomotive. This is for factory test purposes. Note, you will always need to download and install a sound profile for your locomotive, this action will also update the APP with the appropriate Function Button configuration. Even if your locomotive is an A1/A3 it will still be necessary to download and install the A1/A3 locomotive sound profile in order to configure the APP Functions page for this locomotive.
- If at some point the user wants to install a different locomotive sound profile on one of their decoders, it is simple to do so. This would happen if a decoder were to be repurposed for use in another locomotive., A new Sound Profiles can be downloaded free of charge via the Hornby HM7000 APP. The sound profile update for the desired locomotive contains the complete sound update plus all the functionality required for that locomotive. i.e., support for diesel/steam/ or electric playback etc. Appropriate Spot sounds and motor control set ups for the desired locomotive will be included. The sound updates overwrite any sound profile already installed on the decoder. Also, the APP will update the function screens and Function control will be set up automatically for the particular locomotive model. There is no limit to the number of times a decoder can be overwritten with a new sound profile.
- There is no need to uninstall the previous Sound Profile from the decoder before uploading another.
- Please see [Appendix 10: Need Help?](#) regarding contacting Hornby for assistance. However, the answers you need are likely to be within this reference guide.

## Decoder Updates and firmware structure... Sound Decoders

### Structure Notes... and updates

A full description of the internal structure and operation of the decoder is outside the remit of this manual. However, the Sound Downloads from the HM7000 web site will be referred to as the “Sound Profile” in reference to a specific locomotive.

Sound Profiles will contain all the parts that make up the entire sound project. Mainly this will be two bundled parts... The code for the APROM and the SPIROM. Within the APP versions screen these are referred to as the “PROFILE ROM”

Also contained within these updates are the Function configuration data used to set up the Function pages within the APP. When carrying out an update all code parts described below will be updated in one operation via the APP. This is automatic.

In addition to the above there maybe occasional updates for the Bluetooth part of the decoder. These are handled separately, and you will be notified of any update by the APP... follow the instructions within the APP to carry out this type of update.

### General Description of the decoder internal firmware structure...

#### LDROM ... the Boot code

This part is responsible for MCU boot processes. It is rarely updated... and can be regarded as fixed. It is mostly responsible for the OTA process of the APROM area. The software of the sound IC is always initiated by the LDROM i.e., it will check if valid software exists in APROM before the software jumps into APROM for the normal operation. If there is any issue with the APROM software, the system will stay in LDROM mode and await the next OTA update as initiated from the APP.

#### APROM ... the Control Code

The APROM is equivalent to what was referred to as the PIC code of the early (first generation) TTS decoder. This is the “Control Processor Firmware.” The APROM code is mostly responsible for the following: Loco motor control and NMRA functionality. i.e., responsible for Motor control, Sound Playback, NMRA detection and response, CV management... i.e., read/write etc. It is responsible for the OTA process for the audio part of a Sound Profile. Without valid APROM software the OTA of audio files cannot proceed.

#### SPIROM ... the Sound Code etc

Mainly responsible for storing the audio content of a sound profile.

**Please note:**

Within the APP the "Device Versions" screen refers to the LDROM, APROM and SPIROM differently...

BOOT ROM... i.e., the LDROM Boot code

PROFILE ROM... this the APROM and SPIROM combined.

This was done to simplify the user experience when talking to customer care etc when referring to the APP.

[Firmware Version Numbers](#)

The decoder itself holds the full break down of the SPIROM and APROM version numbers using CVs if more detailed information is required...

Control Processor Firmware version		APROM	Subject to Change	
47	Firmware Version Major	STC	1-255	Control Processor Firmware Version... READ ONLY
48	Firmware Version Minor	STC	1-255	The format of the software version of the decoder is: "v[Major].[Minor].[Patch]"
49	Firmware Version Patch	STC	1-255	

Sound IDs and Versions...		SPIROM	Subject to change.	
200	Sound ID (High Byte)	STC	0-255	2 Bytes = 16-bit value for the ID of the sound file... READ ONLY
201	Sound ID (Low Byte)	STC	0-255	
202	Sound Version (High Byte)	STC	0-255	2 Bytes = 16-bit value for the version of the sound file... READ ONLY
203	Sound Version (Low Byte)	STC	0-255	

[Decoder Updates and firmware structure... Non-Sound Decoders](#)

Updates for Non-Sound Decoders are similar to the Sound Decoder types but will not contain the SPIROM content (see above.) Apart from bug fixes and future enhancements (feature additions etc,) non-sound decoder will be rarely updated.

## HM7000 Bluetooth Mesh operations ... System Overview

The HM7000 “ecosystem” utilises Bluetooth communications. Originally, Bluetooth was designed to offer a wireless alternative to USB. USB was designed to connect many peripherals to a central PC etc. The HM7000 utilises a more recent variant of Bluetooth called “Bluetooth Mesh.”

Bluetooth Mesh allows many Bluetooth devices to talk to each other thus forming a cross connected network that passes data around. This “Mesh” allows more reliable Bluetooth communications between “distant devices” etc. Each device within the Mesh network is called a node. If a “node” fails, transmission of data around the “Mesh” is maintained.

Another advantage of a Mesh system is that Bluetooth transmitters do not need to be high power i.e., a transmitted signal will be picked up by a node nearest to the transmitter and the data transmitted through the “Mesh” to the target device i.e., a locomotive or accessory. Thus, this form of Bluetooth communication is called Bluetooth Low Energy... BLE for short. Thus, power requirements are modest and can be designed to use very small power sources.

The HM7000 system makes full use of the Bluetooth BLE Mesh. This increases wireless range within the system and communications reliability.

The more items installed on your layout the better re overall system reliability. In the future the HM7000 “ecosystem” will be made up of many peripheral devices e.g., Point and Accessory Controllers (PACs) and other trackside devices as well as locomotives.

Because there are many “nodes” within the Mesh, the system is “self-healing” i.e., if a “node” is removed i.e., a Locomotive is lost e.g., derails etc, its node disappears from the Mesh.) On restoration of the locomotive on the track it’s “node” is re-established and automatically reconnects to the APP.

## The Common CVs...

### General Description

This range of CVs is common to all decoders with exception to CV12 which is unique to this decoder.

#### CV1... Primary Address

May contain an address with a value between 1 and 127.

Note some controllers may store addresses 100-127 in this location.

Note some controllers maybe restricted to less that 127 e.g., Hornby SELECT – Locomotive address rage 1-59.

Default Value	Range
3	1 - 127

Please see [Appendix 2: How Decoder addressing works...](#) for the full explanation of how decoder addresses are stored.

#### CV2... Vstart

Vstart is used to define the voltage drive level used as the start voltage on the motor at Speed Step 1.

Part of “Basic Speed Table” See [Explanation of the Speed Step Curve Graphs](#). for explanation regarding “Speed Tables”.

Maximum "255," i.e., the full available voltage is applied.

Default Value	Range
2	1-255

#### CV3... Acceleration Rate

Determines the decoder's acceleration rate. The acceleration rate change per increment in CV value is determined according to a formula issued by the NMRA. Please check the NMRA web site for a full description.

If the content of this parameter equals "0" then there is no programmed momentum during acceleration. (i.e., there will be no throttle lag.)

Default Value	Range
15	0-255

See [Explanation of the Speed Step Curve Graphs](#). for explanation regarding “Speed Tables”.

### CV4... Deceleration Rate

Determines decoder deceleration/braking rate, in the same fashion as acceleration above (CV3.)

Default Value	Range
15	0-255

If the content of this parameter equals "0" then there is no programmed momentum during deceleration. (i.e., the locomotive will slow at its normal pace as dictated by the motor fitted and BEMF braking effect. i.e., there will be very little throttle lag.)

See [Explanation of the Speed Step Curve Graphs](#). for explanation regarding "Speed Tables"

### CV5... Vhigh

Vhigh is used to specify the motor voltage drive levels at the maximum speed step. When the contents of CV5 equals "255", the full available voltage shall be applied.

Tip: You could use this CV to limit the top speed of a loco making it "safe" for unexperienced drivers, children etc. Alternatively, the locomotive speed can be capped to ensure prototypical scale top speed of the locomotive can be maintained.

See [Explanation of the Speed Step Curve Graphs](#). for explanation regarding "Speed Tables".

Default Value	Range
255	0-255

### CV6... Vmid

Vmid specifies the voltage drive level at the middle speed step.

Tip: If CV5 (Vhigh) is reduced then it may be advisable to reduce the Vmid value to suit the new Vhigh value.

See [Explanation of the Speed Step Curve Graphs](#). for explanation regarding "Speed Tables".

Default Value	Range
72	0-255

### CV7... Manufacturer Version number

NMRA Version ID - this is unused in the HM7000 decoder series. This CV exists as a NMRA requirement, nothing more.

Various version numbers applying to different aspects of the internal firmware are held in different CV locations.

For more information see... [Firmware Version Numbers](#)

Default Value	Range	Comments
254	N/A	NMRA requirement... no purpose in HM7000 decoders...

## CV8... Manufacturers ID and RESET decoder.

Each manufacturer of DCC equipment etc has a specific ID allocated by the NMRA.  
Range not specified... Default is 48 indicating "Hornby."

Default Value	Range	Comments
48	N/A	Values assigned by NMRA

### Special RESET functionality:

By writing the value 8 to this CV it is possible to reset all CVs of the decoder. In the case of sound decoders, writing the value 5 to this CV it is possible to reset all sound volumes only.

## CV10... Back-EMF Feedback Cut-out Speed Step

The decoder supports BEMF monitoring for maintaining a constant speed with varying load. i.e., this could apply to the locomotive negotiating curves and inclines etc. This CV allows the user to pre-set the point where BEMF compensation ceases to be supported dependent on a Speed Step value.

Default Value	Range
127	1-127

Note, when the controller is set to transmit 14 or 28 speed steps (NOT RECOMMENDED) the value set here will be truncated.

When tuning the Motor Control Algorithms, it is advised to reset the decoder to Default status before carrying out Auto-Calibrations or other motor tuning actions.

## CV12... Decoder Control mode select... DCC/BLE/DC... Sound Decoders Only.

The decoder may be controlled via NMRA DCC data transmitted from a controller via the track or via radio using its onboard Bluetooth receiver. (BLE)

The decoder will also support analogue (DC) operation with reduced functionality. DC operation is not recommended.

To support DC analogue operation, it is necessary to also configure CV29 bit2 to allow DC power conversion see...

This CV sets the mode of control.

Default is DCC mode.

Default Value	Range	Comments
0	0 – 2	0: DCC (NMRA) 1: DC 2: Radio (BLE)

**Note: CV12 applies only to Sound Decoders.**

## CV17 and CV18... Storing Long Addresses

CV17 and CV18 are used to store “Long Addresses.” There are two CVs involved i.e., 2 bytes of information.

A long address is generally any address above 127. However, some decoder will store addresses above 99 in these CVs. This will depend on the controller in use. To the user the process is transparent...

Please see [Appendix 2: How Decoder addressing works...](#) for the full explanation of how decoder addresses are stored.

CV#	CV Name	Default Value	Range	Comments
17	Extended Address High Byte	192	192-231	These two bytes form the Extended Address.
18	Extended Address Low Byte	100	1-255	

For these CVs to be active i.e., the address stored is in use... CV29 bit5 must be set on...(Decimal 32)

In most cases, when controllers etc program long addresses CV29 is handled automatically thus the process is simplified. On some very old DCC controllers CV29 would have to be programmed separately in order to activate a long address. Also, it is know that some Controllers do not support Long Addresses.

**Note: The default values of 192 and 100 as shown above give a long address of 100.**

The decoder will hold two addresses i.e.

CV3 = 3 (default) is address short address 3

CV17/18 as described above the default values will give a long address of 100.

Which address is active is set by CV29 bit5... see [CV29... Decoder Configuration ... general explanation](#)



There are 3 ways consisting is handled on DCC systems...

**Consisting by “Decoder Common Address”** Simply by using the same address for all locos you wish to operate in a consist group. If one or more of the locomotives is to operate in reverse, CV29 will usually be programmed for “reversed default direction.

**Consisting by “Controller Address Grouping”** The controller stores a group of decoder addresses and send one command sequence i.e. speed direction etc to all of the addresses in the group. Usually there will be a group address number (a virtual address) ... this is all controlled within the controller. The ELITE and SELECT use this system, however, by using the CV editor on these controllers, CV19 may be accessed, which means that decoder based consisting can be supported... see next. Early Hornby decoders i.e. R8249 and the very early R8215 did not support CV19.

**Consisting Internally within the decoder via CV19** All HM7000 decoders support this mode of consisting.. see below for the full explanation of CV19 etc.

**Explanation...**

CV19 contains overriding decoder address, which can be shared by other decoders (CV19) to support “Consisting” or “Double heading” etc. i.e., it becomes a common address between decoders. When CV19 = more than “0,” this address overrides all others stored. Ensure that CV19 = Zero or you will not be able to control your locos by usual addresses.

Default Value	Range	Comments
0	1 - 255	Default = 0 (Not part of a consist) Address range is 1 -127 Add 128 to the address number to reverse direction of the locomotive.

**Detail...**

This CV uses a 7bit format. Bits 0-6 contain the consist address. Bit7 indicates the relative direction of this unit within a consist, with a value of "0" indicating normal direction, and a value of "1" indicating a **direction opposite** the unit's normal direction.

Effectively, this means that a consist address can only be between 1 – 127... if you wish the locomotive to operate in reversed direction (e.g., “a push me pull you” type of consist configuration) one of the locomotives has to operate in the opposite direction from the other. Typical locomotives where a “push me - pull you” configuration is required include.. Class 43, Class 800, FLIRT, Class 91/DVT etc.

This is where 128 is added to the Consist number for that one locomotive. So, in a two Locomotive “push me – pull you” configuration, while they may both operate when commanded with the “consist” address will be programmed differently. e.g., two locomotives “push me- pull you” configuration responding to consist address “6” will readback as 6 and 134.

Rule... To make a locomotive run in the opposite direction add 128 to it’s consist number.

For Locomotives set up in a “push me pull you” type of consist selective function control depending on direction may be of use....

See... [CV119... Function Mask Select for multi decoder locomotives...](#)

### **Special Note re APP control...**

The APP has a GUI dedicated for setting up consists.

The GUI actually access CV19 to set up a consist.

However, the APP has an extra feature to make consist operations “superior” to running from a DCC controller. i.e. with the APP it is possible to apply speed compensations for different types of locomotive within a consist i.e. not all locomotives on the consists may respond equally to a common throttle speed step due to motor type/gearing/locomotive variations etc.

## CV27... Asymmetric DCC (ADCC) Configuration... (ABC operation) ... rail select.

Originally invented by Lenz, Asymmetrical DCC Control facilitates a simple way of creating basic locomotive automation on your layout. Sometimes this feature is referred to as Automatic Brake Control (ABC.)

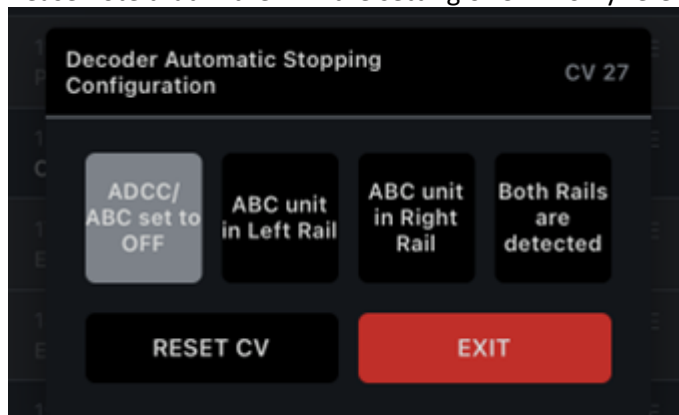
ADCC/ABC operation can be used to stop a loco automatically, reverse a loco or other actions without any input from the user on the DCC control system i.e., decoders with an ADCC function can be programmed to carry out a range of automatic actions.

These automatic “actions” are triggered when the voltage condition on the rails differs between the two rails... This condition is set up by arranging one section of rail to be isolated and have it power feed via a small diode matrix connected to the main DCC power signal... this causes the “imbalance of track voltages that are detected by the decoder... i.e. Asymmetrical DCC... ADCC.

There are several CVs associated with the configuration of ADCC operations... i.e., CV27 and CV125-CV127. CV27 is used to select which rail the ADCC condition is present.

Function	Decimal Value	
ADCC/ABC is OFF.. There is no rail Detection	0	
ABC unit in Left Rail..... Right Rail is detected	1	<b>Note: The rail set for detection is not the rail with the diode matrix installed!!!</b>
ABC unit in Right Rail.... Left Rail is detected	2	
Both Rails are detected ***	3	

Please note that in the APP the setting of CV27 only refers to the track position of the diode matrix that creates the ADCC state.



Please refer to [Appendix 4: Setting up Asymmetrical DCC Control... \(ADCC\)](#) for a full description of ABC/ADCC operations and configuration

## CV29... Decoder Configuration ... general explanation

This CV is used to set up how some of the decoder features work. e.g., loco default direction, which speed table to use etc... see below for full list.

Default Value	Range
2	1-255

The CV stores a simple binary number, i.e., a string of “ones and zeros.” The stored binary number is usually referred to in its Decimal form for simplicity.

The position of each “one or zero” in the binary number enables or disables a particular decoder feature.

The chain of “ones and zeros” is called a byte in computer language. This “byte” has 8 positions that can contain a “one or zero.” The positions of the “one or zero” is numbered 0 to 7... each “one or zero” is called a single “bit” and 8 “bits” make up one byte.... Thinking in Decimal terms since each bit position in the binary number has a specific Decimal value equivalent.

Bit #	Purpose	Default State	ADD to enable
0	Reverse Motor Direction	Disable	1
1	Headlight/rear light direction control... FL	Enable	2
2	Power Conversion mode	Disabled	4
3	RAILCOM® Enable	Not supported	8
4	Speed Table Select	Disable	16
5	Address selection... “short” or “long address” mode	Disable (Short Address mode)	32
6	Reserved for future use	Not Supported	64
7	Decoder type Select	Disable	128

In order to work out the basic “plain” number equivalent of enabling or disabling and of the features controlled by CV29 simply refer to the ADD column. Each feature has a Decimal value shown here... add these numbers together to turn on the features you want.

Examples...

If CV29 = 6 ... then Bit1 and Bit2 are enabled i.e.  $2 + 4 = 6$  ... the table above shows that only Headlight/rear light and Power Conversion are enabled.

If CV29 = 7 ... then Bit0, Bit1 and Bit2 are enabled i.e.  $1 + 2 + 4 = 7$  ... the table above shows that the loco is reversed, and only Headlight/rear light and Power Conversion are enabled.

If CV29 = 18 ... then Bit1 and Bit5 are enabled i.e.  $2 + 32 = 34$  ... the table above shows that Headlight/rear light and “Long Addresses” are selected.

There are tools available on the web which can help with CV29 value calculation... e.g. <http://www.2mm.org.uk/articles/cv29%20calculator.htm>

## CV29 ... Examination of each bit and its function...

bit0 ... Reverse Motor Direction ... EQD = 1 (Equivalent in Decimal.)

Explanation... Used to change the default direction which can be set to run the locomotive in reverse when the controller display is indicating a forwards direction. This CV is usually set to default “Normal”. Changing to “Reversed” can be useful if a motor has been ‘wired in reverse’ in order to correct the direction of running without dismantling the locomotive and rewiring the motor. Not to be confused with reversing the direction of a loco in a consist (i.e., double header) – see CV19... Consist Address Detail...

Default is 0... no change in decoder direction

bit1 ... Headlight/rear light direction control... FL ... EQD =2.

### Explanation...

Speed step setting for headlight / rear light control. Some decoders do not read the ‘direction’ correctly from the speed command sent from the controller. Changing this parameter within CV29 tells the decoder where to find the direction information within the speed command. On most decoders lighting direction is handled correctly no matter which speed step setting is used i.e., 14, 28 or 128 speed steps.

### Detail...

If Bit 1 has a value of 0 (zero), then bit 4 of the speed instruction is used controls the state of FL. This provides 14 discrete speed steps. If the decoder is configured for 14 speed steps, and is operated using 28/128 speed steps, the headlight will toggle correctly.

If Bit 1 is set to a value of 1 (default value), the decoder will operate in 28/128 speed step mode.

bit2 ... Power Conversion mode ... EQD = 4

### Explanation...

Loco decoders usually by default can operate under DC control on an analogue layout. However, on the Hornby HM7000 series decoders, you can disable this feature by changing this bit. If a decoder fitted locomotive is not going to be run on any analogue layout Hornby recommends that the parameter is set to “DCC Only”. i.e., this bit is set to 0.

bit3 ... RailCom enable ... EQD = 8...

However, RAILCOM is not supported in HM7000 decoders.

#### **Explanation...**

Some decoders support RailCom®. This is a feature which enables a decoder's CVs to be read back while the locomotive is on the Main Track. i.e., this applies to DCC operation only. This decoder supports BLE communications and decoder configuration can be readback via the Hornby BLE APP.

RailCom® is a registered trademark of Lenz Systems.

#### **Detail...**

Since this feature is not supported... the default is 0 ... this cannot be changed.

bit4 ... Speed Table Select ... EQD = 16

#### **Explanation...**

By default, the way a locomotive responds to the throttle is governed by CV2, 5 and 6. These CVs govern Vstart, Vhigh, and Vmid, which sets a basic speed curve.

However, advanced decoders allow you to build a custom speed curve by programming values into CVs 67-94.

This bit in CV29 allows you to choose which speed curve the decoder will apply.

#### **Detail...**

Bit4 is set to 0 (default) directs the decoder to use the basic speed curve set by Vstart, Vmid and Vhigh.

Bit4 set to "1" directs the decoder to use the complex speed step curve defined in CVs 67 through to CV94.

#### **Note:**

- The preset default Speed Table is referred to as the Complex Speed Curve.

- CV67 to CV94 hold values that describe the curve.
- Depending on the locomotive type i.e. Diesel, Electric, Steam etc. The default values of CV64 to CV94 are preset to a range of suggested values that offer a “complex” speed curve that may improve superior locomotive performance. However, all CVs in the range are designed to be programmable thus offering user control of the “Complex” speed curve shape.

bit5 ... Address Selection... “short” or “long” address mode ... EQD = 32

### Explanation...

Most decoders can store a long and a short address simultaneously. This CV sets which address is used (i.e., in play.)

Detail...

Short addresses are usually 1-127 are stored in CV1, long addresses 1-9999 are stored in CV17 and CV18 i.e., they work together to store the “long address.” bit5 is disabled by default. Thus, indicating a short address is active. Long addresses are active when this bit is enabled.

Bit5 is usually handled automatically when programming a decoder address and does not require programming by the user.

See [Appendix 2: How Decoder addressing works...](#) for more information regarding how addresses are stored in the decoder.

Tip: Since this bit is responsible for selecting between either the short or long addresses as “active,” you can use it to switch between them... i.e., use either the short or long address. When the decoder addresses are set to default values the two addresses will be “03” short address and “100” for the long address.

bit6 ... Reserved...

bit7 ... decoder type select...

### Explanation...

This sets the decoder type i.e., Multifunction or Accessory. Locomotive decoders are “multifunction.” Thus, this bit is fixed at zero... read only.

## CV47, CV48 and CV49... Control Processor Firmware Version... APROM

Decoder APROM firmware release information is stored here... the decoder can be updated over the air (OTA.) We use these CVs to keep track of the current version of firmware currently loaded.

The format of the software version of the decoder is: "v [Major#] [Minor#] [Patch#]" This CV is Subject to Change... STC

Control Processor Firmware version APROM Subject to Change				
47	Firmware Version Major	STC	1-255	Control Processor Firmware Version... READ ONLY The format of the software version of the decoder is: "v[Major].[Minor].[Patch]"
48	Firmware Version Minor	STC	1-255	
49	Firmware Version Patch	STC	1-255	



## CV51 to CV58... Lighting Configuration description...

### General Description

Generally, all lighting used in a modern locomotive will be LED types. However, other types of load can be connected... see notes in [Appendix 3: Using AUX Outputs... i.e. the Hardware Function Outputs... \(HFOs\)](#) re connecting various other types of load to the HFOs.

Sound decoder supports up to 4 Aux type Hardware Function Hi-Level Outputs (HFOs) and 2 Logic outputs HFOs.

Non-Sound decoders support up to a maximum of 3 AUX type Hardware Function Outputs. Note the number of HFOs available will depend on the decoder plug/socket arrangement.

Please see individual decoder specifications for full details of HFO support per decoder connector type, please see [Sound Decoder Types and Connection](#)

### Summary... Hi-Level Outputs

**HFO1 and HFO2** are connected to directional lighting which is activated by **F0** on the controller.

..

**HFO3 and HFO4** can be connected to lighting e.g., LEDs and are toggled on/off via F numbers on your controller (see below.)

For Non -Sound decoders use **F1** and **F2** respectively.

For Sound decoders use **F21** and **F22** respectively.

Alternatively, these HFOs are referred to as AUX1 and AUX2

...

### Summary... Logic-Level Outputs

**HFO5 and HFO6** are logic level outputs designed to interface to digitally controlled ancillary features. i.e., A logic level output is rated at low current capability and a reduced voltage to directly drive logic level inputs. They may be used for dedicated functionality dependent on the decoder firmware type... e.g., STEAM generator control.

These HFO5 and HFO6 are controlled by **F3** and **F4** respectively on non-Sound decoders, for sound decoders use **F23** and **F24** respectively.

Alternatively, these HFOs are referred to as AUX3 and AUX4

..

## Setting Lighting Effects and Brightness...

**Warning...** HFOs can also be utilised for loco features other than lighting. When connected to non-lighting features the following CV information may or may not apply. This depends on the nature of the feature to be controlled. However, some “effect” modes listed below may have use with other types of connected peripheral devices.

HFO1, HFO2, HFO3 and HFO4... the action/effect and brightness of HFO outputs can have various lighting type effects and brightness may be configured. See below.

HFO5 and HFO6 are toggle only digital outputs for logical control of other peripheral electronics. Unlike the above, they are not configurable. See next for configuration of lighting effects etc re HFO1 – HFO4

Lighting.... HFO0 – HFO4 Function					
CV#	CV Name	Hardware	Default Value	Range	Comments
51	Lighting Effect F0 - (Front)	HFO1	0	0-7	Lighting Control 0: Constant bright light 1: Random flicker (fire box) 2: Mars light 3: Flashing light 4: Single pulse strobe 5: Double pulse strobe 6: Rotary beacon 7: Gyra light
52	Lighting Effect F0 - (Rear)	HFO2			
53	Lighting Effect F1/F21	HFO3			
54	Lighting Effect F2/F22	HFO4			

Lighting.... HFO0 – HFO4 “Brightness”					
CV#	CV Name	Hardware	Default Value	Range	Comments
55	Lighting Brightness F0 - (Front)	HFO1	8	0-8	9 Brightness levels available...  0: Off ... to 8: Maximum Brightness
56	Lighting Brightness F0 - (Rear)	HFO2			
57	Lighting Brightness F1/F1	HFO3			
58	Lighting Brightness F2/F2	HFO4			

## CV59 to CV66... Auto Function Control (AFC)

The decoder can be configured to play a random spot sound at a random/sequential interval between 25 and 36 seconds...

Two different sets of Spot Sounds can be configured for play depending on whether the locomotive is stationary or on the move.

The only limit to the number of spot sounds that can be selected in each mode will depend on the sounds available for the particular locomotive sound profile you have loaded.

..

Also, if this feature is turned on some sounds will be played automatically anyway.... i.e., this is in addition to the Spot Sounds selected for random/sequential play....

### **Steam Engines**

Background Steam plays as usual, on moving off a whistle will be played. On braking to a halt, brake sounds will be heard.

### **Diesels, Electric and Electro-Diesels**

The normal locomotive "Idle" sounds will play as usual, on moving off a horn will be played. On braking to a halt, brake sounds will be heard.

When AFC is active the locomotive main lights will be active i.e., Front/Rear.

See... [F28... Enable/Disable Auto Function Control/Spot Sound Play \(Sound Decoders only.\) ... CV59 – CV66](#)

## CV67 to CV94... Complex Speed Table Configuration

Depending on locomotive type... values held in this range of CVs may differ. i.e, diesel or steam etc... In the example below we have shown a list of values pertaining to Diesel/Electric types of locomotive.

The default values are “suggested” for each locomotive type.... They may be configured further to suit your requirements.

The table below lists the CVs values making up a preset “Speed Curve” for a Diesel type locomotive.

For a more complete description of “Speed Tables/Complex Speed Curves” and how they are used in other types of locomotives e.g. Steam Locomotives... See... [Appendix 6: All about Motor Control and Tuning... Speed Curves. PIDs and Things... .. CV143 to CV155](#)

CV#	Default Value	CV#	Default Value
CV67	5	CV81	90
CV68	8	CV82	100
CV69	11	CV83	110
CV70	15	CV84	121
CV71	19	CV85	132
CV72	24	CV86	144
CV73	30	CV87	156
CV74	36	CV88	169
CV75	42	CV89	182
CV76	49	CV90	195
CV77	56	CV91	209
CV78	64	CV92	224
CV79	72	CV93	239
CV80	81	CV94	255

CV value range is 1-255 for all CVs listed above.

**If the Complex speed table is to be implemented CV29 bit4 must be enabled in order to select the table.**

## CV119... Function Mask Select for multi decoder locomotives...

Some locomotives have two decoders fitted within the rake... e.g. Class 43, Class 800, FLIRT, Class 91/DVT etc. In these cases a decoder will be fitted in both the power car and dummy car.... i.e., at each end of the rake.

The decoders are set up to have different responsibilities...i.e., the power car decoder will be used to control the motor and lighting, where as the “dummy car” decoder is only responsible for light control... However, the HM7000 decoder is a sound decoder, and it may be desirable for sounds (typically horns) to be played by either “power car” or “dummy car” ... but, not both at the same time. This is usually dependent on the locomotive direction.

Since it usual to configure the decoders in the above scenario with a common address, it is therefore not possible to set up the system so that e.g. “horns,” are only played from the desired “end” of the rake... dependent on direction. Other, sound functions could also be direction dependent.

By using CV119 it is possible to select a preset function mask in each decoder so that common commands to the decoder pair will only be active in the desired decoder...

The masks are referred to as “Non-Motorised”, “Motorised” and “Normal” Please check the tables below for full details... there are mask states...

CV#	Default Value	Range	Comment
CV119	0	0 - 2	0: Normal Function Mask 1: Motorised Function Mask 2: Non-motorised Function Mask

### Example..

By setting the motorised car (power car) decoder to value 1 and the non-motorised car (dummy car) decoder to value 2 the correct sounds will be played by each car according to direction.

Function	Normal Mask (default)		Mask for Motorised Profile		Mask for Non-motorised Profile	
	Forward	Reverse	Forward	Reverse	Forward	Reverse
F2	✓	✓	✓	X	X	✓
F3	✓	✓	✓	X	X	✓
F4	✓	✓	✓	✓	✓	✓
F5	✓	✓	✓	✓	✓	✓
F6	✓	✓	✓	✓	✓	✓
F7	✓	✓	✓	✓	✓	✓
F8	✓	✓	✓	✓	✓	✓
F9	✓	✓	✓	✓	✓	✓
F10	✓	✓	✓	✓	✓	✓
F11	✓	✓	✓	X	X	✓
F12	✓	✓	✓	✓	✓	✓
F13	✓	✓	X	✓	✓	X
F14	✓	✓	✓	✓	✓	✓
F15	✓	✓	✓	X	X	✓
F16	✓	✓	✓	✓	✓	✓
F17	✓	✓	✓	X	X	✓
F18	✓	✓	X	✓	✓	X
F19	✓	✓	✓	X	X	✓
F20	✓	✓	✓	X	X	✓
F23	✓	✓	✓	✓	✓	✓

## Special Decoder Functions... F25/28 Sound Decoders ... F5/F8 Non-Sound Decoders... configured by CV120 to CV124

### General Description

The HM7000 decoder has several special features that are enabled via Function numbers on the controller.

Each the action of each of these “special functions” may be configured with its own dedicated CV range.

Special Function	F# Sound Decoders	F# Non-Sound Decoders	Description
<a href="#">Shunting Mode</a>	F25	F5	Engage Shunting Mode
<a href="#">Coupling Assist (creep) mode</a>	F26	F6	Engage Creep
<a href="#">Brake while decelerating</a>	F27	F7	Apply Brakes
<a href="#">Random Automatic Spot Sound Play (AFC)</a>	F28	N/A	Enable/Disable AFC operation
<a href="#">Push Button Control of motor</a>		F8	Non-sound decoders Only.

Configuration of each special function is described in the following sections...

Note: another advanced feature is the support of Asymmetrical DCC operation... [Appendix 3: Setting up Asymmetrical DCC Control... \(ADCC\)](#)

### F25... Shunting mode... CV120

This feature facilitates better manual control of the loco speed in low-speed operations. The CV value held here sets the speed scaling factor applied to the Speed Step set by throttle position.

Default Value	Range	Comments
1	0-2	Percentage of current Speed Step value 0: 25% 1: 50% 2: 75%

## F26... “Creep” mode... Coupling Assist CV121-122

The loco can be set to “creep” forwards or backwards at a pre-set speed. This feature is designed to assist when coupling or carrying other shunting operations. **The direction of “creep” will depend on the last selected direction.** On activation of F26, the locomotive will “creep” for a preset period of time... it is also possible to configure the “Creep” action to be continuous operation.

A set period maybe useful for coupling etc.

CV#	CV Name	Default Value	Range	Comments
121	Creep speed	1	1-15	
122	Creep pre-set duration (Seconds)	0	0 - 10	CV122 = 0 ... Continuous Operation (Toggle)      CV122 = 1- 10 ... Preset Operation Duration (Momentary)

### “Creep Mode usage suggestions...

Generally, “Creep” mode is manually controlled by F26, however preset “creep” durations can be set up via CV. i.e. if implemented will probably be used in continuous operation under user control... however, preset duration may have there uses see below...

#### “Creep” ... carrying out precise coupling procedures etc.

Coupling Speed is set as required, duration is set as required... see table above.

- 1, Drive locomotive up to the rollingstock to be coupled... Stop locomotive.
- 2, Press F26 to enable the “creep” function. Repeat until the rollingstock has been coupled to the locomotive.
- 3, Experiment with the “creep” duration setting to suit your own driving style e.g., if you tend to stop short of the rolling stock when coupling you may want to set the “creep” duration to longer... or conversely shorter if you are skilled in getting close to the target rolling stock.

#### “Creep” used with trackside uncouplers ... uncouple/coupling operation.

This feature is ideal for use with uncouplers etc... i.e., allowing precise placement of the locomotive/rollingstock in relation to the uncoupler.

- 1, Drive locomotive so that the rollingstock coupling is close to the uncoupler position... Stop locomotive.
- 2, Press F26 to enable the “creep” function. Repeat until the rollingstock coupler is precisely positioned over the uncoupler. (Experiment with the “creep” duration setting to suit your own driving style e.g., if you tend to stop short of the rolling stock when coupling you may want to set the “creep” duration to longer... or conversely shorter if you are skilled in getting close to the target rolling stock.
- 3, Enable “Uncoupler” ... rolling stock is uncoupled.
- 4, Reverse the direction of the locomotive and drive the locomotive away either manually or using “Creep” mode.
- 5, Disable Uncoupler.

**It can be seen from these operational notes the “Creep” Feature has many possibilities...** e.g., a shuffle along tool for dropping coal, wagon by wagon at a Coal Depot.

**Note:** If F26 (Creep Mode) is enabled... “rail select” for ADCC is disabled i.e. overridden.. No ABC action will be triggered.



## F27... Manual Application of Brake during normal deceleration... CV123

When the loco is decelerating extra brake effort may be applied. CV4 is used to set up a deceleration level for normal use. CV123 allows you to set a secondary deceleration level to simulate locomotive braking. This secondary level is activated when F27 is enabled in the controller.

F27 should be applied for as long as braking is required.

A CV value of 1 will give an almost instant stop i.e., instant deceleration. Higher values will give lesser braking effects.

Using F27/F7 it is possible to control the locomotive action completely. If the locomotive is set to operate at a preset speed, then using F27/F7 you can decelerate/accelerate/stop the locomotive as desired... it is worth experimenting with various values of CV123 for different driving effects using these Function numbers.

Default Value	Range	Comments
5	0-255	Set deceleration level... similar functionality of <a href="#">CV4</a>

The default value of 5 allows you to apply a modest braking effect compared to the normal deceleration rate set by CV4. CV4 has a default of 15, generally speaking the CV123 will always have a smaller value than CV4.

F27 braking will eventually stop the locomotive if applied for long enough... as previously explained the locomotive will start moving again when the brake is released (disable F27.)

Generally, locomotives will start to move again after any brake release/steam cocks etc are played before movement. The locomotive will accelerate to whatever throttle level/speed has been previously set. However, diesel locomotives will not move off immediately due to the diesel engine ramp up delay set by [CV225](#).

This feature is fun to play with and worth spending some time experimenting with different locomotive types and different brake settings (CV123.)

## CV125 to CV127... ABC/ADCC Actions...

See Appendix 4... [Appendix 4: Setting up Asymmetrical DCC Control... \(ADCC\)](#)

## F28... Enable/Disable Auto Function Control (AFC) of Spot Sound Play ... CV59 – CV66

The sound decoders can be configured to play a random spot sound at a random interval between 25 and 36 seconds...

When “Auto Function Control” (AFC) is enabled, the decoder will automatically play a horn/whistle sound as the locomotive moves off. The horn/whistle played is from the group of whistles/horns associated with F2 as configured in CV205 ... In addition, when the locomotive come to a halt “brake squeal” will be played.

Also, the user has the option to configure the play of other sounds to be played at random intervals between 25 and 36 seconds. These sounds can be set to play sequentially or randomly.

The user can choose which sounds are to be played. However, it is recommended that only momentary Spot Sounds are chosen for AFC control.

The sounds played by AFC system when the loco is stationary can be set to be different from when the locomotive is on the move.

While AFC is enabled F0 lighting is always active.

The following CV range shown in the table described below allows you to select which spot sounds that are played in either locomotive running or stationary situations.

AFC Sound Selection .... Sounds while Locomotive is Running...												
CV#	CV Name	Default Value	Range	Comments								
59	Play Mode while running	0	0-1	0 = Sequential 1 = Random								
				<i>Bit#</i>	7	6	5	4	3	2	1	0
				<b>ADD:</b>	128	64	32	16	8	4	2	1
60	Loco Running Spot Sound Select F2 – F7	0	0-255		F7	F6	F5	F4	F3	F2	F1	F0
61	Loco Running Spot Sound Select F8 – F15	0	0-255		F15	F14	F13	F12	F11	F10	F9	F8
62	Loco Running Spot Sound Select F16 – F20	0	0--31		X	X	X	F20	F19	F18	F17	F16
AFC Sound Selection .... Sounds while the locomotive is Stationary ...												
CV#	CV Name	Default Value	Range	Comments								
63	Play Mode while stationary	0	0-1	0 = Sequential 1 = Random								
				<i>Bit#</i>	7	6	5	4	3	2	1	0
				<b>ADD:</b>	128	64	32	16	8	4	2	1
64	Loco Stationary Spot Sound Select F2 – F7	0	0-255		F7	F6	F5	F4	F3	F2	F1	F0
65	Loco Stationary Spot Sound Select F8 – F15	0	0-255		F15	F14	F13	F12	F11	F10	F9	F8
66	Loco Stationary Spot Sound Select F16 – F20	0	0--31		X	X	X	F20	F19	F18	F17	F16

F0 and F1 are turned on automatically under AFC operation. Therefore, bit0 and bit1 are not programable.

F0 and F1 are turned on automatically under AFC operation. Therefore, bit0 and bit1 are not programable.

Programming explanations...

CV59 selects whether sounds are played in sequential or random order while the loco motive is running.

CV63 selects whether sounds are played in sequential or random order while the locomotive is stationary.

Sound Selection... help...

By setting the bit representations of the sound in each of the CVs listed in the table, it is possible to select which sounds you want to play during AFC operation.

Note: these sounds are additional to the automatic sounds played as the locomotive starts to move or comes to a halt.

Each CV stores a Decimal value which when converted to binary enables/disables the actual sound stored in a particular Function number to be active or not within AFC play. For a complete understanding of this some knowledge of binary arithmetic is required. However, we have avoided this in the explanation given below. Working out CV values to enable specific sounds...

(For more information on binary programming etc please review the explanation of CV29 where an alternative explanation is given... CV29... Decoder Configuration )

When F28 is used to enable AFC operation no sounds will be played other than the expected Start, Stop sounds as mentioned above. By default, all sound selection CVs are set to = 0.

Sounds can be added on the fly by using OPERATIONAL mode programming... this is recommended. However, sounds can be enabled in the usual way via programming on the SERVICE track. See next for programming procedure...

<table border="1"> <thead> <tr> <th colspan="3">CV60 (Running) or CV64 (Stationary)</th> </tr> <tr> <th>Function or Sound</th> <th>Bit#</th> <th>ADD</th> </tr> </thead> <tbody> <tr> <td>0 Lights</td> <td>0</td> <td>**</td> </tr> <tr> <td>1 Loco Running Sound</td> <td>1</td> <td>**</td> </tr> <tr> <td>2</td> <td>2</td> <td>4</td> </tr> <tr> <td>3</td> <td>3</td> <td>8</td> </tr> <tr> <td>4</td> <td>4</td> <td>16</td> </tr> <tr> <td>5</td> <td>5</td> <td>32</td> </tr> <tr> <td>6</td> <td>6</td> <td>64</td> </tr> <tr> <td>7</td> <td>7</td> <td>128</td> </tr> </tbody> </table>	CV60 (Running) or CV64 (Stationary)			Function or Sound	Bit#	ADD	0 Lights	0	**	1 Loco Running Sound	1	**	2	2	4	3	3	8	4	4	16	5	5	32	6	6	64	7	7	128	<table border="1"> <thead> <tr> <th colspan="3">CV61 (Running) or CV65 (Stationary)</th> </tr> <tr> <th>Function or Sound</th> <th>Bit#</th> <th>ADD</th> </tr> </thead> <tbody> <tr> <td>8</td> <td>0</td> <td>1</td> </tr> <tr> <td>9</td> <td>1</td> <td>2</td> </tr> <tr> <td>10</td> <td>2</td> <td>4</td> </tr> <tr> <td>11</td> <td>3</td> <td>8</td> </tr> <tr> <td>12</td> <td>4</td> <td>16</td> </tr> <tr> <td>13</td> <td>5</td> <td>32</td> </tr> <tr> <td>14</td> <td>6</td> <td>64</td> </tr> <tr> <td>15</td> <td>7</td> <td>128</td> </tr> </tbody> </table>	CV61 (Running) or CV65 (Stationary)			Function or Sound	Bit#	ADD	8	0	1	9	1	2	10	2	4	11	3	8	12	4	16	13	5	32	14	6	64	15	7	128	<table border="1"> <thead> <tr> <th colspan="3">CV62 (Running) or CV66 (Stationary)</th> </tr> <tr> <th>Function or Sound</th> <th>Bit#</th> <th>ADD</th> </tr> </thead> <tbody> <tr> <td>16</td> <td>0</td> <td>1</td> </tr> <tr> <td>17</td> <td>1</td> <td>2</td> </tr> <tr> <td>18</td> <td>2</td> <td>4</td> </tr> <tr> <td>19</td> <td>3</td> <td>8</td> </tr> <tr> <td>20</td> <td>4</td> <td>16</td> </tr> </tbody> </table>	CV62 (Running) or CV66 (Stationary)			Function or Sound	Bit#	ADD	16	0	1	17	1	2	18	2	4	19	3	8	20	4	16
CV60 (Running) or CV64 (Stationary)																																																																																			
Function or Sound	Bit#	ADD																																																																																	
0 Lights	0	**																																																																																	
1 Loco Running Sound	1	**																																																																																	
2	2	4																																																																																	
3	3	8																																																																																	
4	4	16																																																																																	
5	5	32																																																																																	
6	6	64																																																																																	
7	7	128																																																																																	
CV61 (Running) or CV65 (Stationary)																																																																																			
Function or Sound	Bit#	ADD																																																																																	
8	0	1																																																																																	
9	1	2																																																																																	
10	2	4																																																																																	
11	3	8																																																																																	
12	4	16																																																																																	
13	5	32																																																																																	
14	6	64																																																																																	
15	7	128																																																																																	
CV62 (Running) or CV66 (Stationary)																																																																																			
Function or Sound	Bit#	ADD																																																																																	
16	0	1																																																																																	
17	1	2																																																																																	
18	2	4																																																																																	
19	3	8																																																																																	
20	4	16																																																																																	

Please note... \*\* Functions 0 and 1 are not selectable... they are always enabled during AFC control.

## Working out CV values to enable specific sounds...

From the tables above it is possible to calculate the Decimal value required to be entered in a CV to select specific sounds for play.

1, Select the sound you desire

2, Ignore the Bit# column and look at the number shown in the ADD column. Remember this number.

Keep repeating this process until you have a string of numbers that represent the sounds you wish to play during AFC operation. ADD these numbers together and programme the CV with the result... that's it.

## Disabling a sound from AFC control.

If you wish to remove a sound, simply subtract its corresponding number which appears in the ADD column.

Note for advanced users... the Bit# column shows the bit position for each sound represented in the list... some controllers require this information... consult your controller manual.

## Notes re Selecting sounds for AFC control... Please read this.

It is possible to select any of the 18 sound functions for inclusion in the AFC play sequence. (i.e., F2-F20.) However, not all of these spot sounds are necessarily suitable or desirable for AFC control... e.g., loop sounds? The suitability of a particular spot sound may depend on whether the locomotive is "stationary" or "running."

For advice re selecting which spot sounds maybe suitable for play when the locomotive is either stationary or running etc please consult your decoder function list leaflet. The leaflet is specific to the sound set of that decoder.

While it is possible to select loops etc for AFC play, when played they will be interrupted as the next sound is selected for play.

Selection of sounds is not limited, but the above notes will help you select suitable sounds for each AFC mode.

Please check decoder function list documentation for more information re whistles and horns and other sounds...

F8... “Push Button” operation, set speed... CV??? This feature applies only to non-sound decoders.

This feature is in development....

By enabling F8 on the controller the decoder motor output will accelerate and then hold a pre-set speed. On disable the motor will decelerate and stop. Primarily aimed for when the decoder is used for simple motor control scenarios e.g., motor driven trackside accessories etc. Acceleration and deceleration values are set by CV3 and CV4.

CV#	Default Value	Range	Comments
???	1	0-255	

CV??? Sets the pre-set speed step for “Push Button” operation.

Under review.... To be developed after HM7K sound variants are completed... applies to non-sound type decoders only.

## Sound Decoders... adjusting sound volumes etc.

The Common CV relating to Global Volume is discussed first. CVs pertaining to each locomotive type i.e., diesel/electric/steam are described under their own section.

### CV158... Global Sound Volume set... Common CV for all Sound Decoders.

When sound files are created for each locomotive “sound set,” Hornby have tried to set up the relative volumes of the sounds to give a “more or less” balanced experience. Changing the Global Sound volume changes the general volume level of playback of all sounds equally. You can adjust individual sound volumes of all sound types using CV162 – 180 ... see later.

**WARNING:** The decoder is fitted with a 1.68W amplifier. The HM7000 decoder amplifier is designed to have enough power to drive other third party speaker systems.

We do not wish to cap the maximum output of the amplifier. This practice would make the decoder inflexible in practice.

Sound volumes for all locomotive types are pre-set to a default value... see below.

### Steam Locomotives...

Default Value	Range	Comments
35	0 - 127	Write a value to this CV will set all sounds to the same volume level value

### Diesel Locomotives... Electric Locomotives etc.

Default Value	Range	Comments
35	0 - 127	Write a value to this CV will set sounds to the same volume level value

We have set the default volume level for each locomotive type to a value which will suit most environments.

In practice due to the vast range of speaker types that get used with decoders (including Hornby speaker types) we have decided that setting a lower default volume rather than mid-way was prudent. This is because not all speaker types are as efficient as others while some can't handle high volume settings.

It is unlikely that setting the volume high will damage any speaker arrangement but, it could however, sound distorted in practice. However, if fitting the locomotive with a different speaker, ensure that it has an impedance of 8Ω!

Bear in mind that if you turn your home entertainment HiFi amplifier volume to maximum there is an extreme likelihood of getting distorted reproduction. The sound decoder is no different in this respect.

For more information re “Speakers” please [Appendix 10: Speakers.... Sugar Cubes and the rest...](#)

### CV159... Volume of F0 (re Sound Only Projects... Does Not Apply to Locomotive decoders.)

This CV only applies to specialised sound only type decoders i.e, it, does not apply to locomotive control decoders. Note that “sound only decoders” use the same basic hardware as the locomotive types. Hence this entry to the CV table. This is to allow for further development of the Vent Van concept as seen with early TTS releases. It is possible that the new decoder could be the basis of future development. This CV was added the HM7000 sound decoder series to allow for this development in the future.

Default Value	Range	Comments
35	0 - 127	Volume F0 only... Special Case for sound only decoders (No motor control)

### CV160... ELECTRIC motors volume

#### ELECTRIC locomotives only

Default Value	Range	Comments
35	0 - 127	Volume Locomotive motors ELECTRIC only. Also applies to stationary sounds.

### CV161... Steam/Diesel engine volume on Acceleration and Deceleration

#### Steam and Diesel locomotives only

Default Value	Range	Comments
35	0 - 127	Volume Locomotive motors Diesel/Steam. Also applies to stationary sounds.

## CV162 to CV180... Set individual volumes of Spot Sounds F2 to F20

Spot sounds each have their own dedicated volume control CV to allow users to balance the audio of the locomotive. In the APP there is a master volume control slider. Note, in some cases not all F# are dedicated to spot sounds as this depends on the type of loco etc.

Each sound decoder sound set is tailored for a particular locomotive, and therefore may well differ in spot sound content between specific locomotives. When you download a locomotive sound set from the Hornby website you will be provided with a QuickStart guide for that locomotive download i.e., it will list the actual sounds implemented re the locomotive... check your download documentation. For users of the HM7000 APP the APP will automatically list the sounds used on the locomotive and allocate sounds to control buttons etc. Also, the CV listing will be updated to reflect the names of each sound within the volume configuration area.

Special note...

Spot sounds allocated to F2 and F3 are usually locomotive whistles and/or horns. These sounds are manually triggered by their corresponding F number. There are up to 8 possible whistle/horns allocated to each F number. They are played in either random or sequential order on each activation of each F number. Random or sequential is selected via CVs. Which whistles or horns are included in the play sequence are selected using CV205 - CV208.

See... [Horn and Whistle Selection re F2 and F3... Configuration... CV205 to CV208...](#)

..

Spot sound by F#... "Volume configuration" CV table...

CV#	CV Name	Default Value	Range	Comments
162-180	Volume of F2 - F20	35	0 - 127	Volume control from F2 to F20
<b>See below for full list</b>				

F#	CV#	F#	CV#	F#	CV#	F#	CV#	F#	CV#
F2	CV162	F6	CV166	F10	CV170	F14	CV174	F18	CV178
F3	CV163	F7	CV167	F11	CV171	F15	CV175	F19	CV179
F4	CV164	F8	CV168	F12	CV172	F16	CV176	F20	CV180
F5	CV165	F9	CV169	F13	CV173	F17	CV177		

**Note: CV162 and CV163 set volume levels for F2 and F3 respectively, thus setting the volume for each horn/whistle within each Function Group to a common volume.**



## CV200 to CV203... Sound IDs and Versions... SPIROM

General Description... Decoder sound firmware release information is stored here... the decoder can be updated over the air (OTA.) We use these CVs to keep track of the current version of sound firmware currently loaded.

Default does not apply... Subject to change.

Sound IDs and Versions... SPIROM		Subject to change.		
<b>200</b>	Sound ID (High Byte)	STC	0-255	2 Bytes = 16-bit value for the ID of the sound file... READ ONLY
<b>201</b>	Sound ID (Low Byte)	STC	0-255	
<b>202</b>	Sound Version (High Byte)	STC	0-255	2 Bytes = 16-bit value for the version of the sound file... READ ONLY
<b>203</b>	Sound Version (Low Byte)	STC	0-255	

Note: the version number held in these CVs does not reflect the “profile version” as shown in the APP. These references are for engineering use only.

## Horn and Whistle Selection re F2 and F3... Configuration... CV205 to CV208...

General Description... F2 and F3 are used to play horns or whistles etc.

Each F# has several different Horns/Whistles “lodged” under it. i.e., each time F2 or F3 are enabled a different horn or whistle is played. Which horns/whistle is played is configurable via CVs.

The Horns/whistles can be played in either random or sequential order. Thus, a different horn/whistle is played at each press of F#.

Each of these two F numbers can have up to 8 different horns/whistles etc associated with it.

Full function listings are available for each “Sound Profile” from the Hornby website. These “profiles” contain a full list of all the whistles available re F2 and F3.

Note the APP does not display the content i.e., horns/whistle list for F2 and F3. Thus, it is recommended downloading the full function list for your “Locomotive Profile.”

The “Function List” will contain full details of the “Horns/Whistles” available for each function.. . e. F2 and F3.

Using the list, you will be able to configure which horns/whistles are in play... see below.

CV#	CV Name	Default Value	Range	Comments
205	Sound Selection F2	***	0 - 255	bit7 bit6 bit5 bit4 bit3 bit2 bit1 bit0
206	Sound Play Mode F2	0	0 - 1	0: Sequential 1: Random
207	Sound Selection F3	***	0 - 255	bit7 bit6 bit5 bit4 bit3 bit2 bit1 bit0
208	Sound Play Mode F3	0	0 - 1	0: Sequential 1: Random

**CV206 and CV208 Explanation...** These CVs set whether each press of F2 or F3 cycles through the selected horns/whistles sequentially or randomly.

**CV205 and CV207 explanation...** Horn/Whistle selection for play.

\*\*\* The default value shown in the table above, will depend on the maximum number of horns/whistles available for play for F2 and F3. These values may change dependent on locomotive type. These CVs work in a similar way to CV29, and the AFC setup procedure described earlier... i.e they are bit maps. Each bit position selects a whistle/horn for inclusion for either F2 or F3.

e.g. if for a particular locomotive the maximum number of horns/whistles is F2= 4 and F3 = 2 ...then the default CV value for that locomotive would be as follows.... CV205 = 15 and CV207 = 3

## Programming tips...

The system can support up to 8 sound slots per Function #... i.e., F2 and F3.

Referring to the table below... Select the desired whistle/horns and add the number in the ADD column to arrive at simple Decimal value to programme the CV with.

Please download the specific "Function List" for your sound profile from the Hornby Web-site. This will give a full list of all Horns/Whistles available for use with F2 and F3.

Once you have downloaded the "Function List," ascertain how many sounds are associated with each function. Once this has been determined, when programming you only need to consider the first applicable bit positions for CV205 and CV207.

e.g.

If there are 4 different whistles/horns associated with F2 then you only need to consider bit0 to bit3.

Bit numbers higher in the CV value are ignored, i.e., in the example above this will be... bit4 to bit7. Attempts to programme non-existent "bits" will leave the current CV value unchanged.

The default of 255 means that all possible whistles and Horns will be available for each Function #. i.e., all will be available only limited by the number actually installed. On a power down, the system will revert back to the first Horn/Whistle in the sequence for that F number.

<b>CV205/207 Horn/Whistle Selection re F2 and F3</b>		
<b>Horn/Whistle Reference</b>	<b>Bit#</b>	<b>ADD</b>
<b>F2a F3a</b>	0	1
<b>F2b F3b</b>	1	2
<b>F2c F3c</b>	2	4
<b>F2d F3d</b>	3	8
<b>F2e F3e</b>	4	16
<b>F2f F3f</b>	5	32
<b>F2g F3g</b>	6	64
<b>F2h F3h</b>	7	128

## DIESEL LOCOMOTIVES Engine Running Sound Playback... 3 Notch and 4 Notch Systems.

Earlier/Original released TTS diesel locos were designed with a 3 notch + Idle engine sound system. The configuration of this system only differs from the full 4 notch + Idle system employed on later TTS projects by the addition 2 extra CVs for the parameters controlling transition from the 3<sup>rd</sup> notch to the 4<sup>th</sup> notch and back again.

### 3 Notch Diesel... Configuration... CV210 to CV215

CV#	Description	Default	Range	Explanation
	Idle			Applies to SS of < <b>DTT1</b>
<b>CV210</b>	Trigger Threshold 1 ( <b>DTT 1</b> )	5	5-15	Applies when SS > <b>DTT1</b> but < <b>DTT2</b> ... Plays Notch 1
<b>CV211</b>	Trigger Threshold 1 Window ( <b>DTTW 1</b> )	5	5-9	<b>DTTW1</b> ... Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
<b>CV212</b>	Trigger Threshold 2 ( <b>DTT 2</b> )	30	25-45	Applies when SS > <b>DTT2</b> but < <b>DTT3</b> ... Plays Notch 2
<b>CV213</b>	Trigger Threshold 2 Window ( <b>DTTW 2</b> )	5	5-14	<b>DTTW2</b> ... Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
<b>CV214</b>	Trigger Threshold 3 ( <b>DTT 3</b> )	60	60-80	Applies when SS > <b>DTT3</b> ... Plays Notch 3
<b>CV215</b>	Trigger Threshold 3 Window ( <b>DTTW 3</b> )	5	5-15	<b>DTTW3</b> ... Forces Notch to Decrease back to Notch 2

### 4 Notch Diesel... Configuration... CV210 to CV217

The operation of the 4 Notch variation of the diesel playback system is very similar to that of the 3 Notch system described above. All it does allow for an extra 4<sup>th</sup> “Notch” in the playback sequence.

In configuration, the only difference is that the 4 Notch introduces two more CVs in order to allow the parameters for the 4<sup>th</sup> Notch to be applied. i.e., CV216 and CV217 are added to the sequence. CV defaults and parameter ranges differ slightly from the 3 “Notch” system. **See full table in next section.**

..

[Diesel Sound... How it works... 3 or 4 notches... Detail...](#)

For this explanation we are assuming a 4 Notch system... see above for explanation of the difference between 3 Notch and 4 Notch Systems.

..

When the locomotive is stationary Diesel Idle sounds are played.

To add further “realism” to the driving experience we have also added a CV associated with each Trigger Threshold (**DTTx**.) This additional CV is the **Trigger Threshold Window (DTTWx)**. This window allows the driver of the locomotive to apply a higher notch for a short time in order to get the locomotive up to speed. The drive would then reduce the Notch back to the previous Notch.

In each case, the TTW CV sets a value that is added to the DTTx value. This creates a window of speed steps values that are used to control the engine sound in a specific way i.e.

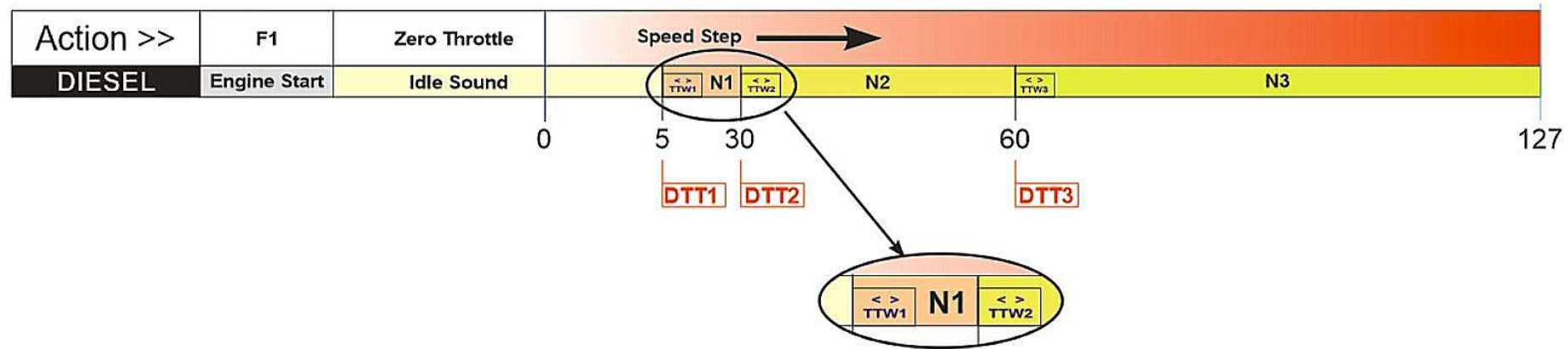
When the speed step transmitted from the controller falls into the range between the DTT and DTT + DTTW the engine sound will NOTCH up and then immediately NOTCH down. Please note that once the speed step transmitted is in this range no further automatic NOTCH Up/Down action will occur until, after the speed step has increased/decreased and then re-entered the TTW. This process limits the engine transition lag between minute throttle changes.

If the speed step transmitted exceeds DTT+DTTW than the engine will NOTCH up and remain at that NOTCH.

See below...

CV#	Description	Default	Range	Explanation
	Idle			Applies to SS of < <b>DTT1</b>
<b>CV210</b>	Trigger Threshold 1 ( <b>DTT 1</b> )	5	5 - 15	Applies when SS > <b>DTT1</b> but < <b>DTT2</b> ... Plays Notch 1
<b>CV211</b>	Trigger Threshold 1 Window ( <b>DTTW 1</b> )	5	5 - 9	<b>DTTW1</b> ... Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
<b>CV212</b>	Trigger Threshold 2 ( <b>DTT 2</b> )	20	20 - 30	Applies when SS > <b>DTT2</b> but < <b>DTT3</b> ... Plays Notch 2
<b>CV213</b>	Trigger Threshold 2 Window ( <b>DTTW 2</b> )	5	5 - 14	<b>DTTW2</b> ... Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
<b>CV214</b>	Trigger Threshold 3 ( <b>DTT 3</b> )	45	40 – 50	Applies when SS > <b>DTT3</b> but < <b>DTT4</b> ... Plays Notch 3
<b>CV215</b>	Trigger Threshold 3 Window ( <b>DTTW 3</b> )	5	5 – 14	<b>DTTW3</b> ... Forces Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3
<b>CV216</b>	Trigger Threshold 4 ( <b>DTT 4</b> )	65	65 - 70	Applies when SS > <b>DTT4</b> ... Plays Notch 4
<b>CV217</b>	Trigger Threshold 4 Window ( <b>DTTW 4</b> )	5	5 - 14	<b>DTTW4</b> ... Causes Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3

## Default Diesel Playback Configuration... Idle + 3 Notches



### Diesel... Examples of operation

**Acceleration.** Here are some examples of how the system responds using the default settings set out in the table above...

1. You turn the throttle up to just get the locomotive moving. The speed step applied is less than 5.

Decoder plays the following sequence of engine sounds...

    IDLE Only – **explanation...**

2. You turn the throttle up from zero to speed step 8

Decoder plays the following sequence of engine sounds...

    IDLE – Transition to NOTCH 1 – then back to IDLE.

3. You turn the throttle up from zero to speed step 12

Decoder plays the following sequence of engine sounds...

    IDLE – Transition to NOTCH 1 – Remains in NOTCH 1.

4. You turn the throttle up from zero to speed step 33

Decoder plays the following sequence of engine sounds...

    IDLE – Transition to NOTCH 1 – Transition to NOTCH 2 - then back to NOTCH 1.

5. You turn the throttle up from zero to speed step 66

Decoder plays the following sequence of engine sounds...

IDLE – Transition to NOTCH 1 – Transition to NOTCH 2 – NOTCH 3 – Remains at NOTCH 3

**Note:** When the locomotive moves off, brake release sounds are played automatically.

### Deceleration.

So far, we have talked about acceleration, deceleration follows different rules. Basically, at any given speed step the appropriate NOTCH or IDLE sound will be playing. On first decrement of the Speed Step the NOTCH playing will transition to the NOTCH below it. The second decrement of the speed step will cause the system to transition to the next NOTCH downwards. This process will repeat until the sound playing is “IDLE” and it is not possible to go any lower.

If the throttle is increased after a deceleration event, the acceleration rules will apply as described previously.

### CV225... Start delay after Brake release ... Diesel Locomotives Only

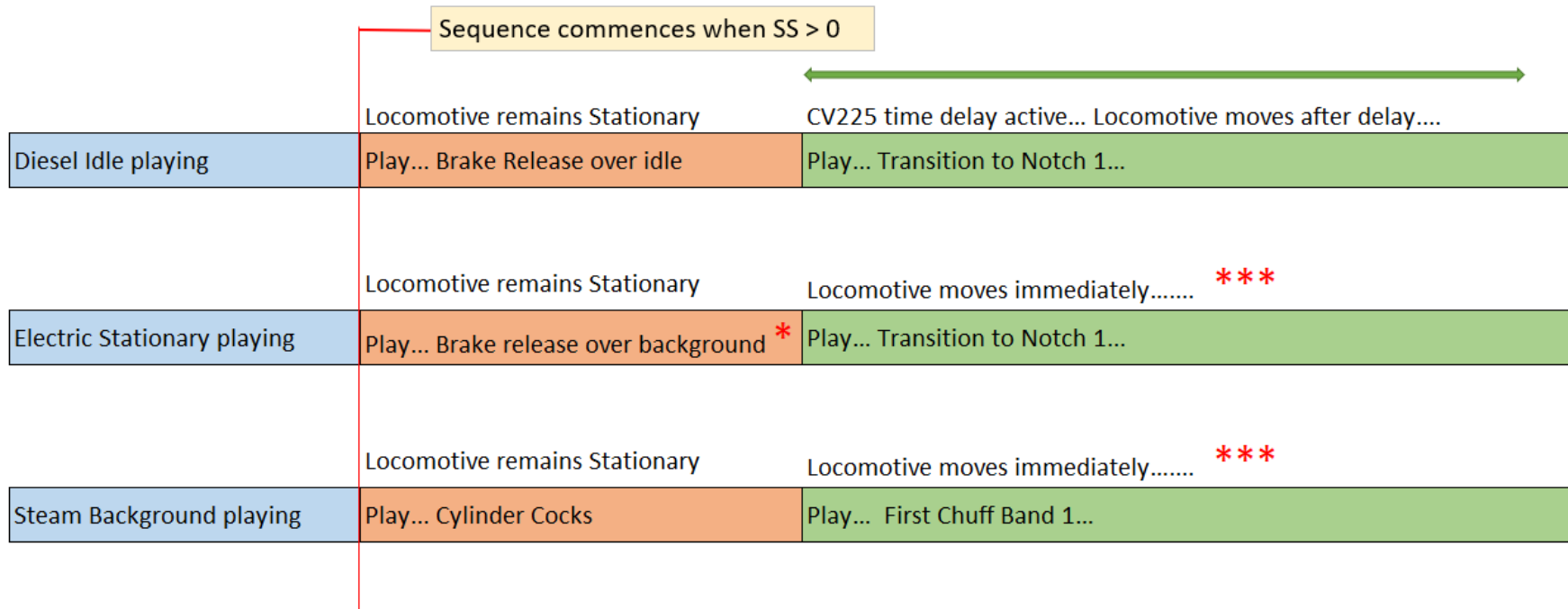
CV225	Default	Range
Start delay before Brake Release	25	0-255

This CV applies to diesel locomotives only. When the locomotive is commanded to move... the first thing that happens is a brake release sound will be played. Diesel locomotives typically rev the engine up before the locomotive actually moves. This CV allows to set a time delay to suit your running requirements. i.e., have the locomotive start movement almost immediately or part through the increase from Idle throttle to the first running Notch. Or for that matter, allow the locomotive to reach Notch 1 before moving off.

..

Other types of locomotive operate differently. i.e., steam and electric locomotives will start to move immediately after the cylinder drain cocks have been opened or the brakes have been released. In each locomotive type there is a sound played for these events. See next diagram for full details.

Movement on initial throttle increase from 0... the locomotive start sequence.... movement delay... CV225 only applies to Diesel engines. \*\*



Notes...

- \* This is a new sound sample created specifically to introduce "brake release" to the Electric Locomotive.. Thus, making it similar in operation to the Diesel type locomotives. Steam locomotives have "Steam Cock" sounds which play a similar role before the locomotive moves.
- \*\* The time delay set by CV225 only applies to Diesel locomotives. Prototypically, a diesel locomotive will "rev up" before moving off. At other times the locomotive may move off during the "rev up" period. CV225 sets a time delay that is triggered at the **end of the "Brake Release" sample** play before the locomotive commences movement. This allow the user to simulate the way the diesel engine works in relation to locomotive movement at start.
- \*\*\* Electric and Steam Locomotives move off immediately after the "Brake Release" or Cylinder Cocks have played.



## ELECTRIC LOCOMOTIVES... Engine Running Sound Playback...

[Explanation and Configuration... CV218 to CV222](#)

The system of operation is similar to the Diesel system described earlier. The decoder in your locomotive is designed to operate at 5 different rev levels... i.e., Notches. Each rev level above “**IDLE**” is referred to as “**NOTCH.**” There is also a “**Stationary Idle sound**” made up of background engines sounds and occasional compressor sounds... this is a random loop.

The system will play the Stationary/Idle sound loop from SS 1 to 3... above 3 Notch 1 is in play... SS=3 has been chosen as the first “threshold” as the locomotive will not usually start moving until SS=2.. or 3

### Engine rev levels...

**NOTCH 1...** Initial loco movement... the decoder ramps the electric motors up and holds at a very low rev rate. (The decoder plays background while the loco is Standing until SS >1 is applied. When SS >3, Notch 2 is then applied.... See list below.)

**NOTCH 2** (Revs increase)

**NOTCH 3** (Revs Increase)

**NOTCH 4** (Revs Increase)

**NOTCH 5** (Max rev Speed)

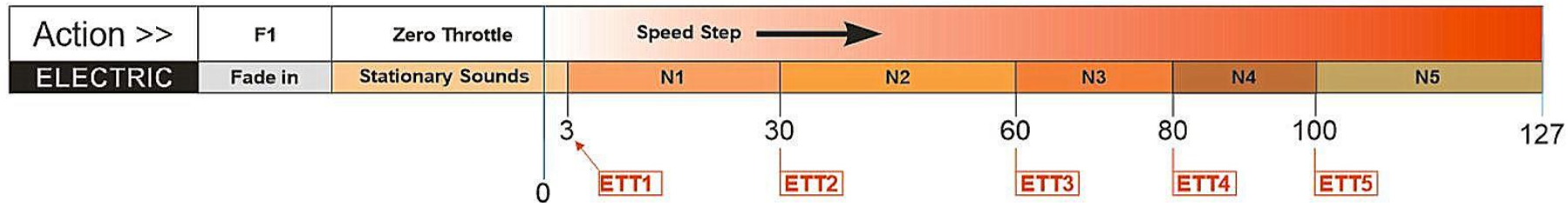
The way that the locomotive engine sound responds is controlled by the throttle on your controller i.e., as you increase the actual speed of your locomotive on the track, so the sound responds accordingly.

This CV range allows configuration of how the electric engine sound playback operates.

CV#	Description	Default	Range	Explanation
	Automatic Idle			Applies to SS of > <b>ETT1</b>
<b>CV218</b>	ELECTRIC Trigger Threshold 1 ( <b>ETT 1</b> )	3	1-127	Applies when SS > <b>ETT1</b> but < <b>ETT2</b>
<b>CV219</b>	ELECTRIC Trigger Threshold 2 ( <b>ETT 2</b> )	30	1-127	Applies when SS > <b>ETT2</b> but < <b>ETT3</b>
<b>CV220</b>	ELECTRIC Trigger Threshold 3 ( <b>ETT 3</b> )	60	1-127	Applies when SS > <b>ETT3</b> but < <b>ETT4</b>
<b>CV221</b>	ELECTRIC Trigger Threshold 4 ( <b>ETT 4</b> )	80	1-127	Applies when SS > <b>ETT4</b> but < <b>ETT5</b>
<b>CV222</b>	ELECTRIC Trigger Threshold 5 ( <b>ETT 5</b> )	100	1-127	Applies when SS > <b>ETT5</b>

Please check the following diagram for more information.

## Default Electric Playback Configuration... 5 Notches



## ELECTRO-DIESEL LOCOMOTIVES... Engine Running Sound Playback...

Explanation and Configuration... CV210 to CV222

General Description... This type of locomotive has the ability of running on either electric or diesel engines. It can swap between engine types when running. i.e., the decoder sound system can playback either electric or diesel sounds and transition between them as desired.

The playback/operation and configuration of each motor type i.e., diesel or electric is as per the single engine types. i.e., the Diesel and Electric Locomotives described previously.

Note that on this type of locomotive the diesel has 4 Notches, and the ELECTRIC has 5 Notches. This is explained further below.

The DIESEL part...

Please refer to the section above regarding DIESEL engine setup etc. The DIESEL engine part of the ELECTRO-DIESEL loco works in an identical way. The only difference being that in the ELECTRO-DIESEL diesel engine configuration there is an additional 4<sup>th</sup> Notch with its associate TT and TTW.

The ELECTRIC part...

Please refer to the section above regarding ELECTRIC engine setup. The ELECTRIC engine part of the ELECTRO-DIESEL loco works in an identical way.

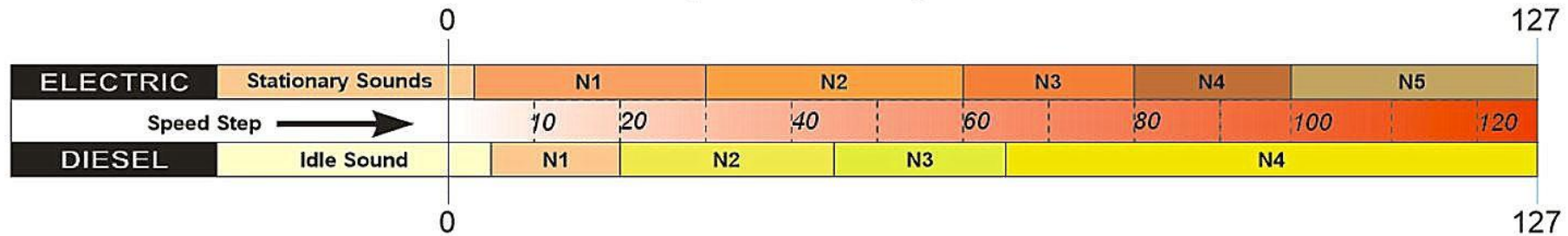
On the operation of F5 the transition between ELECTRIC/DIESEL/ELECTRIC will be made. The transition is made by playing two different sounds concurrently that contain the appropriate sounds for the transition i.e., the diesel engine running down and turning off and electric motor starting and running up to speed dictated by the current speed step, or conversely the electric motor turning off and running down to silence and the diesel starting and running up to the notch dictated by the current speed step. How it works... more detail.

Each DIESEL notch has a “fast” run down and Off sound corresponding to each of the “4 notches” available in DIESEL mode. Conversely, there are 4 “fast” DIESEL “start and run up” sound corresponding to each of the 4 notches.

ELECTRIC works in a similar way...

Each ELECTRIC notch has a “fast” run down and Off sound corresponding to each of the “5 notches” available in ELECTRIC mode. Conversely, there are 5 “fast” ELECTRIC “start and run up” sound corresponding to each of the 5 notches

# Default Electro-Diesel Transition Playback Configuration



## Special note...

It must be remembered that the “notches” for either engine do not match/correspond with each other. Check the diagram above for more information...

## Examples of transition...

### DIESEL to ELECTRIC

If the DIESEL is running with “Notch 4” playing i.e. Speed Step is between approx. 65 and 120, and a transition made to ELECTRIC, a transition will be made to... either “Notch 3,” “Notch 4” or “Notch 5” of the ELECTRIC.

The actual ELECTRIC notch will depend on the actual speed step at the time of transition... i.e. Notch 4 of the DIESEL spans across “Notch 3,” “Notch 4” and “Notch 5” of the ELECTRIC.

### ELECTRIC to DIESEL

If the ELECTRIC is running with “Notch 2” playing i.e. Speed Step is between approx. 30 and 60, and a transition made to DIESEL, a transition will be made to... either “Notch 2” or “Notch 3” of the DIESEL.

The actual DIESEL notch will depend on the actual speed step at the time of transition... i.e. Notch 2 of the ELECTRIC spans across “Notch 2” and “Notch 3” of the DIESEL.

Please study the diagram above for help with these explanations.

## STEAM LOCOMOTIVES... Non-Synchronised Wheel/Chuff system... Explanation and Configuration...

Utilising 18 pre-set chuff rates an approximate synchronisation of chuff/wheel rotation is possible.

When F1 is enabled background steam sounds are played e.g., the hiss of the boiler etc. Chuff rate is controlled by Speed Step value.

The controller sends Speed Step values between 0 and 127 to the decoder. This is the target speed of the locomotive... The decoder actually applies acceleration/deceleration to this speed step value, thus controlling the rate of acceleration/deceleration. i.e., the actual speed step applied to the motor will be delayed from the original speed step value sent from the controller. So, the speed step in use will gradually meet the target speed step sent from the controller. This delayed speed step value is the REAL speed step applied.... i.e., the "RSS." The RSS value determines what "Chuff" rate is applicable at any time. There are 18 pre-set chuff rates capable. This process is continuous.

When the RSS value drops the decoder will assume the locomotive is decelerating and play deceleration sounds applicable to the RSS value detected, until the RSS value stabilises, then a new chuff rate applicable to the new RSS value is selected and played until any other changes the RSS value are detected. i.e., a rise in RSS value thus, indicating a change in the locomotive speed etc.

To simulate when the locomotive is "coasting" it is possible via F20 to force constant rate "deceleration" sounds... as above these will change depending on the RSS value.

There are no user CVs to directly configure the Non-Synced Wheel/Chuff system.

### Steam locomotive specific Complex Speed Curve...

We have introduced "tuned" "Complex Speed" curve to suit the locomotive thus offering a more accurate approximation of the chuff rate to the speed of the loco. By default the locomotive will use the standard "basic" speed curve described thus... CV2 Vstart = 2 CV5 Vhigh = 255 CV6 Vmid = 72 CV29 = 2 (default)

To enable the "Complex Speed" curve add the value of 16 to the current value held by CV29... e.g. the CV29 value will become 18.

All sound steam locomotives have had a the "complex speed" "speed curve" curve fine tuned to give an improved approximation of the chuff rates vs locomotive speed.

Note.. These "Complex Speed" curves also cap the top speed of the locomotive to a more realistic top speed for the given locomotive.

For more details on these tuned "Complex Speed" curves see... [COMPLEX Speed Curves... Steam Locomotives types...](#)

## STEAM LOCOMOTIVES... “Piston Sync” Puff/Chuff system... Explanation and Configuration...

More Information to follow... sorry!

## STEAM LOCOMOTIVES... Turbomotive ... Explanation and Configuration...

There are no special CVs involved in configuration of the sound system.

It seems likely that there will only ever be one locomotive in the Turbomotive range.

Hornby have developed a unique sound set and control system of this locomotive. The sound of the steam turbine system will change as the locomotive accelerates or decelerates. i.e. rising and dropping in pitch.

Note: The "Wheel Slip" feature is not supported on Turbomotive. Due to the drive system being totally different from "traditional locomotives" the likelihood of "wheel slip" is thought to be unlikely. Turbomotive does not support this feature.

...

### Turbomotive: Operation Modes...

The Turbomotive has two modes of operation .i.e. "Default" and "Realistic." These affect how reverse operation is used.

The Turbomotive is unique in that the main motive power unit comprises 2 multi-stage turbines. The largest one is used whilst the locomotive is operating in a forwards direction and is connected to a treble reduction gear. For reverse running, a separate, smaller turbine is used having an additional single reduction gear, making in all, a quadruple reduction gear between the turbine spindle and driving axle.

The steam from the boiler is fed to a steam chest containing six control valves which are hand operated from the cab. From the steam chest, the steam passes through pipes to groups of nozzles in the high pressure end of the turbine cylinder, each nozzle group being controlled by one of the six valves. The speed of the turbine which governs that of the locomotive, is controlled by hand from the cab by opening these valves progressively, the steam from the turbine then exhausting via the smokebox and chimney in the usual manner

Operation of the Turbomotive is as such that the reverse turbine cannot be engaged until the locomotive comes to a stand. The locking gear provided in the control box in the cab, is used to select either "forwards" or "reverse" running. For reverse running a separate, smaller turbine is engaged using a dog clutch. A disadvantage of the design was the smaller reverse turbine only had sufficient power for manoeuvring "light engine".

Please see below for the CV and it's associated values for 2 different operating modes of the reverse turbine:

Turbomotive unique CV settings...

**CV227 = 0 (Default mode)**

Locomotive will operate in both directions.

F5 enabled - plays the reverse turbine spot sound.

F5 disabled - plays the reverse turbine spot sound.

**CV227 = 1 (Realistic Mode)**

Locomotive must be stationary before the F5 reverse turbine spot sound commences playback.

F5 enabled/toggle on - Locomotive will operate in a reverse direction only and at a reduced top speed.

F5 disabled/toggle off - Locomotive will operate in a forwards direction only.

**Acceleration and Deceleration settings...**

CV#	Description	Default Value	Value Range
3	Acceleration	25	0-255
4	Deceleration	25	255

Please note, any values other than '25' is likely to cause the steam turbine acceleration / deceleration sound playback to operate incorrectly.



## Steam Locomotives... Automatic Wheel slip behaviour simulation ... CV213 and CV216

This feature allows the user to simulate a “wheel slip” incident, clearly the wheels don’t actually “slip” but we can simulate the sound of “wheel slip” happening, and possibly set up the locomotives driving behaviour during the wheel slip incident, i.e. the user to experience the wheel slip incident... please see below.

This feature is supported on “non-syncing” and “piston syncing” steam locomotives.

### Manual Mode...

In default operation pressing **F6** will activate a “wheel slip” sound. (This is “manual mode.”)

### Automatic Mode...

Wheel slip can be initiated automatically when too much throttle is applied at low speeds, this is achieved by configuring CV213 = 1... (Automatic Wheel Slip enable.)

In Auto mode, wheel slip sounds will be activated if the amount of throttle increase is greater than the “overshoot value” set by CV214. During a “Wheel Slip” event while in automatic mode the speed of the locomotive will not increase. Think of this as what happens when you apply too much throttle in icy weather when driving your car.... i.e., the wheels will spin, and you go nowhere.

The speed range (in speed steps) where Automatic Speed Step is possible is set by CV215 and CV216...

When CV213 is set to enable pressing F6 will temporarily disable the wheel slip action.

### Summary Table...

CV#	CV Name	Default	Range	Explanation
CV213	Wheel Slip Automatic Mode Enable	0	0-1	0 = Manual 1= Auto
CV214	Wheel Slip Triggering Step Difference	7	5-15	Overshoot value... i.e., how many speed steps you can apply before wheel slip engages
CV215	Wheel Slip Deactivating Speed (Low Range)	2	0-5	Speed step of the locomotive below which the wheel slip operation will be disabled in automatic mode.
CV216	Wheel Slip Deactivating Speed (High Range)	25	15-75	Speed step of the locomotive above which the wheel slip operation will be disabled in automatic mode.

### Note:

No sound will be played if F1 is disabled.

**Turbomotive does not support this feature.**

## Appendix 1: CVs... what are they?? What do they do? And dealing with binary, if you really want too...

A Locomotive decoder is a complex device whose main purpose is to control the locomotives motor and other functionality (e.g., lighting etc.) How the decoder controls these features is configurable. The configuration information is stored in “data slots” referred to as “Configuration Variables.” In computer terms, each slot is actually made up of a single byte of memory space. The single byte is made up of 8 bits i.e., 8 x ones or zeros which representing the value of the stored data. Generally, when thinking about these values we refer to standard base 10 numbers in the range 0 to 255. Fortunately, your controller will usually do the maths for you i.e., covert the number into binary i.e. the ones and zeros that will be stored in the memory slot. All you have to do is enter Decimal numbers i.e., 0 – 255.

However, some CVs do require a little deeper understanding. While the CV contains an array of ones and zeros that represent a Decimal number, the pattern of these ones and zeros when read out in a row, are used to control individual features in the decoder. CV29 is a good example of the use of this technique. You can think of Decimal numbers representing a “bit pattern.” These “bit patterns” are explained next. See next section for more on this “fascinating “subject....

### Bytes and bits.... and nibbles...

Within a byte, the positions of each “one or zero” is numbered 0 to 7... each “one or zero” is called a single “bit” and 8 “bits” make up the byte. (Just for your amusement... half a byte is called a “nibble” ... seriously!)

As explained previously, a single byte can store the equivalent of a Decimal number in a binary value. The largest number that can be stored in a single byte is 255. The following explanation will explain all....

### Convert a Decimal number to binary...

Explanation: each “bit position” 0 – 7 represents a Decimal value. see table below.

### OK, try this...

**How to store any Decimal value as a binary number... this isn't as bad as it looks... once you have worked through an example it will be clear what s going on.**

Think of a number between 0 and 255.

Using the table below divide the number you thought of by the first number in the “Divide by” row... reading from left to right. If the number does not divide by the number move on to the next cell to the right... when you get to a divide number that works simply out a 1 in that cell (it will then have a bit position e.g., bit6 etc.

**Rule 1:** If there is no remainder after the division then you have finished. i.e. you will have a 1 written in one of the bit positions, now enter a zero for each bit position to the right until you get to Bit0.... You will get something that looks like this: 1000... in this example, the 1 is written in bit position 3.... Which means the number you thought of was 8.

**Rule 2:** If there is a remainder, after entering the 1, divide the remainder by the next number to the right in the “Divide by” row.... If you manage to divide the remainder put a 1 in that bit position... and move on to divide the remainder by the next number in the “Divide by” row. Keep going through this procedure repeating Rule 1 and Rule 2 until you have finished i.e., there is no remainder left...

Tip: If the number you thought of was odd, then bit0 will always contain a 1. So, clearly if the number was “even” bit0 will contain a zero (0)

If you have got this far.... you will now have a row of “one” and “zeros” which is the binary number equivalent of the number you first thought of.

The following table shows some examples of how binary is generated from a Decimal number.

Examples	Bit Position								Decimal Check
	bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0	
Divide by...	128	64	32	16	8	4	2	1	
Example 1 = 2							1	0	$2 + 0 = 2$
Example 2 = 6						1	1		$4 + 2 = 6$
Example 3 = 12					1	1	0	0	$8 + 4 + 0 + 0 = 12$
Example 4 = 20				1	0	1	0	0	$16 + 0 + 4 + 0 + 0 = 20$
Example 5 = 42			1	0	1	0	1	0	$32 + 0 + 8 + 0 + 2 + 0 = 42$
Example 6 = 127		1	1	1	1	1	1	1	$64 + 32 + 16 + 8 + 4 + 2 + 1 = 127$
Random Example ***			1	1	0	1	0	1	$32 + 16 + 0 + 4 + 0 + 1 ... = 53$

### Convert a binary number to Decimal?

If you have been through the example above, converting between binary to Decimal numbers should be clear.

Write the binary number down. i.e., as it appears.

Starting at the most right-hand digit, i.e., this will be bit0, moving from right to left follow this rule...

Looking at the table above you will see each bit position has an equivalent Decimal value... basically, if you write the binary number down all you have to do is add together the Decimal values present where a 1 is written in each bit position. See table.

Example 1... e.g., 101011 becomes  $32 + 0 + 8 + 0 + 2 + 1 ...$  which is equivalent to 43 in base 10, i.e., Decimal... i.e., normal counting...

**Have you given up? Please try again... it really isn't too difficult, it is not that you don't understand, the failure is in our explanation.**

### Other help....

There are many explanations on YouTube. The calculators installed on your PC often have conversion functions. There are other resources online...

<https://www.rapidtables.com/convert/number/binary-to-decimal.html>

## Appendix 2: How Decoder addressing works...

Note: This explanation is quite complex to those unfamiliar with binary etc... We do strongly recommend that you consider using an online resource to calculate Long Addresses etc... this is a possible resource... <http://www.2mm.org.uk/articles/cv29%20calculator.htm>

Or... check [Appendix 1: CVs... what are they?? What do they do? And dealing with binary, if you really want too...](#) for some light entertainment....

..

Note: if you wish to examine the explanation below, we it might be worth using a converting binary calculator to work through the example below... e.g., the Windows Calculator in Programmer Mode... best of luck....

### Definitions...

Short Address... this a locomotive address in the range 1 – 127

Long Address... this is a locomotive address above 127. The maximum address can vary between different controllers. E.g., A maximum of 9999 is typical for controllers with 4 digit displays. E.g., the ELITE. *Other controllers may limit at a lower value...e.g., Digitrax Zephyr at 9983*

*It should be noted that some controllers e.g., the Hornby Select will artificially cap the highest address allocatable to a decoder. (The Selects will only allow locomotive addresses between 1-59.)*

### General Description...

A CV is equivalent to one byte of binary data... a byte is 8 individual bits, usually referred to as bits 0 - 7... Note: some systems may refer to them as 1-8 (e.g., Lenz.)

Short Addresses are stored in the first 7bits of CV1 i.e., this is one byte of data. Long Addresses are stored in two bytes i.e., CV17 and CV18

From the above it can be seen that a decoder can actually store two different addresses at the same time... i.e., a short address and a long address. However, which address is active is controlled by the value set in CV29... see next.

### Address selection... Long or Short?

Due to the above, it can be seen that a decoder contains two different addresses. CV29 is used to select which address the decoder internally uses as its active ID address. If CV29 bit5 is set to “off” will mean that CV1 as the active address. Clearly, if bit5 to “on” the decoder will use the long address stored in C17 and CV18 as the decoder ID address.

The two default addresses stored will be... 3 for a short address and 100 for a long address.

However, a CV29 has a default value that sets bit5 as “OFF” or zero. Thus, “out of the box” the default address for any decoder will be 3.

### How a Short Address is stored...

When Short Addresses are used only the first 7 bits of CV1 are used... i.e., bit0 to bit6, if you carry out a little math... you will see that 7 bits only allows you to store a maximum Decimal value of 127... Hence, short addresses are limited to a max of 127.

Note, in practice the control system may regard values of above 99 as a Long Address... and will programme the appropriate values to CV17 and CV18... CV29..... see next.

During the programming process the controller will write to CV1 and then CV29... i.e. two write cycles.

### How a Long Address is stored...

Address numbers regarded as “Long” types are stored using two different CVs i.e., CV17 and CV18. The way this is done is dictated by the following rules...

Basically, the address’ Decimal value is converted to hexadecimal and then split into two parts...

During the Long Address programming process the controller will write to CV17, then CV18 and finish by writing CV29... i.e. three write cycles.

See next for an explanation re Hexadecimal.... If you really feel the need!!!

### Calculating values for CV17 and CV18

The Hexadecimal way... this the way programmers will calculate the values ... and it is convoluted!!!

Hexadecimal is base 16 counting and uses the usual Decimal symbols of 0 – 9 but also uses A to F... a full explanation of hexadecimal is outside of the manuals scope at the moment... however, there is a full explanation to be found here...

[https://www.youtube.com/watch?v=J3ekb5JnX8Y&ab\\_channel=CircuitBread](https://www.youtube.com/watch?v=J3ekb5JnX8Y&ab_channel=CircuitBread)

The thinking process is very similar to the explanation of Binary in [Appendix 1: CVs... what are they?? What do they do? And dealing with binary, if you really want too...](#)

Long Address Example...

**Using a Long Address 9999 as an example... the full Hexadecimal way...**

**1,** The Decimal value is converted into a hexadecimal value... e.g., 9999 becomes 270F

**2,** The hexadecimal value is split into two components... the most significant byte (**msb**) i.e., **27**, and the least significant byte (**lsb**) i.e., **0F**

3, The hexadecimal values **MSB** and **LSB** are then converted into binary numbers to be stored in CV17/18...

*Hexadecimal MSB rule...*

CV17 contains the **msb**... 27 Hexadecimal, which is 39 decadic + **192 \*\*\***... i.e. in binary , **100111+1100,0000** = 11100111... *this is E7 in hexadecimal.*  
**\*\*\* It is standard practice when calculating the value for CV17 to add Decimal value 192 to the final result...**

*Hexadecimal LSB rule...*

CV18 contains the **lsb** i.e., Hexadecimal 0F .... which is binary... 00001111 When reading CV18 back you will see a Decimal value of 15.

..

This is easier... Binary only... no mention of hexadecimal!!

Again using Long Address 999 as an example...

Decimal 9999 is equal to "0010 0111 0000 1111" in binary.

Now change left two digits to "11" i.e. "0010 0111 0000 1111" becomes "1110 0111 0000 1111" (you have added "1100 0000")

Split this into two 8 digit binary numbers.... "**1110 0111** 0000 1111"

The left is "**1110 0111**" which is 231 in decadic (normal counting) this is the value for CV17

The right "**00001111**" which is 15 in decadic (normal counting) this is the value for CV18.

The default addresses set in the decoder are...

Short Address...

CV1 = **3** .... This is the default short address (and the default address of the decoder when all CVs are reset to default.)

Long Address...

CV17 = **192** (some controllers will report this CV as = 000 thus removing the value "192" previously added.) (See hexadecimal explanation above.)

CV18 = **100** ... thus, setting the Long Address default to **100**.

### Controllers old and new and programming Addresses.

A decoder can hold two different addresses simultaneously i.e., a “short address” and a “long address.” Since the way these two types of addresses are stored in the CV range there are two different approaches to carrying out the actual programming process... see above.

#### Older controllers...

Controllers in this group were not designed to handle Long Address programming and required the user to programme the relevant CVs manually.

The user would have to follow the rules outlined above... i.e., for a “short address” programme CV1 and ensure that CV 29 had Bit5 turned off.

When it came to “long” addresses the user would have to carry out calculations as outline above and programmer CV17 and CV18 with the calculated values, then CV29 Bit5 would have to be turned On.

#### More recent Controllers...

More modern controllers accepted general input of the address, then determined it’s type i.e., Short or Long, and then carry out the appropriate programming procedure...

i.e., Writing directly to CV1 and check the state of CV29 in the case of a “Short Address,” or carrying out the 3 CV write process i.e., CV17, CV18 and CV29 as required without any further user intervention in the case of “long addresses.”

## Appendix 3: Using AUX Outputs... i.e., the Hardware Function Outputs... (HFOs)

### Introduction...

Please check the table below to understand how the naming conventions relate to each other. For some practices it easier to refer to an HFO when talking about the electrical connection. The term HFO is short for “Hardware Function Output,” this refers to the physical electronic connection on the decoder.

The term “AUX” refers to any HFO other than the ones allocated to head light/rear light functionality... i.e., ones that are generally available for users to connect to different devices like LEDs etc. This means that AUX1 will refer to HFO3. On some locomotives AUX numbers starting at AUX1 are already allocated for internal functions within the locomotive model... e.g., cabin lights or other functions. Check your locomotive documentation for more information.

If you have spare AUX/HFOs available on the decoder in your locomotive, you can use them for connection of various types of features. E.g., LED lights, or may be electromechanical devices like relays etc.

The number of AUX/HFO connections will depend on the type of decoder fitted... please refer to [Sound Decoder Types and Connection](#) for details of the decoder you have chosen to use in your locomotive.

### The table below...

The first two hardware connections (HFO1 and HFO2) are controlled by F0 on the control system, F0 is either ON or OFF these operate the main lighting circuits i.e., HFO1 or HFO2 however, each HFO operates on a mutually exclusive basis... i.e., when F0 is toggled only one of these two HFOs will be enabled, the actual one that is enabled will depend on the direction set for the locomotive. Generally, HFO1 will be enabled when the locomotive is set to a Forwards direction, HFO2 will be enabled when the locomotive is set for a reverse direction. In either state the locomotive can be stationary.

This is how the directional lighting systems generally work within locomotives. In some locomotives the first two hardware connections are unused (HFO1 and HFO2.) (This is typical in a locomotive with no lights at all.) This leaves F0 controlled HFO1 and HFO2 available for use, but remember the stipulation previously mentioned re “direction” of locomotive if you intend to use them. (Do not make the mistake of connecting cabin lighting etc to HFO1/HFO2 as it will only work when the locomotive traveling/set for one direction.)

### The first 6 hardware outputs.... Some decoders will have more function output support but will follow the convention in the table below...

Actual Hardware	General Term	Controller Function #		Output Level	Typical Current Limit
HFO1		F0 Forward Direction		Analogue 14VDC	100mA
HFO2		F0 Reverse Direction		Analogue 14VDC	100mA
HFO3	AUX1	F1		Analogue 14VDC	100mA
HFO4	AUX2	F2		Analogue 14VDC	100mA
HFOd5	AUX3	F3		Digital Level 3.3V	Low
HFOd6	AUX4	F4		Digital Level 3.3V	Low



## Load Type.. LEDs

### LED Current Draw...

It is usual to run LEDs with a current between 10mA and 20mA for general purposes.

While lower or higher currents may be desired for some types of LED than the 10mA to 20mA range, for our purposes in these notes we will consider the 10 to 20mA current levels as they more commonly used in model railway applications. With a common connection of +14V for each LED circuit, all LEDs without internal resistors will require a series resistor to be connected.

The value of this resistor is easy to work out, however, it is almost guaranteed that the value will be between **500 and 1000 ohms**. The value of the resistor will be dependent on the colour of the LED and brightness desired. Because the value of the resistor is fairly wide it is best to experiment with a few resistor values and LEDs, to see what can be done.

### *Calculating resistor values for use with LEDs...*

All LEDs have a “working voltage;” this is called their “forward voltage.” All you have to do is subtract the “forward voltage” from the supply voltage (in this case +14V) and divide the result by the current you want to flow through the LED. The result of this little bit of arithmetic will give the resistance value of the resistor required.

Example... A red LED with a “forward voltage” of 2VDC, ( $14V - 2V = 12V$ .) Then all we have to do is divide 12V by the current desired. Let’s choose 20mA. So...  $12V/0.02A = 600$  ohms.

As a rule of thumb... to halve the current, double the resistor value. If doubling the current, halve the resistor value.

When you come to buy resistors, you will find that they come in what is termed preferred values, i.e., there is a pre-set range of specific values that make up the range of resistors available. These may not exactly match your calculations. Buy the one closest in value as you will find out with experience none of this is very critical... see table below.

If you can’t be bothered to do the sums... go here <https://www.hobby-hour.com/electronics/ledcalc.php> ... added extra... the colour code of the resistor will be shown!

### Different colour LEDs... voltage ratings

Below are some typical examples of “forwards voltages” and typical current levels that apply to different colour LEDs. The forward voltage of a LED is specific to that LED and can be checked in the specification of the LED to be used. However, the guide below will apply for the purposes of calculation of series resistors... as stated previously, none of the calculations are that critical. The table gives some typical preferred value of resistors. The nearest preferred value is the value that can easily be sourced. Bare in mind also that all resistors are manufactured with a value tolerance (or accuracy) ... usually 5%... so again, you can see that these values are not super critical in any way!

Examples of LEDs powered from a 15VDC Source.... e.g., HFO etc.				
LED Colour	Forward Voltage	Typical Current	Calculated Series Resistor	Nearest preferred value generally available
Red	2.0 V	15mA	800Ω	820Ω
Green	2.1 V	20mA	595Ω	560Ω
Blue	3.2 V	20mA	540Ω	560Ω
White	3.2 V	20 mA	540Ω	560Ω

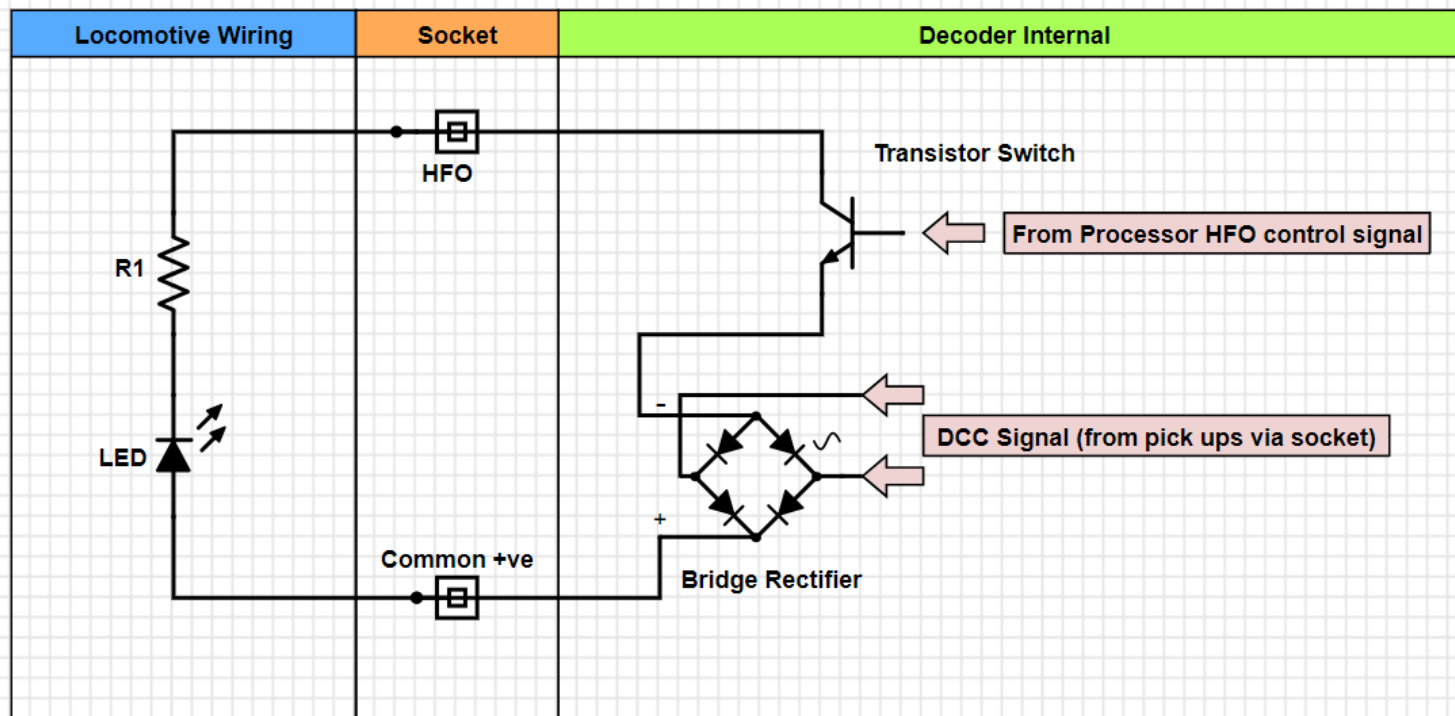
Preferred values commonly available will fall in this range: 56, 68, 82, 100, 120, 150, 180, 220, 270, 330, 390, 470, 560, 680, 820, 1000, 1200, 1500.... and so on... This is the E12 range.. for more information regarding resistor ranges and colour codes look here...

[https://en.wikipedia.org/wiki/Electronic\\_color\\_code](https://en.wikipedia.org/wiki/Electronic_color_code) and [https://en.wikipedia.org/wiki/E\\_series\\_of\\_preferred\\_numbers](https://en.wikipedia.org/wiki/E_series_of_preferred_numbers)

Connecting LEDs to 8 pin, 21 pi and Nex18 decoders.

These types of decoders have a common positive bus available on the plug/socket. This common positive bus will be used to terminate LEDs within the locomotive. Each LED has a switched negative connection i.e., HFO.

## LED Wiring ... HFO and using common positive ground from decoder via decoder socket.



### Explanation...

The Bridge Rectifier converts the track AC DCC signal to DC for use in the decoder. i.e., it provides a positive and a negative voltage.

The transistor acts as a simple switch which is controlled from the decoder processor.

The LED to be controlled is connected to an HFO output on the decoder socket, and the Common positive return provided on the socket.

When the transistor turns on... current can flow through the LED and resistor, through the transistor to the negative side of the Bridge Rectifier thus, it illuminates.

This is the most common arrangement for powering LEDs using decoder HFO Hi-Level connections.

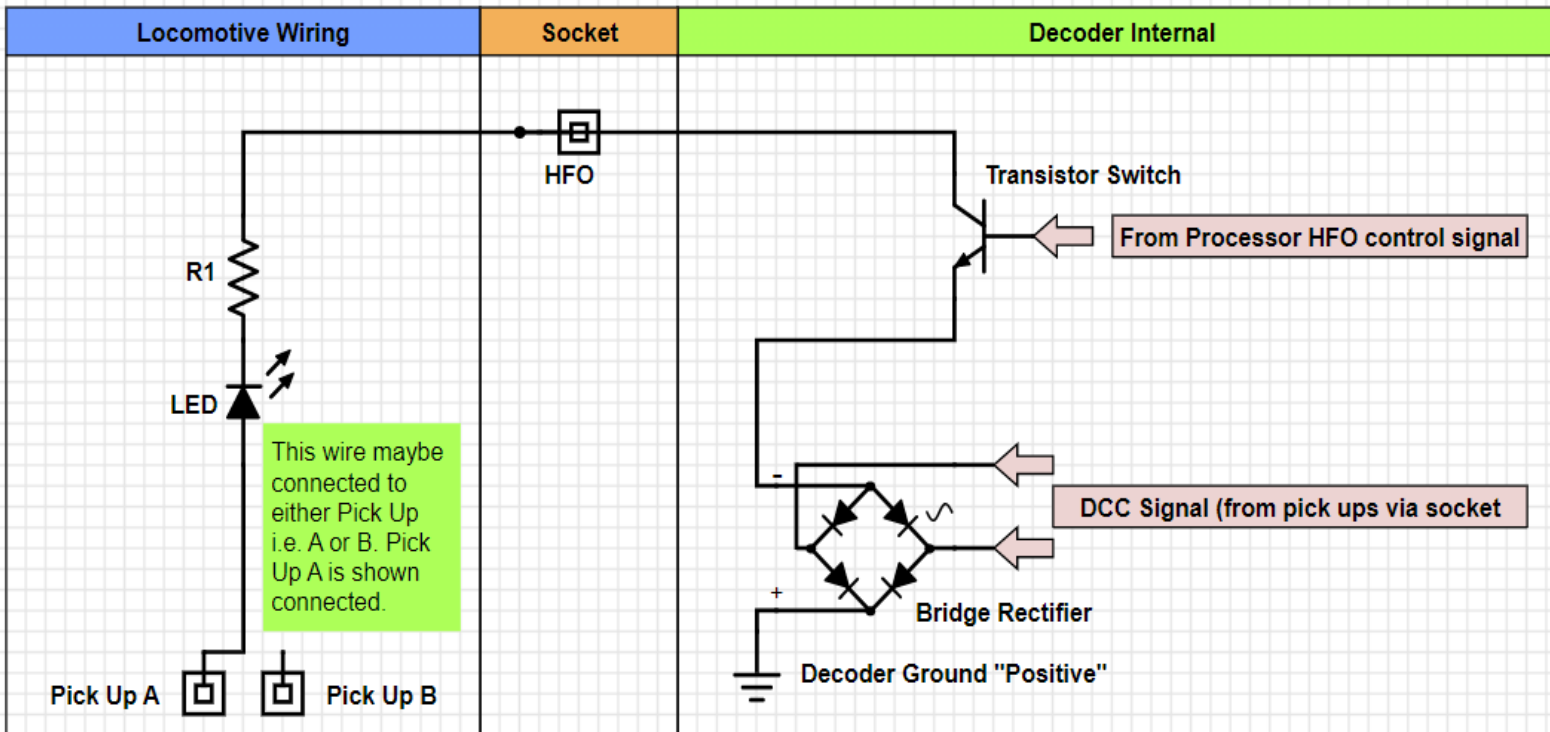
Tip: The resistor shown in the diagram will very likely have a value between  $470\Omega$  and  $1K\Omega$ .

Resistor values are explained further here... [Calculating resistor values for use with LEDs...](#)

Connecting LEDs to 6 pin decoders.

Unlike other decoders there is no positive bus connection for the LEDs available on the decoder plug/socket. The only LED connections supplied on the decoder plug socket are the switched negatives (HFOs) for the Reverse/Forward lighting arrangement. i.e., HFO1 and HFO2. Clearly the LED lighting arrangement requires a common positive connection. This common positive connection is derived from the locomotive pickups. There are two methods generally used, they are referred to as Half wave and Full wave Rectification... each has its advantages.

### LED Wiring ... 6 Pin Decoder Variant... HFO using single track connections for the common positive ground. LED will run at approximately half brightness.



#### Method 1... Half Wave Method Explanation...

As in the example above each component within the decoder has the same function.

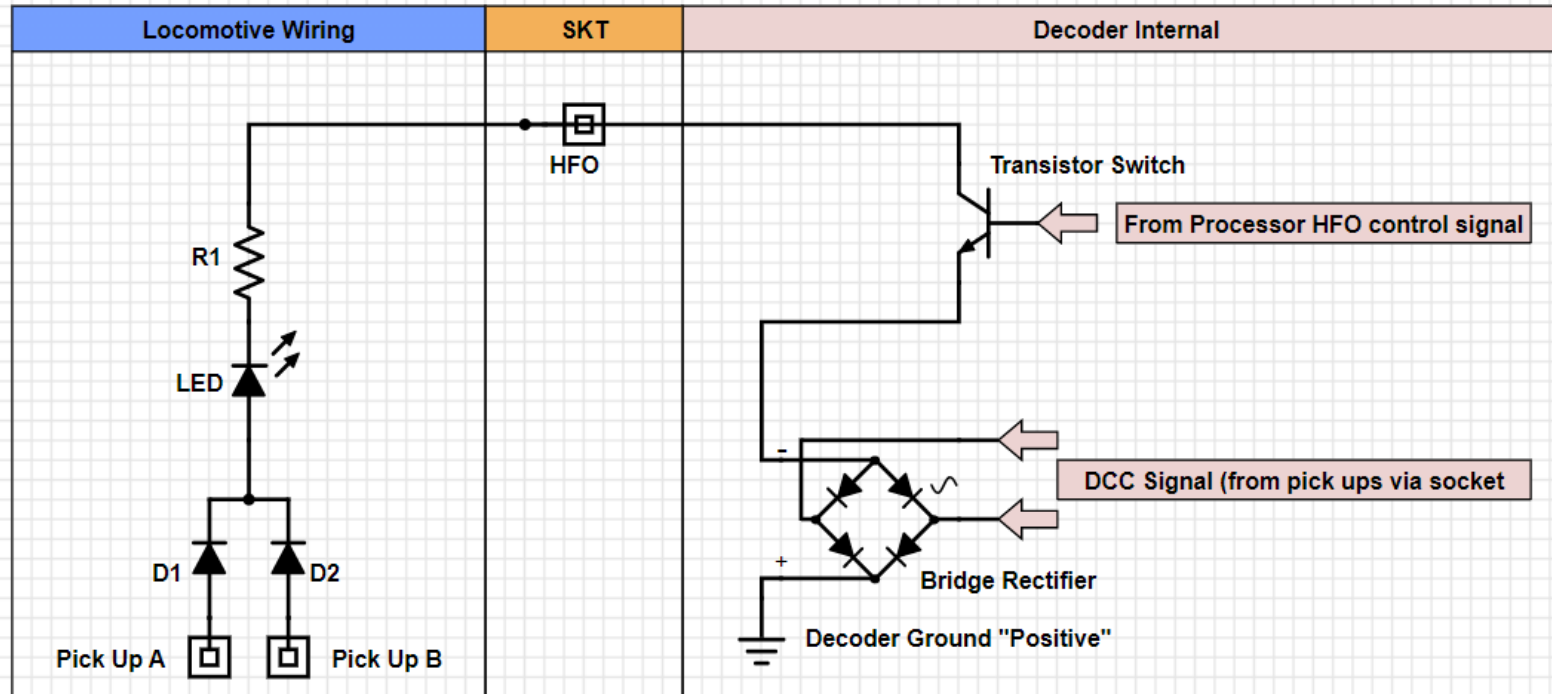
However, since the Common +ve derived from the Bridge Rectifier does not appear on the 6-pin decoder socket, the LED has to be connected to an alternative +ve voltage source.

This is achieved by connecting the LED to one of the rails via the pickups within the locomotive.

While this does work, because the signal on the rails is effectively AC, the common +ve is only available over one half of the AC wave.

This means the LED will only be actually illuminated for half the time when compared with a normal +ve Common connection.

LED Wiring ... 6 Pin Decoder Variant... HFO using both track connections via diodes for the common positive ground. LED will run at approximately full brightness.



### Method 2... Full Wave Method

#### Explanation...

As in the example above, the LED has to be connected to an alternative +ve voltage source. i.e the rails

The LEDs is connected to both rails (via the pickups) using a pair of diodes ("Pick Up Diodes") within the locomotive.

The signal on the rails is effectively AC, the common +ve is available for both halves of the AC waveform, alternating between the rails at high frequency.

This provides a virtually continuous positive ground signal which is applied via both diodes.

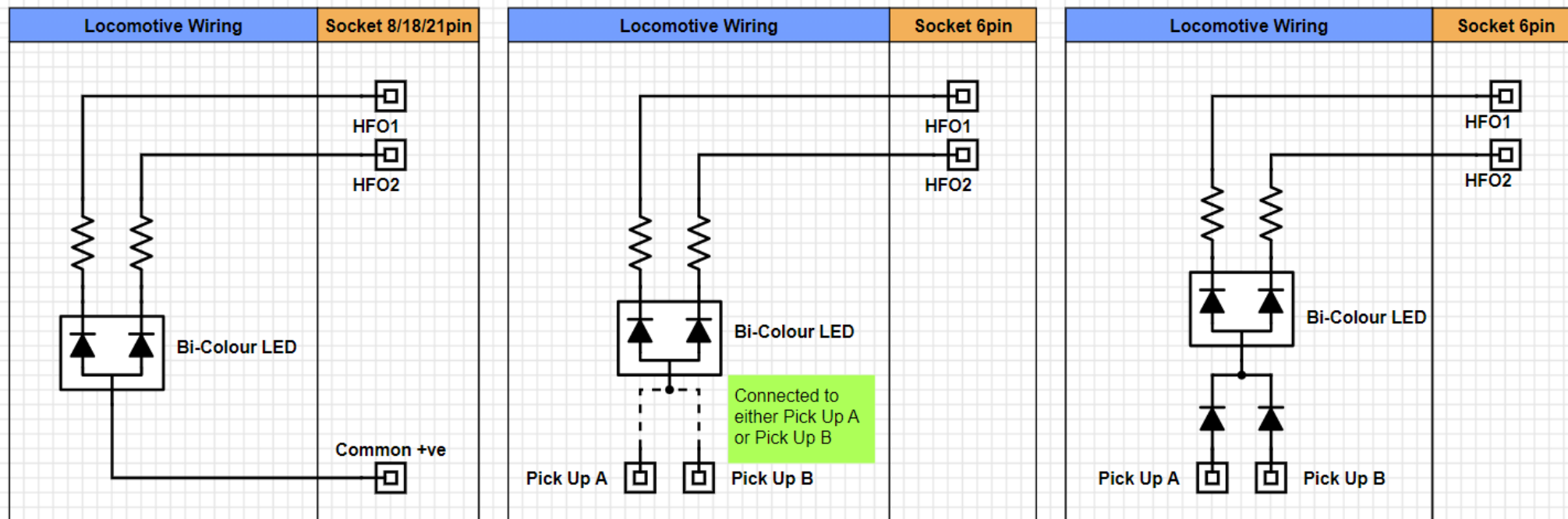
This means the LED will be actually illuminated for most of the time based on the square wave DCC signal.

However, there will a slight brightness drop due to the voltage drop across the "pick up diodes," this can be compensated for by choosing the value of R1 carefully.

## Bi-Colour LED Types...

Generally, the types of LED you will use will be single LED packages. However, there are packages used that have two different colour LEDs within the same package. These can be useful in coloured signals etc. If using this type of LED, it is important that it is a “common anode” type. See the diagrams below. For a full explanation see above.

## Connecting Bi-Colour LEDs



These diagrams generally represent how multiple LEDs would be connected to the decoder. If you are installing many single LEDs to various HFOs the same principles apply.

## LED types and sizes...

Physically, LEDs come in to two main types... Through Hole (TH) mounting and Surface Mounting Devices... (SMD.) TH LEDs are designed to be mounted on a printed circuit board with connection wires soldered to the underside of the pcb. The fact that they have actual wire connections can make them flexible when creating a lighting fixture for a locomotive by soldering resistors etc directly to the LED wires... i.e., no need for a pcb.

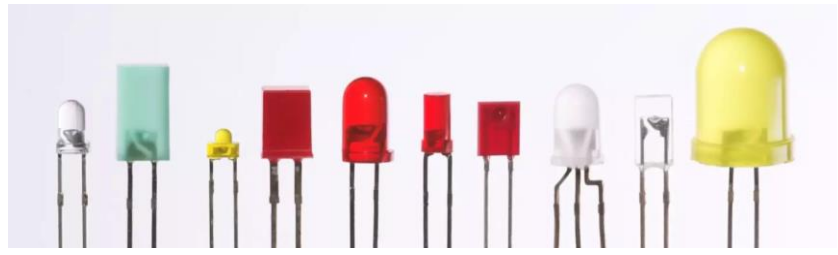
If you need to look at smaller LED solutions, then you may have to look at SMD types. These types are designed to be mounted on pcb but are soldered to the topside of the pcb. SMD LEDs can be tiny and very hard to handle/solder/see.

Various third-party companies will offer lighting kits which will contain either type of LED prewired for installation in the locomotive. In some cases, very fine wires are soldered directly to the SMD LED... a job for a steady hand!

*Through Hole Mounting.... A few pictures and diagrams referring to LEDs... for information.*

Through Hole (TH) types can range in sizes starting at about 2mm upwards and come in many different shapes.

TH Mono Colour LED Package.... Note that with these types of LEDs the Anode connection is the longest lead. (Not shown!!) (Can you spot the Bi-Colour LED?!?)



Basic Bi-Colour LED



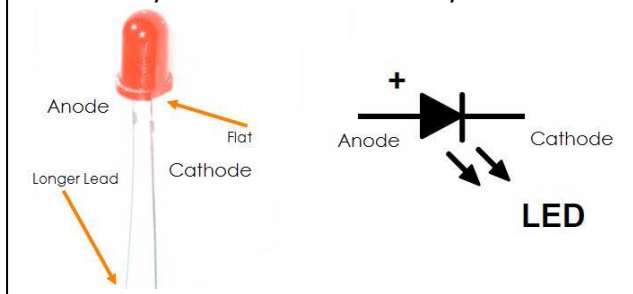
Simple 3 wire connection as per the diagrams above. Red, Green LEDs with common Anode.

Tri-Colour LED...



This Tri-Colour LED has 4 wires... these represent Red, Green, Blue LED colours... and one common anode wire. It is just 3 LEDs in a common package.

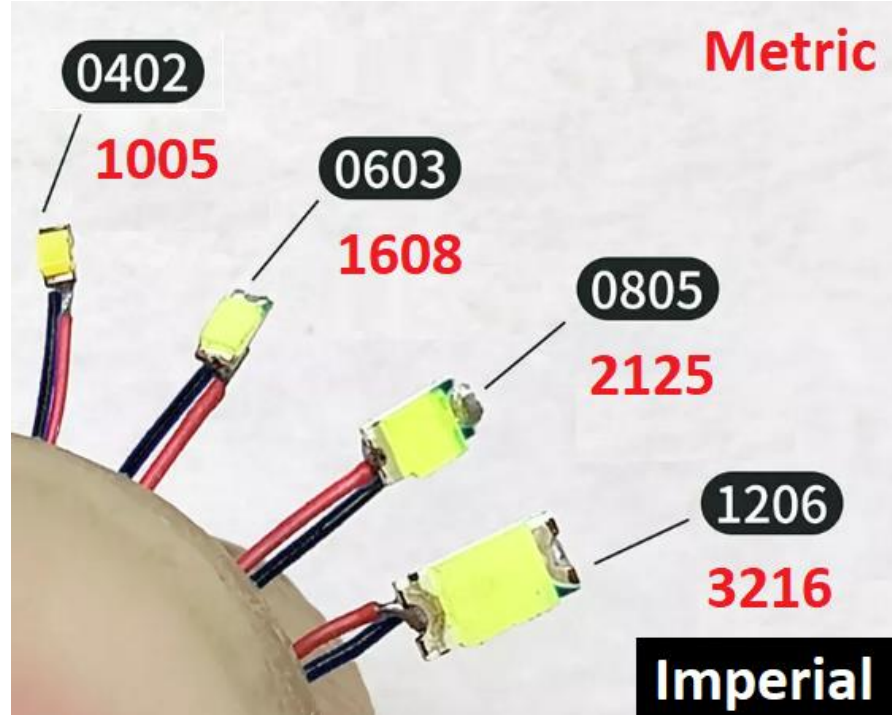
This illustration shows the relationship between an ordinary LED and its schematic symbol.



Surface Mount LEDs... A few pictures and diagrams referring to LEDs... for information.

SMD LEDs sizes (metric) are usually referred to by a 4-digit number e.g., 2520 would indicate an LED measuring 2.5mm x 2.0mm. Sizes can generally range from 0201 upwards to 5025... or further. Just to make thing complicated SMD LED sizes may be quoted in imperial sizes... this may also show up as a 4-digit number... see illustration below.

This illustration shows different examples of SMD LEDs and there metric/imperial size.



This is an example of a SMD RGB 3 colour LED... size 2020 metric.



LEDs... Web further references...

There are many websites discussing LEDs for modelling etc... e.g.,...

<https://evandesigns.com/pages/information-about-led-sizes>



## Load type... Filament Bulbs/Incandescent lamps etc. ...

These are ordinary incandescent lamps/bulbs; unlike LEDs they are not polarity sensitive and may be connected “anyway round.”

Check their current requirement of the “lamp” before connecting to the HFO. However, most “Grain of Rice” type bulbs draw approximately 60mA at approximately 14VDC. These may be directly connected to the HFO.

Provided the “lamp” is rated at approx. 12 - 15v you will not require a series resistor. However, if a lower voltage lamp is to be used, you will need to carry out the same calculations as discussed above re LEDs. (It is not really recommended that you use low voltage lamps.)

The calculation for a lower voltage lamp works the same way as when carrying out calculations for LEDs. All you have to do is subtract the lamps rated voltage from 14v... divide the result by the current to give the series resistor value.

Consider a relay arrangement if you are likely to exceed the current limit of the HFO... [Load Type... RELAYS](#)

## The Last Word... Resistors and power dissipation. IMPORTANT

When considering any resistor in the above LED and Filament Lamps etc, we should consider level of heat dissipation...

All resistors when passing current will heat up to some degree. In most cases in our use within locomotives etc the increase in temperature of the resistor will be small... i.e., warm at the most.

When you buy resistors, you will find them rated in Watts... i.e., rated by the amount of heat they can handle without going up in smoke!

In the section above you have learnt how to calculate the value of the resistor required for your application. We can now easily find the power that the resistor will dissipate when in use. See below...

Multiply the voltage across the resistor current flowing through it.

The voltage across the resistor is equal to the supply voltage minus the voltage across the LED.

Example... For a red LED running at 15mA....  $14V - 2V = 12V$  across resistor.  $12V \times 0.015A = 0.18W$  ... that is not a lot of heat i.e., the resistor might get warm!

When buying resistors, you will probably use... “quarter” (0.25W) Watt or “eighth” (0.125) Watt types. The smaller the rated wattage the smaller the resistor will be.

Generally, it is unlikely that you will run into heat issues with simple LED circuitry.

## Load Type... RELAYS

If you are going to exceed the current limit of the HFO you wish to connect to, it is usual to use the HFO to control an external switch which is rated to suit the higher current you wish to switch. This “external switches” could be a transistor circuit or a relay. Below we will discuss the use of relays... if a user intends to use transistors for switching electrical loads, he will already know how to use the HFO “negative” going switch...

**There are two basic types of relays, i.e., latching or non-latching...**

### *Latching Relays...*

*This type of relay requires two pulses of voltage for operation i.e. one pulse to turn on the relay and a consecutive pulse to turn it off. This is achieved by using independent coils within the relay. This operation would commit two HFO connections as there are two coils that need to be switched momentarily.*

*Also, if, using latching relays with HFOs, the HFO must be configured for single pulse operation. The one thing that makes “latching” relays attractive in use is that they require no current while latched... i.e., current is only used when the relay state changes. This makes them ideal for “momentary” switches e.g., possibly push-button types with no internal mechanical latch. A decoder HFO is not usually programmable to provide a pulse single pulse operation, and as mentioned before therefore difficult to use with some controllers.*

**Summary... Latching relays are generally not suited for decoder HFO connection because they require two independent HFO connections. This can lead to confusion in operation on some controllers.**

..

### *Non-Latching Relays...*

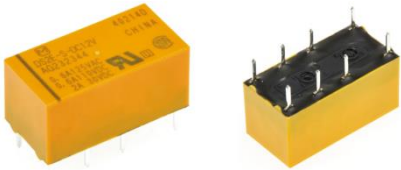
These types of relays have one coil. For operation the non-latching relay requires current flow through the relay coil to hold its state. Therefore, connection to a single HFO is straightforward without any special programming of the decoder HFOs etc. i.e. the HFO switch is turned on and off activating the relay coil.

You will need to check the current requirement of the relay before connection to check it does not exceed the current rating of the HFO i.e., 100mA.

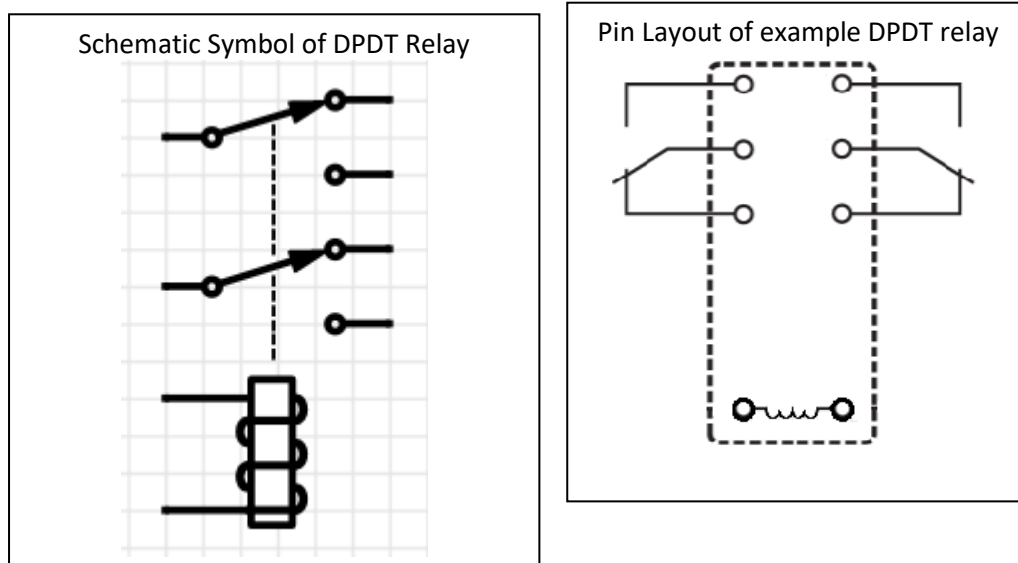
When searching for suitable relays try the following search terms **“12V coil bistable non-latching relay”**

## Example of typical DPDT relay...

Panasonic, 12V dc Coil Non-Latching Relay DPDT (Double Pole Double Throw,) 3A Switching Current PCB Mount... available from various electronics suppliers.



This type of relay consists of two change over switches that make up the DPDT element. The two switches are “ganged” together so they both operate when the relay is activated.



This relay has a coil resistance of  $720\Omega$ ... which will have a current draw of about 17mA.. which makes it ideal for HFO connection.

The current draw of a relay can be calculated simply using Ohms law. i.e., The current draw is equal to the voltage of the relay divided by its coil resistance. Generally, in model rail applications, 12V coils are usually used. i.e., this matches the typical output of a decoder HFO and is also a common voltage used around a layout. In our examples above we have only discussed common relays as a typical example of a common type used in model railway modelling.

## Relays and Fly Back Diodes!!!! IMPORTANT

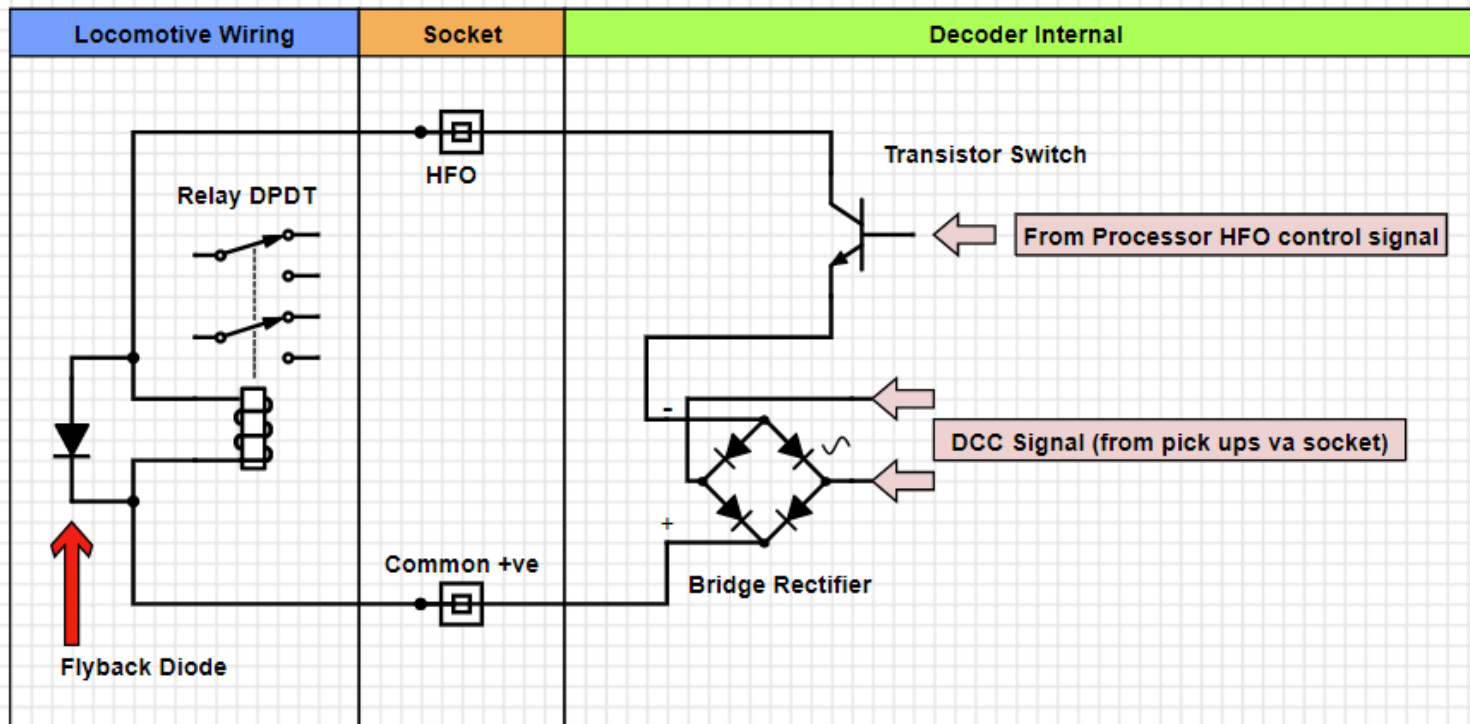
Because of the way a relay coil operates, when the voltage is removed from the relay coil i.e., when it is being switched off, a voltage spike of an opposite polarity is generated across the coil.

A voltage snubber diode (sometimes called a flyback diode) is often placed across the relay coil to protect external circuitry as the flyback voltage can be quite high compared to the relays operational voltage (12V in our case.) This high voltage creates current flow in the wrong direction which could lead to damaged components.

### Fly Back... What's going on!?!?

When the current flowing through a relay coil is turned off, the magnetic field within the relay coil collapses suddenly. The sudden collapse of the magnetic field induces a brief high voltage across the relay coil which is very likely to damage the HFO output transistor. This voltage is effectively the "Back EMF" of the relay coil... those of you familiar with electric motor operations in locomotives will be aware of this concept.

## RELAY Wiring ... Relay connected to HFO via decoder socket. With "Flyback" diode protection.



A "Flyback" diode forms a path for the BEMF current to dissipate, thus forming protection to any external circuitry.

..  
Some relays will have the "Flyback" diode built into the relay itself. The coil connections in these cases are polarised and attention must be paid to the connection polarity.

More commonly, there is no internal "Flyback" diode fitted. In these cases, the relay coil is not polarity sensitive and can be connected either way round. However, it is important that you connect an external "Flyback" diode to protect the HFO.

The diagram shows how a signal diode (e.g., 1N4148) is connected 'backwards' across the relay coil to provide this protection.

Check your relay's documentation to see if an internal "Flyback" Diode is fitted!

## Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)

Please note ADCC/ABC operation is only supported on sound decoders, i.e. it is not supported on non-sound types.

IMPORTANT... definitions... which is the right rail? Which is the left rail?

In this Appendix we will be referring a lot to “right and left rail.” In the context of ADCC/ABC these terms have a specific meaning and definition.

**Definition:** For a given direction, from a cab view, looking out from the windscreen of the locomotive i.e. the driving view, the rail to your right is always called the “right rail.” If you are travelling in the opposite direction the same applies.. i.e. the rail on the right of the driver is the “right rail.” This applies to both steam and electro/diesels locomotives etc. Due to the way that the above rule applies, it is clear to see that the rail designations swap right/left and left/right dependent on locomotive direction. This is an important property and must be understood.

### Introduction to ADCC/ABC

Asymmetrical DCC Control is a Lenz invention and found on many higher specification DCC decoders... Lenz refer to ADCC triggered operation as Automatic Braking Control, ABC.

The HM7000 sound decoder series supports this feature. ADCC/ABC operation can be used to stop a loco automatically, reverse a loco or other actions, without any input from the user on the DCC control system i.e., decoders with an ADCC/ABC function can be programmed to carry out a range of automatic actions.

An ADCC state is applied to an isolated section of track by the use of a simple diode networks/matrixes. There are only 5 diodes involved and these matrixes, and can be constructed in many ways. Full detail are given below.

There are several CVs associated with the configuration of ADCC operations...

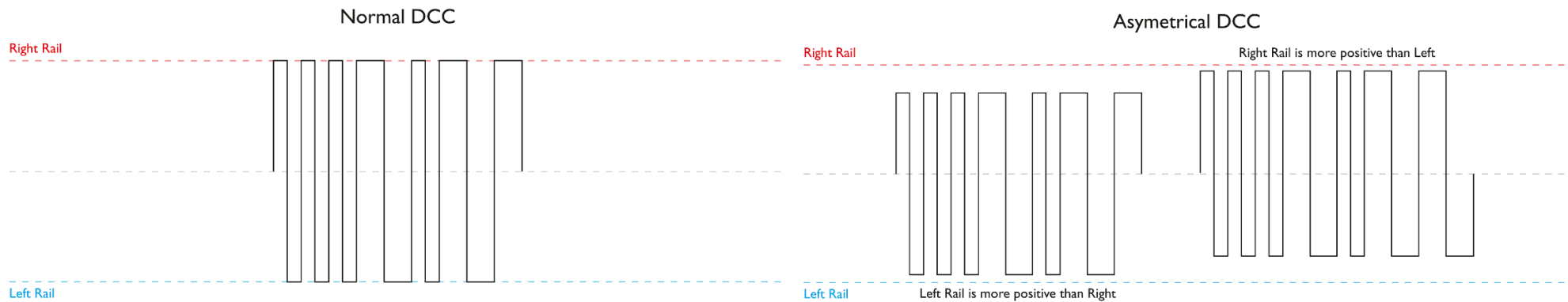
- CV27 is used to set which rail the decoder will detect the ADCC signal state.
- CV125-CV127 are used to set up what action the decoder will carry out.

## ADCC Explanation... how it works

A normal DCC signal is made up of a “square wave” voltage wave form. If you look at the diagram below you can see that the square wave alternates around a zero point i.e., the voltage goes up to +15V and down to -15V many times a second... this is a **symmetrical** DCC wave shape i.e. the positive and negative going parts of the waveform are equally positive and negative,.. ... i.e. it is “balanced” ... normal. The **Asymmetrical** wave form is where one of the voltages has a different level.. e.g., +15V to -12.5V i.e. they are not “balanced” ... this is “Asymmetrical DCC” i.e. ADCC. See diagram below.

The “unbalancing” of the wave form is created by isolating one of the rails of the track and supplying power to the isolated section via a simple **diode matrix**.

The overall result of installing the diode matrix is that one of the rails will have a more positive voltage relative to the other rail over the length of the isolated rail section.



The decoder detects when the ADCC waveform i.e. goes out of “balance.”

In the following examples a diode matrix is fitted to the left rail.. i.e. the “isolated” rail. The result of which makes the RIGHT rail more positive than its corresponding opposing rail. .i.e the red rail is more positive compared to the blue rail during the length of the isolated region .... **Note the locomotive is moving from right to left in these examples.**

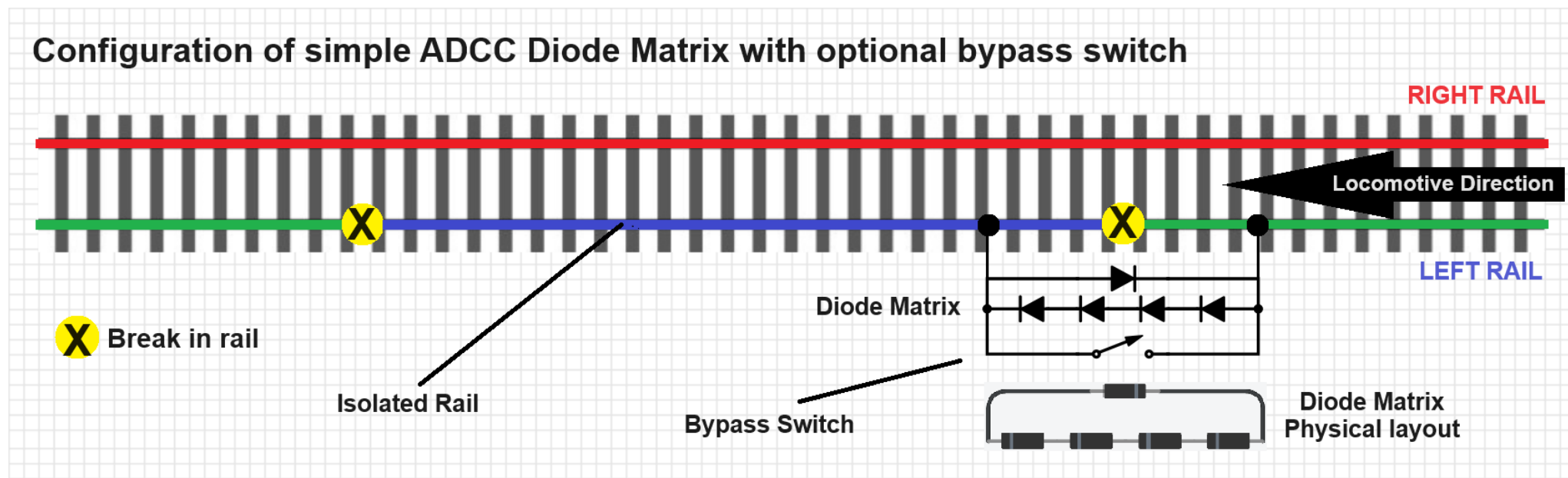
In order to create the voltage states as described above a small diode matrix is used.... See next.

## Simple Diodes Matrix...

The conversion of a DCC waveform into an ADCC waveform is usually achieved by inserting a small diode Matrix inline with one isolated rail to “unbalance” the DCC waveform within a region/length of track... the diode matrix connects to one rail only. This is the ADCC region.

The ADCC region will have one rail isolated from the DCC part of the layout. To achieve this, a rail is cut at each end of the region. The **X** symbols indicate where the rail must be cut.

The now isolated “dead” rail is fed from the diode matrix. Thus, the waveform present in this rail section of the track is going to be ADCC or “not balanced.” (See below. In the arrangement in the diagram the right rail is now more positive than the left rail within the isolated section.)



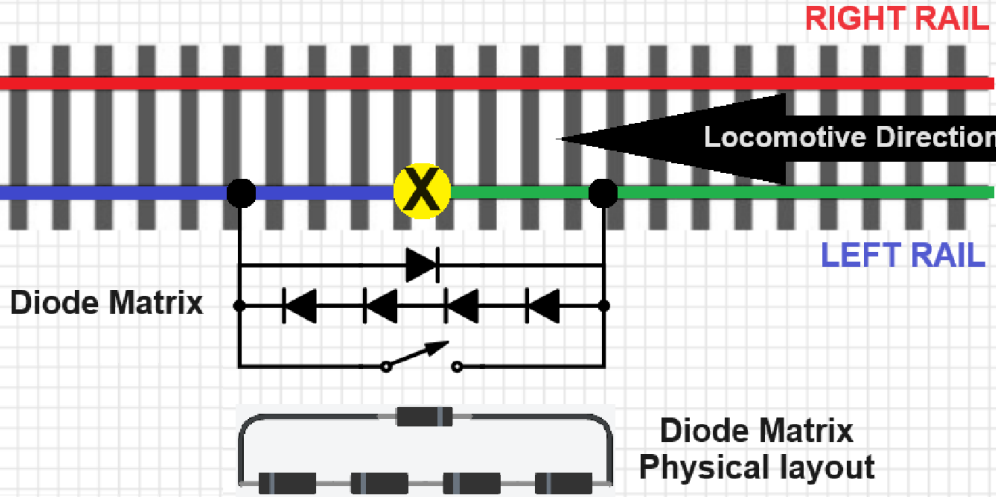
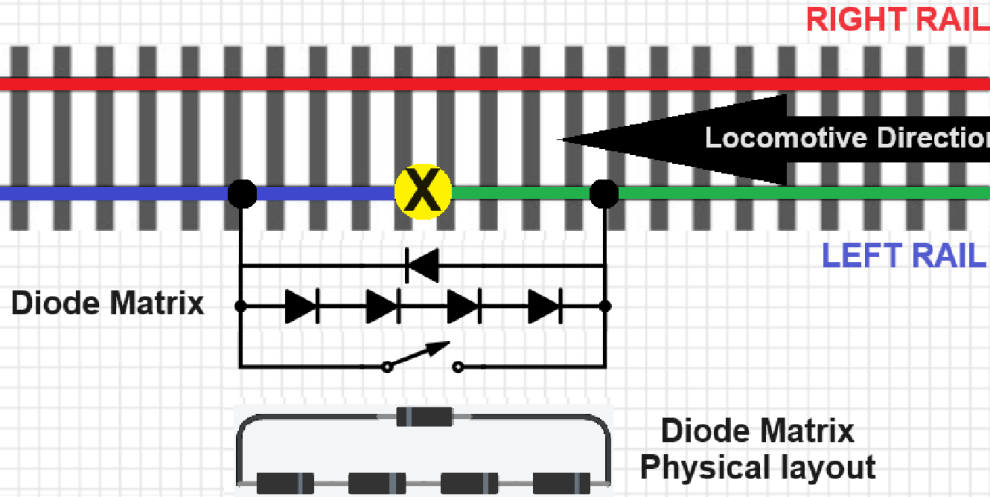
**Notes...** The diode matrix can be made up of 1N4148/1N4001 or similar... it is not critical. The switch in the diagram above is optional. If fitted, It allows the ADCC rail section to be disabled i.e. when closed the system will return to normal DCC operation. If the switch is replaced by the contacts of a relay, it may be possible to set up automatic operation of ADCC rail sections etc. The relay would be controlled by a Point and Controller (PAC) unit. You will note that the diodes are effectively arranged in a ring.. the rail connection is taken across one of the diodes in the ring... it does not matter which one... please ensure if you are fitting a switch that it is connected across the rail connections.

**Note:** The Diagram above illustrates the **Conventional** method of connecting/orientating the Diode Matrix to the rail. For more information see next section.

## Which Orientation should the Diode Matrix be?

Above we discussed the construction and orientation of the Diode Matrix to create ADCC. We emphasised that the diagram above refers to “**Conventional Orientation**” this becomes important when it comes to programming CV27 in order to select which rail i.e. right or left we wish to detect for the ADCC state.

Let’s take a closer look at those diodes...

Conventional Orientation... <b>RECOMMENDED!!!</b>	Inverted Orientation... <b>NOT RECOMMENDED</b>
	
<p>The diagram above shows the “<b>Conventional Orientation</b>” of the Diode Matrix This is the recommended orientation when connecting to the track on your layout.</p> <p>This will orientation corresponds with the explanation of CV27 programming values shown below.</p>	<p>The diagram above shows the “<b>Inverted Orientation</b>” of the Diode Matrix</p> <p><b>This orientation is NOT the recommended orientation when connecting to the track on your layout.... If you mount the Diode Matrix in this manner the explanation of CV27 will not apply and will lead to some confusion.</b></p>

The orientation of the diodes in the Diode Matrix is critical...Also, the orientation of the Diode Matrix connection to the rail is critical. Please refer to the physical diagram of the Diode Matrix to check the orientation of the diodes... the diagram illustrates the band on each diode.

Once you have identified you have the correct “**Conventional Orientation**” set up... we can go on to understanding programming CV27. [CV27... Asymmetric DCC \(ADCC\) Configuration... rail select etc.](#)



## Build idea for the Diode Matrix...

The images below, show how we rigged an ADCC unit with a switch mounted in a 20mm x 40mm speaker enclosure. Note the diodes are insulated with heat-shrink tubing. Note: It is probably a good idea to mark the diode orientation on the box....



## Programming the ABC system...

Once the track section has been modified for ADCC operations the decoder must now be programmed...

There are two steps....

1. CV27 ... which rail to detect'
2. CV125 – 127 ... select which automatic action the decoder will carry out.

### CV27... Asymmetric DCC (ADCC) Configuration... rail select etc.

We need to set a rail for detection i.e. left or right... Once defined the ADCC system will detect a rails status i.e. looking for the condition when the DCC signal it is more positive a rail compared to its opposing rail. This CV is used to define which rail is detected for the ADCC imbalance (positiveness!). Detection of the presence of an imbalance or return to normal of rail voltage will enable/disable the triggered action of the ADCC/ABC system.

Summary: The ADCC detection system can be fully controlled from CV27... i.e. it can be disabled or configured for either left or right rail detection... or if required both rails.

Default Value	Range
0	0 - 3

The CV stores a plain simple number (Decimal value) which is converted to binary number, i.e. a string of “ones and zeros.” The position of each “one or zero” in the chain enables or disables a particular ADCC detection configuration.

The CV value range is 0 – 3 See table below for the possible setting for each value re CV27

Function	Decimal Value	Notes
ADCC/ABC is OFF.. There is no rail Detection	0	
ABC unit installed in Left Rail..... Right Rail is detected	1	The rail set for detection is opposite to the rail with the diode matrix installed!!!  These CV values are only valid provided that the diode matrix is installed with “Conventional Orientation”
ABC unit installed in Right Rail.... Left Rail is detected	2	
Both Rails are detected ***	3	Generally, this is the scenario when using an “Auto Reverse” or “Shuttle” operation. i.e. Both rails need to be detected thus the locomotive will detect when it reverses direction.

**Note:** If F26 (Creep Mode) is enabled... “rail select” for ADCC is disabled i.e. overridden.. No ABC action will be triggered.

## CV27 Summary....

For each **Left** and **Right** placement of the diode matrix the following applies...

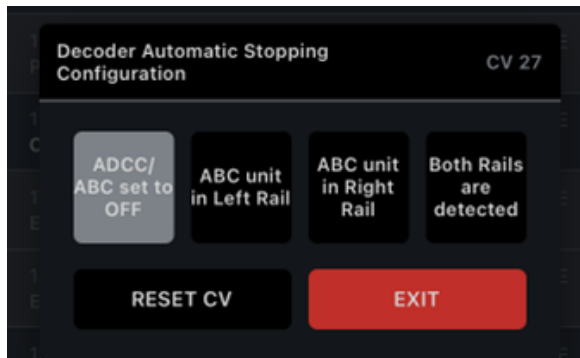
**Right Rail is more positive than Left Rail....** The isolated ADCC section which is fed by the diode matrix is placed in the **left** rail. As the locomotive crosses into this section the decoder will detect the change in the DCC signal level on the rails and proceed to carry out any commands set up in the decoders ADCC configuration. **(CV27 = 1 or 3)**

**Left Rail is more positive than Right Rail....** The isolated ADCC section which is fed by the diode matrix is placed in the **right** rail. As the locomotive crosses into this section the decoder will detect the change in the DCC signal level on the rails and proceed to carry out any commands set up in the decoders ADCC configuration. **(CV27 = 2 or 3)**

**Note:** the value "3" means detection is set for both the A and B rails... useful when in shuttle operations etc.

**Note: When configuring CV27 re which rail is used for detection of the ADCC signal... remember, it is the more **positive** rail that is actually detected. This is the rail opposite the rail where the diode matrix is installed. See later for more information and detail of the diode orientation ...**

Please note that in the APP, the setting of CV27 only refers to the track position of the diode matrix that creates the ADCC state.



## A Final Note re CV27.... This is a warning

As we have stated all along in this explanation re the Diode Matrix i.e. it needs to be installed with “**Conventional Orientation**” for the standard above explanation of CV27 to work...

... if the Diode Matrix is installed “**Inverted**” the logic of the way CV27 operates is inverted... see table below.... **DO NOT DO THIS** it will only lead to confusion when discussing your set up with others!!!

### **INVERTED OPERATION**

<b>Function</b>	<b>Decimal Value</b>	<b>Notes</b>
ADCC/ABC is OFF.. There is no rail Detection	0	
ABC unit installed in Left Rail.... Right Rail is detected	2	
ABC unit installed in Right Rail.... Left Rail is detected	1	
Both Rails are detected ***	3	Generally, this is the scenario when using a “Auto Reverse” or “Shuttle” operation. i.e. Both rails need to be detected thus the locomotive will detect when it reverses direction. Can be used when diode matrix is in “conventional mode” or “inverted mode” and operating in either direction.

## A Final Note re “Bypass Switches” and use with ADCC track sections...

In a simple example of a loop with a single ADCC section there will be two breaks in one of the tracks in order to form the ADCC section. The diode matrix (DM) will bridge between a rail with normal DCC state to a rail in the ADCC isolated section.

There may be a switch connected across the DM to allow switching between the normal DCC state and ADCC state in the isolated section.....thus enabling and disabling the ADCC/ABC action of the decoder.

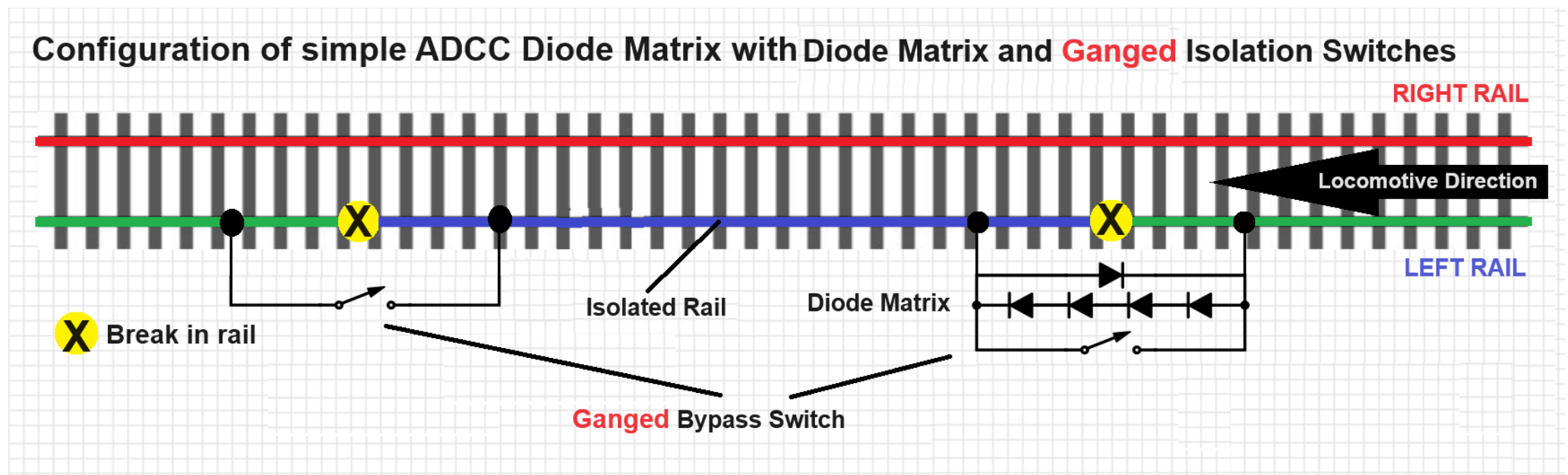
If this switch is closed, thus disabling the ADCC/ABC action there will still be a break at the opposite end of the isolated rail from the DM position. This condition may not be of significance in operations.

But, it is possible that depending on layout/power bus arrangement on your layout that power distribution may not be at an optimum for some locomotives on the layout.

This will depend on their position on the layout etc....

Therefore it can be a good idea to install extra switches on the layout across the basic track breaks in addition to any DM bypass switches.... This will help optimise current flow around the layout.

So each isolated ADCC section has two switches. They are operated in tandem... i.e. “ganged.”



Ganged switches of the type described are referred to as “Twin pole” switches, these are common switch types.

As indicated earlier.. The diode matrix used to create the ADCC state can have a switch connected across it, This is to allow disabling of the ADCC state on a given length of isolated rail. For electrical continuity around your track it may be a good idea to connect another switch across the isolating rail (the one the other end of the isolated rail.)

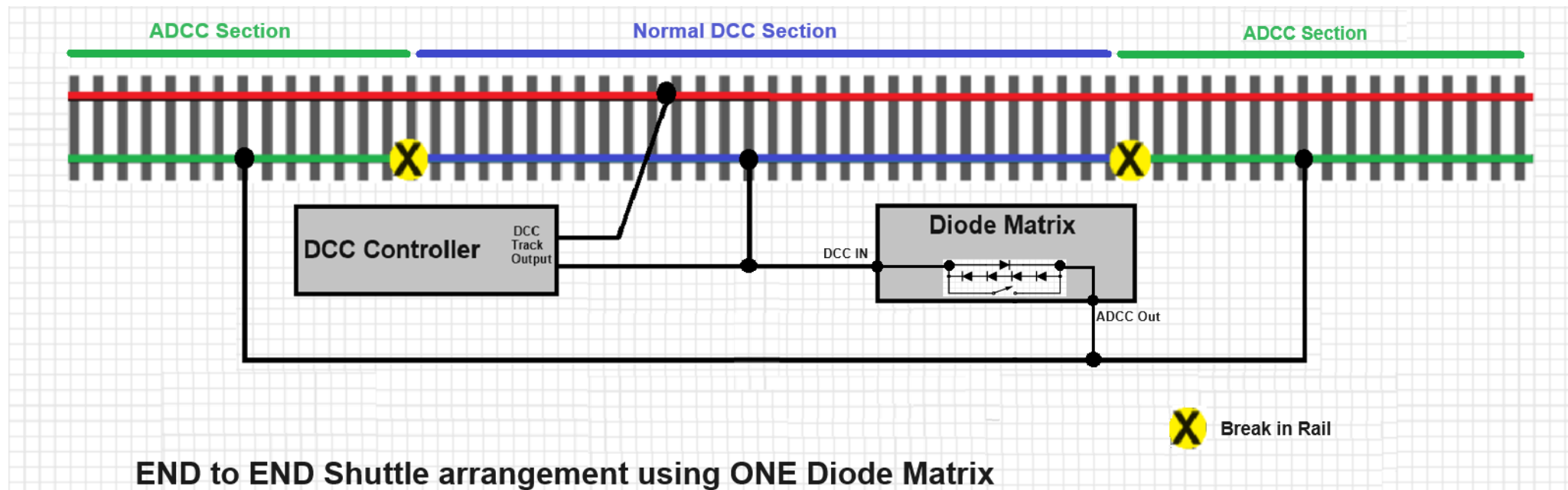
This new switch would be configured to activate in tandem with the switch across the diode matrix. This action would ensure full continuity of the current path in the layout when ADCC is disabled in a track section.

This second switch would be part of a dual pole switch or relay contact.

For Help regarding switches etc... please go here... <https://www.electronicshub.org/switches/>

Some Ideas.. ADCC using a single Diode Matrix... that is, using one Diode Matrix to feed multiple track sections

If you are intending to implement ADCC operation on an “End to End” layout i.e., in order to make the locomotives auto reverse; (shuttle) then the track arrangement, etc would consist of a long section of DCC track with an ADCC section at each end... conventional thinking would assume that you require two Diode Matrix modules. However, this may not be the case... see diagram below for a different concept in the use of a single Diode Matrix. For “Shuttle” operation CV27 must be set to detect both rails i.e., CV27 = 3.



As you can see from the above sample use of ADCC implementation can be quite straight forward. Expanding on the above concept it would be possible on a large loop layout to have multiple “Station Stops” using the single Diode Matrix connected to each isolated section associated with a “station. In this case the decoder would be set configured for a stop/wait and go.. so making the locomotive stop, wait for a set time and then commence journey to the next station.

Note re Diode Matrix bypass switches on One Diode Matrix configurations.

If you have fitted a switch across you diode matrix you can disable ADCC/ABC operation on you entire layout.

If you install a single switch across any isolation break you can disable/enable ADCC/ABC operations for that section of track only... this could be useful for temporarily bypassing a station on a loop.

## CV125 – CV127... Configuring the automatic action when ADCC is detected. (Asymmetrical DCC Operation) “ABC Control”

Using the following CVs, it is possible to set up a series of different actions that are carried out when an ADCC condition is detected on the track... either right or left rails .. see above CV27 for rail select. Actions generally are, stopping within a set distance, holding for a preset time and/or stopping or reversing direction, or shuttle type operations with programmable delay.

Bit #	CV125 ABC Action... Function Explanation	Default is 0	Decimal Value
0	ABC Stop with Deceleration set by CV4. Without Shuttle Operation.	Stop Duration is set by CV126.	0
1	ABC Stop with Constant Braking Distance is set by CV127. Without Shuttle Operation.		1
2	ABC Stop with Deceleration set by CV4. With Shuttle Operation.	Stop Duration is set by CV126.	2
3	ABC Stop with Constant Braking Distance is set by CV127. With Shuttle Operation.		3

CV#	CV Name	Default Value	Range	Comments
126	ABC Stop Hold time	5	0-255	CV = 0... Stop until ADCC status return to normal DCC CV = 1 – 255... number of seconds to temporarily halt/stop.
127	ABC Constant Braking Distance	25	0-255	

CV126... Stop Duration... Further operational notes.

This CV allows the user to select how long the locomotive will stop for on detection of an ADCC status on the rails.

A stopping duration can be set in seconds, or “permanent halt” may be set (CV = 0.)

If using CV = 0 for “permanent halt”.. please note the following.

- The Locomotive will resume standard operation of the ADCC status is removed from the rails.
- If halted within the ADCC rail section and the ADCC status is set to normal DCC, then the loco shall start, however if ADCC status is returned to the rails before the locomotive has cleared the ADCC rail section, it will stop again and so on....
- While the locomotive is halted all throttle input/direction commands are ignored.



CV126... More information re Constant Brake Distances (CBD)

Generally setting up ABC/ADCC operation is simple, it is the only part of the above that will require some trial and error in configuration is “Constant Braking Distance. (CBD) ....

The following notes should help you set up the CBD feature...

- 1, The distance to “stop” is independent of locomotive speed.... Within reason.. i.e. if a locomotive is moving too fast it can overshoot the ADCC section of track.
- 2, Braking distance can differ from locomotive to locomotive due to gearing and other mechanical variations... carry out a stopping distance calibration test for various values of CV127 to ascertain the value required for the desired CBD.
- 3, The CBD is measured from the point on the layout where all pickups of the locomotives pass over the track isolation point to the “nose” of the locomotive when it comes to rest...
- 4, If possible use a straight section of track to carry out calibrations...
- 5, Make sure the locomotive under test has reached the set speed before entering the ADCC section... set acceleration CV3 = 0 to may help.
- 6, Heavier locomotives will tend stop in a shorter distance.
- 7, For any locomotive... Create a table of CBD distances for different values of CV127... this will be handy later. Start at a reduced speed, create a table and then carry out the same test range for increasing speed levels.

See next re samples of real data regarding CBD tests carried out in the lab.

## Examples of CBD test data...

	Class 55 (430g)				Class 67 (631g)		
CV127	SS = 25	SS = 50	SS = 75		SS = 25	SS = 50	SS = 75
25	83	84	89		68	67	71
20	72	72	78		57	60	63
15	60	60	65		48	51	53
10	49	50	52		42	43	40
5	38	37	41		33	36	34

From the table it can be seen that there is no fixed relationship between CBD and the value held by CV127... it is advised to calibrate the CBD for different locomotive types.

### Observations...

- 1, For a given value of CV127 CBD is reasonably constant per locomotive at different speeds..
- 2, Decreasing the value of CV127 decreases the CBD.
- 3, Locomotives with increased weight will stop in a short distance then lighter locomotives.
- 4, It is worth calibrating and writing down this info!!!

## Appendix 5: Reserved.

Page Reserved

## Appendix 6: All about Motor Control and Tuning... Speed Curves. PIDs and Things... ... CV143 to CV155

### Introduction

You are reading this section because you have decided to adjust some variable in order to achieve better control of your locomotive.

When a motor is being controlled by a decoder there are various factors effecting how this control is achieved. It is assumed that CV10 i.e., the BEMF cut of point is set to maximum i.e., CV10 = 127 thus ensuring the BEMF control is in operation at all speeds. This factor is an important part of the motor control process.

The decoder has to translate a throttle input level called the “Speed Step” into a voltage that is applied to the motor.

To derive the desired drive voltage for the motor the decoder refers to a “Speed Curve.” This “Speed Curve” defines the relationship between a given throttle input (i.e., the Speed Step) and the voltage applied to the motor.

Having carried out the above calculations the decoder then has to use a “method” to control the motor... i.e., how to hold the motor to the desired speed under various load conditions etc. This is done using what is termed the “control algorithm.”

So, the first question to ask is, is the low-speed control working in a refined way... i.e., the locomotive is running smooth at the set speed but setting a slow speed is not so easy. This is where you may take a look at the motor “Speed curve.” Many control issues can be fixed by adjustment of the gradients of the “Basic Speed curve” or moving on to using the “Complex Speed Curve” for even more refined throttle control settings.

If the locomotive is running in a poor way, i.e., jerky or inconsistently, the next thing to look at is the “Motor Control Algorithm” in play. There are “3 Stages” of motor calibration....

The procedure we use in the development lab for fine tuning of motor control is basically to first try an Auto-Calibration (AC) procedure as described in “Stage 1” later in this article. Once AC has been carried out further adjustment can be applied via “Stage 2.” There is a “Stage 3” which can take some time to execute... it is really an “Expert” feature.... we try to avoid this as much time can be involved in trial and error. Generally, Stages 1 and 2 will provide satisfactory results.

Remember, a locomotive decoder is nothing more than a train controller, it just happens to be inside the locomotive. It gets information from the track telling it how to set its throttle. It is very similar to a modern DC train controller connected directly to the track i.e., both the decoder and the analogues train controller are probably “Pulse Width Modulation” controllers... (PWM) PWM is just a way of controlling the amount of power applied to a motor.

## About Speed Curves

A Speed Curve basically sets up the relationship between the current speed step (SS) and the voltage level applied to the locomotive's motor. Generally, as the speed step (SS) increases so does the motor voltage. However, it is possible to completely change this characteristic... should you really want to?!?. All speed curves are defined by CV values and can be edited by the user.

The rate of the motor voltage increase is controlled by the "shape" of the "Speed Curve." i.e. Voltage vs Speed Step

The decoder holds two Speed Curves. Which Speed Curve is in use is set by CV29. Bit4

The "Complex Speed" of diesel locomotive is the same across all types. However, the Steam locomotive "Complex Curve" may differ between different chassis types. For more detail see below.

**For the purposes of motor control, the voltage applied to the motor is divided in to 255 steps i.e., 0 = No Voltage and 255 = Maximum Voltage.**

### Evolution of Speed Step Curves...

The BASIC 3-point Speed Curve is a left over from the very early days of DCC technology. Going back to when there were only 8 settable variables i.e., Registers. The advent of Paged mode and Direct mode programming increased the number of stored variables to 255 +... When this advance happened a second, new Speed Step Curve was introduced i.e. "The COMPLEX User define Speed Curve."

..

The various types of Speed Curve are discussed next...

## HM7000 Decoders... implementation of the Basic and Complex Speed Curve system.

In the case of Diesel, Electric and Diesel-Electric locomotives the “Complex Speed Curve” is the same, as illustrated below. For Steam Locomotives with unsynchronised wheel rotation to Chuff rate, the “Complex Speed Curve” will have different values. i.e. the “curves” will be tuned to provide a better approximate synchronisation of chuffing to wheel rotation. This done on a per locomotive chassis basis. However, (to some users,) there may be a drawback in this approach i.e., the top speed of the locomotive will be capped. The cap will actually give a more accurate maximum scale speed for the locomotive in question.

Decoders fitted to locomotive types with support for “Piston Sync” will have their own optional “Complex Speed Curve which provides a top end speed cap and more realistic variation of “chuff” sound variation for given speeds at the higher end of the speed scale. This “Speed Curve” will be implemented by default.

### Explanation of the Speed Step Curve Graphs.

*When Throttle on the controller is increased or decreased, the voltage applied to the motor increases and decreases... simple enough. The throttle setting will cause the controller to send a speed value to the decoder. These values are called Speed Steps” i.e., SS for short. There are usually 128 SS ... i.e., 0 to 127. 0 being when the loco is stationary... zero throttle. For each SS a specific predefined voltage level will be applied to the motor. These multiple voltage levels are defined in tables dependent on locomotive type.*

*These “curves” are defined using CVs. The voltage level is represented with a numerical range of 0 to 255. A value of 0 represents no Voltage, a value of 255 represents full voltage. i.e. each SS will have its corresponding voltage level set between 0 and 255.*

**The Basic Speed Curve (applies to all locomotives...)** is defined by 3 CVs which describe a very simple “linear” graph... these are...

CV2 Vstart... this is the first voltage level applied to the motor... it can be defined so that enough voltage may be applied to overcome start inertia of the locomotive... this avoids “slack” throttle movement where the locomotive does not initially respond to the throttle.

CV6 Vmid... Sets the mid point of the curve.

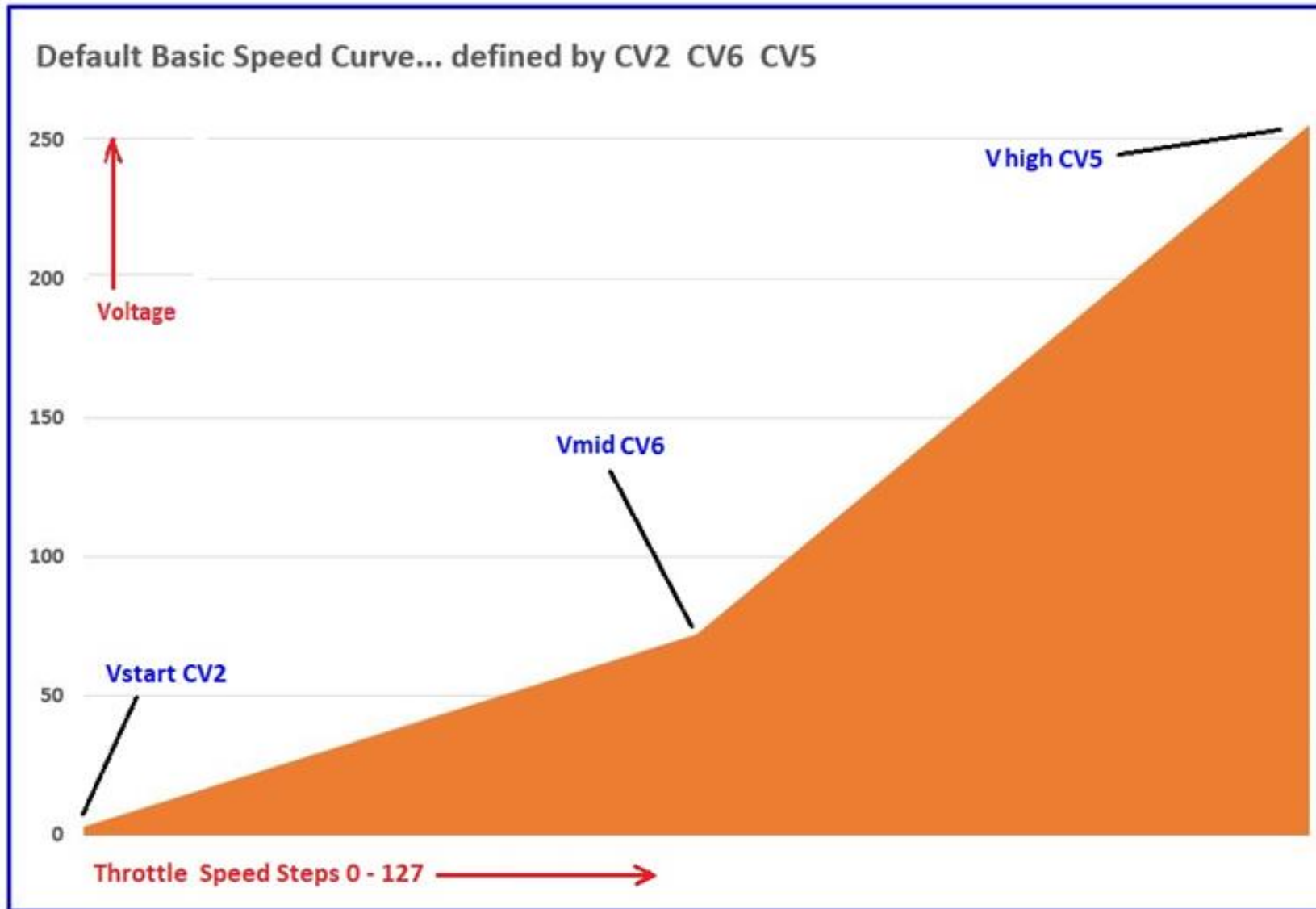
CV5 Vhigh... Sets the voltage applied at full throttle... can be used as a speed cap.

Note the illogical order of these CVs!

**The various “Complex Speed” Curves...** are defined by a range of 27 discrete CV values... i.e. CV67 to CV94... this range of values can describe a more granular curve of non-linear shape as required for your locomotive.

The different Speed Curve graphs are shown next...

The BASIC Speed Curve... applies to all locomotives.



This is the default Speed Curve of all decoders (*CV29 Bit4 = 0*)

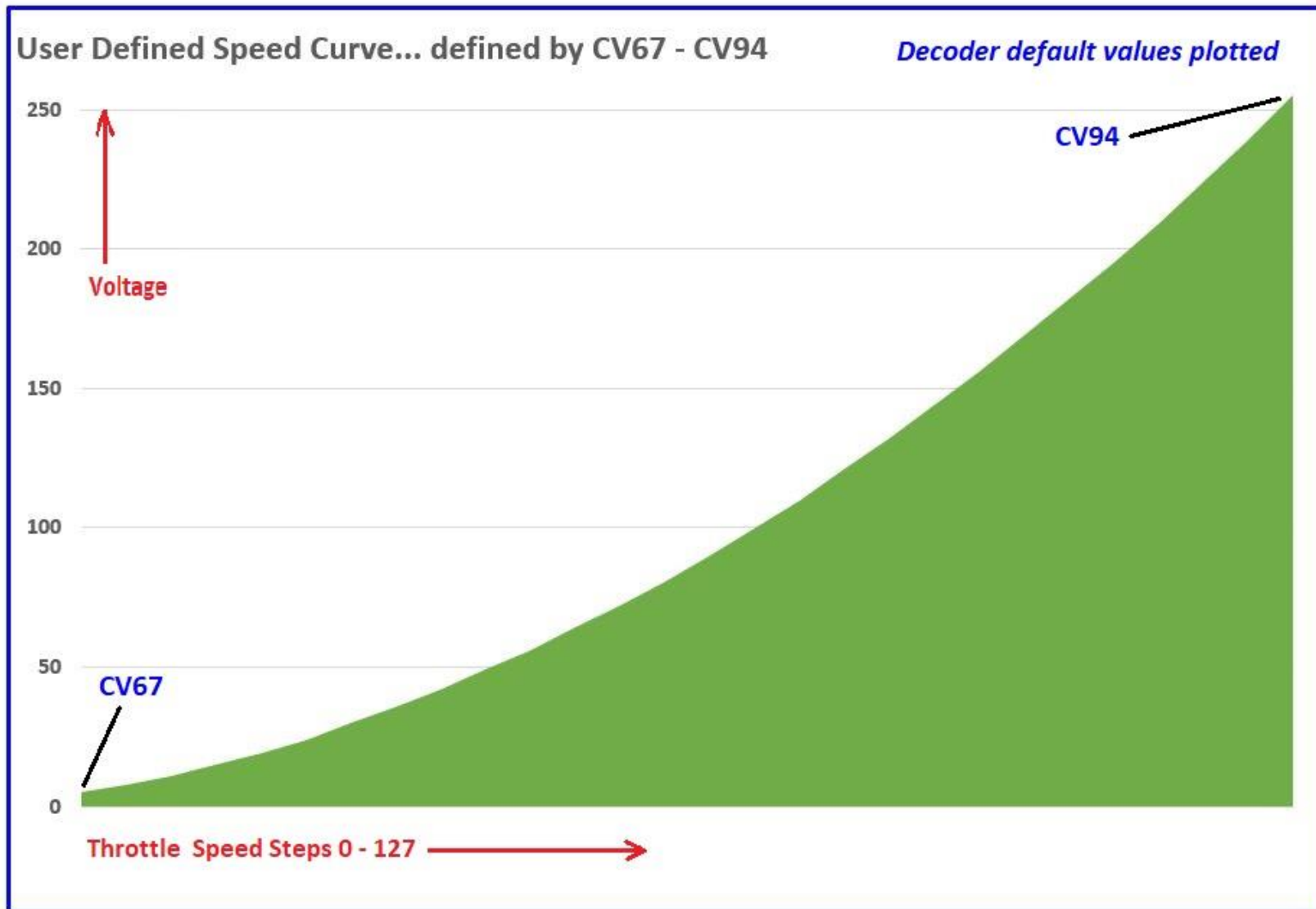
The BASIC curve is described by 3 specific levels of motor voltage. i.e., a table made up of 3 values These are.

CV2 Vstart ... this is the motor voltage when the SS Step = 2

CV6 Vmid ... this is the motor voltage when the SS = 72

CV5 Vhigh ... this the motor voltage wen SS = 255

Since the BASIC SS curve is only described by 3 points it does not offer fine adjustment of the decoder's response to SS applied. This is not ideal.



This Complex Speed Curve applies to all “Diesel/Diesel Electric/Electric” type locomotives.

The curve is defined by a table of 27 values. Each value is held in a CV i.e., CV67 to CV94.

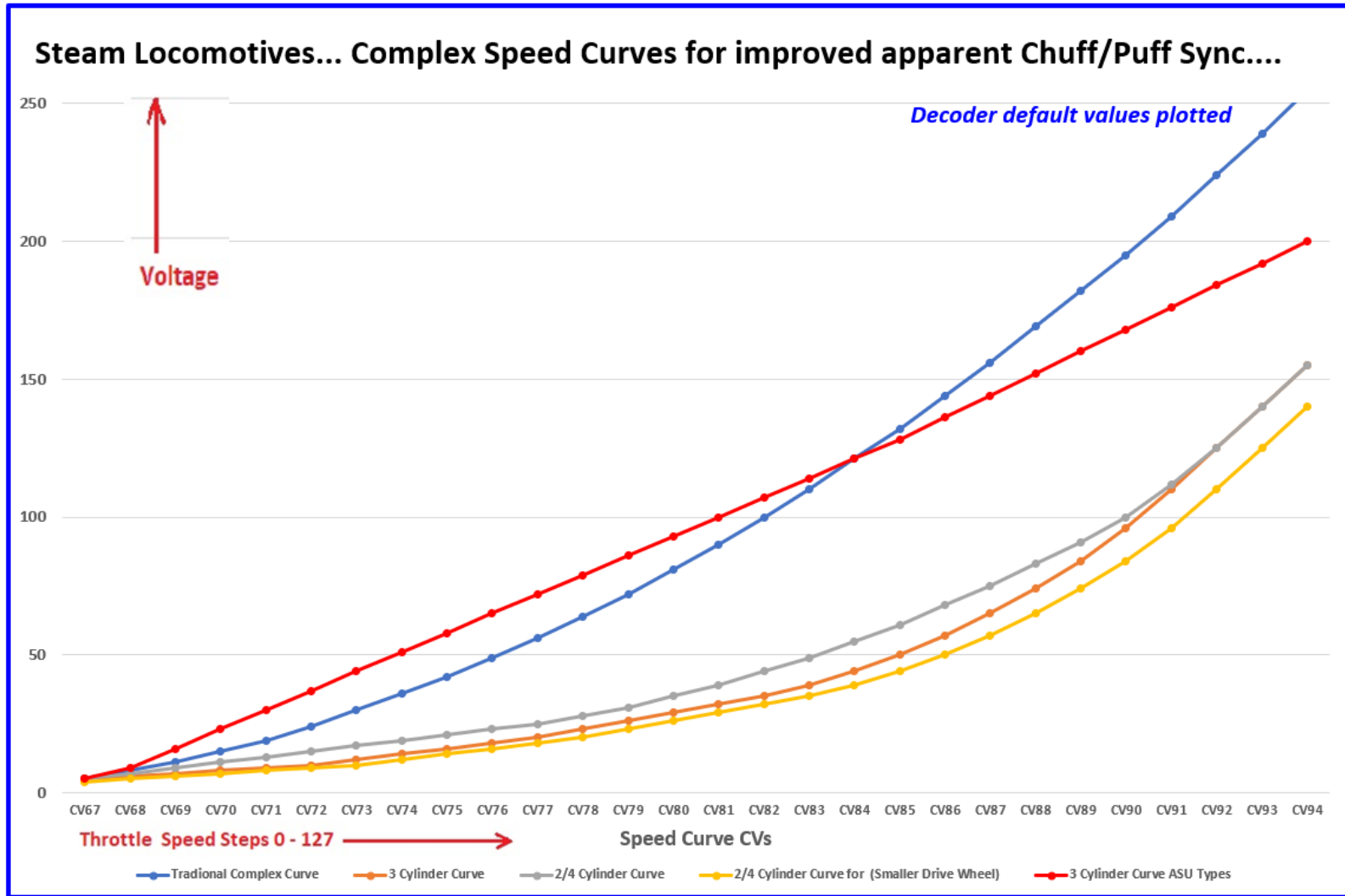
This offers far more detailed control of the shape of the speed curve and thus motor control for each SS.

The default values held in the CV table for the COMPLEX Speed curve describe a shallow curve.

This offers smoother control at low locomotive speeds.

The graph here shows the default “Complex Speed Curve” as defined by the default values for CV67 through to CV94.





These speed curves have been defined to give better apparent “Chuff/Puff wheel syncing” performance.

Note when using these “complex” speed curves, the maximum speed of the locomotive will be capped when compared with the default speed curve. This gives a more realistic locomotive maximum speed.

Locomotive types which fall into the Chuff/Wheel only category will by default use the “Basic” Speed curve. As an alternative the “appropriate” alternative Complex Speed curve is available via CV29 bit4.

Puff/Chuff Locomotives which offer “Piston Sync” i.e. fitted with an ASU steam generator will by default use the “complex” speed curve for realism.

It should be noted that each locomotive chassis type has a slightly different configuration as

shown by each plot on the chart above.

Note... The complex speed curve is selected by adding “16” to the vale of CV29. e.g. default for CV29 = 2... add 16 to become CV29 = 18. ASU equipped locomotives will have a default value of 18 i.e. “Complex” curve enabled.

See next page for a tables giving the actual values of each Complex Speed Curve set up....

CV#	Traditional Complex Curve	CV#	3 Cylinder Curve	CV#	2/4 Cylinder Curve	CV#	2/4 Cylinder Curve (Smaller drive wheel)	CV#	3 Cylinder Curve ASU Fitted ****
CV67	5	CV67	5	CV67	5	CV67	4	CV67	5
CV68	8	CV68	6	CV68	7	CV68	5	CV68	9
CV69	11	CV69	7	CV69	9	CV69	6	CV69	16
CV70	15	CV70	8	CV70	11	CV70	7	CV70	23
CV71	19	CV71	9	CV71	13	CV71	8	CV71	30
CV72	24	CV72	10	CV72	15	CV72	9	CV72	37
CV73	30	CV73	12	CV73	17	CV73	10	CV73	44
CV74	36	CV74	14	CV74	19	CV74	12	CV74	51
CV75	42	CV75	16	CV75	21	CV75	14	CV75	58
CV76	49	CV76	18	CV76	23	CV76	16	CV76	65
CV77	56	CV77	20	CV77	25	CV77	18	CV77	72
CV78	64	CV78	23	CV78	28	CV78	20	CV78	79
CV79	72	CV79	26	CV79	31	CV79	23	CV79	86
CV80	81	CV80	29	CV80	35	CV80	26	CV80	93
CV81	90	CV81	32	CV81	39	CV81	29	CV81	100
CV82	100	CV82	35	CV82	44	CV82	32	CV82	107
CV83	110	CV83	39	CV83	49	CV83	35	CV83	114
CV84	121	CV84	44	CV84	55	CV84	39	CV84	121
CV85	132	CV85	50	CV85	61	CV85	44	CV85	128
CV86	144	CV86	57	CV86	68	CV86	50	CV86	136
CV87	156	CV87	65	CV87	75	CV87	57	CV87	144
CV88	169	CV88	74	CV88	83	CV88	65	CV88	152
CV89	182	CV89	84	CV89	91	CV89	74	CV89	160
CV90	195	CV90	96	CV90	100	CV90	84	CV90	168
CV91	209	CV91	110	CV91	112	CV91	96	CV91	176
CV92	224	CV92	125	CV92	125	CV92	110	CV92	184
CV93	239	CV93	140	CV93	140	CV93	125	CV93	192
CV94	255	CV94	155	CV94	155	CV94	140	CV94	200

\*\*\*\* This curve is only used with ASU "Piston Sync" Locomotives...

## Tuning the Motor Control Algorithms...

### What is a Motor Control Algorithm?

Firstly, we need to explain what a Motor Control Algorithm is!

It is just a way of referring to the complex mathematical formulae that calculate optimal control of a motor. The formulae needs values plugged in to it, in order to carry out the control task. When we adjust the “algorithms” we are plugging in different values in order to find the optimal result regarding the control of the locomotives motor.

### Introduction...

The decoder supports fine tuning of the motor drive system. There is also an auto calibration feature built in. How deep a user wishes to go with “calibration” and motor tuning will depend on the individual user. Often the decoder will work well enough with a decoder/locomotive combination “straight out of the box.” If the locomotive does not run well at first, then the next step is to run the “Auto-Calibration procedure.” This will often sort things out to a reasonable level. However, if the user is inclined, we have provided another stage of tuning to allow absolute flexibility... This is Stage 2... see below... In addition to all this, if the user really wants to get deep into the motor calibration and tuning process, we have also allowed direct access to the PID characteristics of the motor control algorithm. If you don't know what PID refers to ... maybe you should avoid this area of tuning until you have read the section dedicated to the explanation of PID. Be warned... this is a complex process and only really for “Experts and tinkerers!”

**Warning... before any attempts of Auto-Calibration are carried out, it is important that All CVs involving Speed Curves are set to default. Also, ensure that CV10 (BEMF Cut off point) is set to = 127 (default.) Performing a general decoder reset is the easiest method of ensuring that you always start with known basis before carrying out any tuning.**

## Motor Control Algorithm specific to HM7000 Decoders... tuning...

The HM7000 motor drive consists of a PWM waveform at 20kHz. This is interrupted every 15ms for the purpose of monitoring BEMF. Using these two factors the HM7000 motor control algorithms control the motor.

There are 3 Stage of adjusting the motor control algorithms. The recommended approach to adjusting the motor control algorithms is to follow the stages as described below.

Stage 1 ... Default operations and Auto calibration if required.

Stage 2 ... Adding the PA factor to modify the operation of Stage 1.

Stage 3 ... Deep algorithm adjustment. Direct adjustment of the PID factors of the control algorithm.

Brief... The 3 Methods of algorithm tuning/adjustment in detail.

<b>Stages 1 and 2</b>	<b>Stage 1 and Stage 2 adjustment (Auto-Calibration and PA Control Algorithm CV149 = 2 (Default))</b>
Stage 1... <a href="#">Auto Calibration</a>	The PA control algorithm can be automatically written too using the Auto Calibration procedure. Affected are CV143, CV145, CV146 and CV147.
Stage 2... <a href="#">Further adjustment of the effectiveness of Auto Calibration parameters</a>	After AC further adjustment to the motor control algorithm may be made by using CV150, CV151 and CV152. These CV values modify the effectiveness of the tuning factor created after Auto Calibration.
<b>Stage 3</b>	<b>PID Control Algorithm CV149 = 1</b>
Stage 3... <a href="#">Manual PID Calibration.</a>	This ignores the results of any adjustments made in PA mode. You are now editing directly the PID parameters of the motor control system. This is an “Expert Level” form of tuning/adjustment... please read the section on PID control later in this manual for more information. CVs involved are CV153, CV154 and CV155. Generally, it has been found that from default running the Auto-Calibration routine (Method 1) is good enough to get great motor control performance from the decoder.

## 1, Stage One Control Algorithm... CV149 = 2 \*\*\*

When the decoder is in its default state, the motor control system will use a set of variables pre-set in CV143, CV145, CV146 and CV147 to control the basic motor control process. Generally, we have found that the “out of the box” running characteristics have been good with most motors/locomotives. If you need to improve on the default running performance, now consider running the Auto-Calibration process.

The CVs above can be rewritten using the Automatic-Calibration routine. This is the first level of user calibration. \*\*\* CV149 = 2 ... do not be confused... while this indicates that PA mode selected, PA mode has no effect on the use of CV143, CV145, CV146 and CV147 because PA mode is storing system default values.

*Running the Auto-Calibration procedure...*

*Note this procedure can be carried out using the APP... however, please note that stage 6 in the list below is only partially completed i.e. you must still manually return CV149 to value 2 (default).*

1. Ensure that F0 is disabled (turn off the lights!)
2. Programme CV149 = 0 to arm the calibration process. The locomotive will now no longer respond to throttle input. Return to locomotive control on your controller.
3. Beware that the locomotive will move off at a fast pace and stop within about 1.5 metres
4. Place the locomotive on the track and start the calibration sequence by pressing F0 on the control device.
5. The locomotive will accelerate immediately and stop abruptly. CV143, CV145, CV146 and CV147 will have now been populated by the AC process.
6. Auto-calibration is now complete. CV150, CV151 and CV152 are automatically written to default values and CV149 is reset to default. (CV149 = 2 PA... i.e., the Internal Control Algorithm.)
7. Normal throttle control is resumed.

Further tuning and adjustment can be carried out if required... see Method 2..., but this process should bring satisfactory results.

Note: It is usual to run the AC process with a solo loco under no load. However, if you wish to fine tune a locos running for heavier loads you can try running the AC procedure as required i.e., with a rake of carriages in tow.

Note: in DCC it is often desirable to carry out the AC procedure on the MAIN i.e. using OPERATE or POM modes to programme the decoder.

Stage 1 ... Motor Control Algorithm base CVs: initial state and function.

CV#	CV Name	Default Value	Range	Comments
143	Incidence of BEMF reversals re motor type	0		Populated by Auto-Calibration Higher value of this CV indicates a worse quality of motor or a 3-pole motor. Good 5 pole motor has a zero value or a value less than 3.
144	Selects Source of Motor Control settings	0	0 – 1	Value 0 = Internal motor control values for motor control Value 1 = Use the control parameter as defined in CV150, CV151, CV152
145	Calibration result of the motor speed rise time	200		Populated by Auto-Calibration This value multiplied by 20 will give the actual time in ms
146	Calibration result of the motor speed fall time	50		Populated by Auto-Calibration This value multiplied by 20 will give the actual time in ms
147	Calibration result of most suitable motor BEMF Scale	3		Populated by Auto-Calibration
149	Set Motor Control Algorithm/Auto calibration enable	2	0 - 2	0: Arm PID Calibration Process 1: PID Motor Control Algorithm 2: PA Motor Control Algorithm

Manually editing the above CV values will directly/negatively affect Motor Control... DO NOT EDIT.

These CV contains the results of the Motor tests derived from the Auto-Calibration Process.

Note: The values above represent a possible calibration result... i.e. your result for a given locomotive may differ.

## 2, Stage Two ... adding the PA Control factors... CV149 = 2

PA consists of two factors i.e., the PWM frequency of the motor drive and the Amplification factor of the error signal affecting motor control. These are used to modify the effect of CV143, CV145, CV146 and CV147...

If Auto-Calibration does not return satisfactory results, then you can attempt further adjustment of the motor control algorithms using Stage 2. This is referred to as the PA factors.

In this Stage the following CVs ... CV150, CV151 and CV150 allow adjustment of the effect of the values derived by the Auto-Calibration procedure... To enable this adjustment feature programme CV144 = 1

PA Motor Control algorithm further adjustment: initial state of CVs and Function.

CV#	CV Name	Default Value	Range	Comments
150	Number of additional BEMF sampling times in tuning mode	0	0 - 40	Defines the additional BEMF sampling times in tuning mode (CV144=1)
151	Additional PWM output time in tuning mode	1	1 – 20	Defines the additional PWM output time in tuning mode (CV144=1)
152	Strength of PMW Correction	9	0 - 9	Active strength of PWM correction in response to the resulted motor BEMF in comparison to the desired motor BEMF value during control

### 3, Stage 3 ...PID Control Algorithm... (Manual Tuning) CV149 = 1

#### Introduction....

If you have given up with Stages 1 and 2...i.e., you cannot achieve any satisfactory results... Then there is no alternative but to dive deep into the art of motor control calibration. This is where you directly access the PID factors of the motor control algorithm. We strongly recommend that you reset the decoder and start again with stages 1 and 2.... And repeat... Stage 3 can be extremely difficult to execute... it is an “Expert Mode” feature.... We wish you luck.

Enable PID mode by setting CV149 = 1

PID Control Algorithm consists of 3 adjustment factors affecting motor control. These are, the **P**roportional, **I**ntegral and **D**erivative factors, which make up the controlling parts of the algorithm. For more information re PID motor control see... [So... what's PID Motor Control... how does it work?](#)

The PID tuning is carried out by adjusting each factor of the PID control algorithm. The following CV values that offer full PID tuning .... This may involve a lot of trial/test/and error.

PID Motor Control algorithm: initial state of CVs and Function.

CV#	CV Name	Default Value	Range	Comments
153	PID Adjust P Value	4	0 - 255	Manual input
154	PID Adjust I Value	8	0 - 255	Manual input
155	PID Adjust D Value	1	0 - 255	Manual input



So... what's PID Motor Control Algorithm... how does it work?

The explanation of PID control systems can be quite involved. However, you can think of it as a 3-way control system which works by reading the difference between the motors actual speed and the speed desired. This difference is the "error signal".

The PID system consists of 3 different systems/algorithms to give 3 different calculated values. These values are then added and used to correct the motor control output. This is a continuous process.

The 3 different algorithms manipulate the "error signal" in different ways to produce their own calculated results for error correction.

**Proportional... CV153** This is the simplest part of the process. The system looks at the current speed and compares it to the desired speed, it then subtracts one from the other to give an "error signal" this is then processed and fed back into the control system to correct the motor speed. The amount of the "error signal" once multiplied by the calculated control action is referred to as the "Proportional Gain." It is this value that you adjust via **CV153**. This coarse gain control can cause the current motor speed to hunt about the desired speed hence it may need to be further refined as follows...

**Integral... CV154** is the total of all the "error signal" values seen over a set period of time... the algorithm uses this information to create another "correction" value that once processed works with the Proportional value to further correct the motor speed. It is this value that you adjust via **CV154** to refine motor control over the basic Proportional correction above.

**Derivative... CV155** Often the actions of the Proportional and Integral parts are enough to give efficient control of a system. However, the "Derivative part is added to further control the action of the Proportional and Integral systems. Its purpose is to improve the responses of the P & I parts thus speeding up their actions and improving error correction. It does this by mathematically projecting the current rate of change of the motor system into the future i.e., it is acting as a sort of prediction of the future state of the motor control system. The amount of effect that the Derivative part has is set by **CV155**.

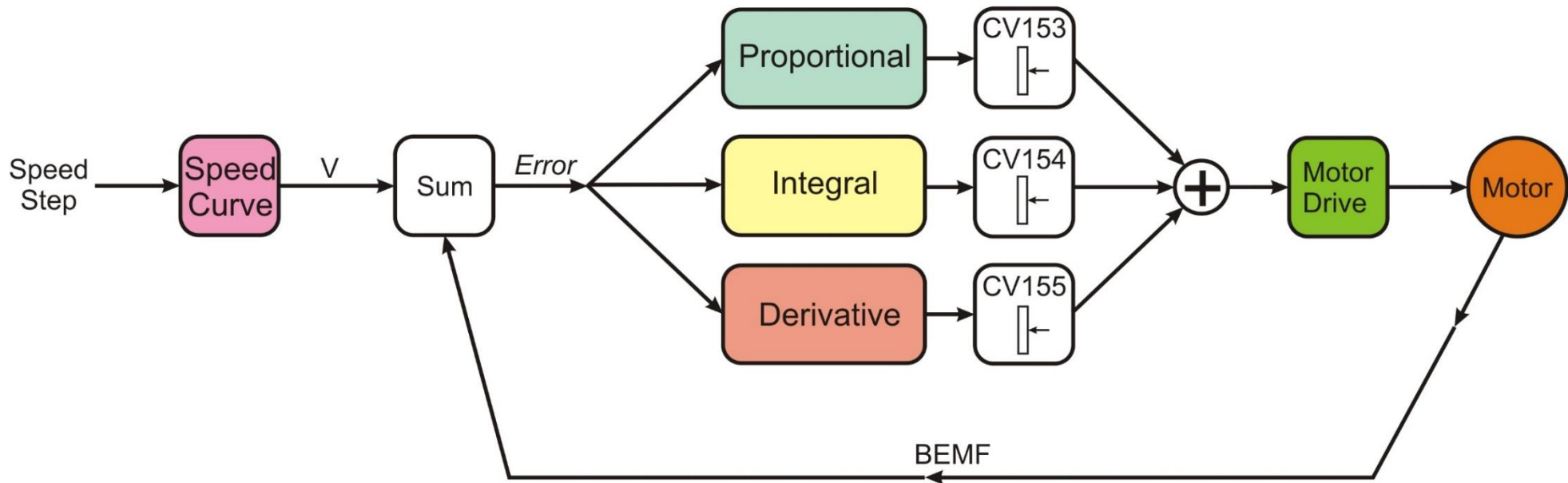
#### *PID In Summary...*

The summation of all three parts (P, I and D) is applied by the motor control part of the decoder to give better control. The process of refining motor control is not exact, and some experimentation may be required to adjust P-I-D values in sequence to find the best balance.

#### *Suggested PID tuning procedure...*

This is difficult to advise on but, in general a P value should be increased until any improvement achieved is seen to degrade, at this point back off the P value slightly. If the locomotive is tending to hunt in speed, adjusting the I value may help. Adjustment of the D values may improve the response further. It seems likely that starting with low settings of the PID adjustments is the best approach. Remember... Auto-calibration of the motor using **CV149** will give a basic set of values to work with if necessary.

# Simple Block Diagram of the PID Control System



## A very basic explanation...

- 1... Using the Speed Curve, the Speed Step is Converted to a representative desired motor Voltage V.
- 2... The BEMF from the motor tells the system what the motor is actually doing at any one time.
- 3... V and BEMF are added together to produce an "error" signal.
- 4... The "error" is fed to each of the PID parts i.e., the P, I and D
- 5... After each part of the PID have carried out their own calculations the output of each is passed on to the "level adjusters." CV153, CV154 and CV155
- 6... The output of the "level adjusters" is added together to produce the "corrected" Motor Drive for the motor.
- 7... This is a continuous loop.

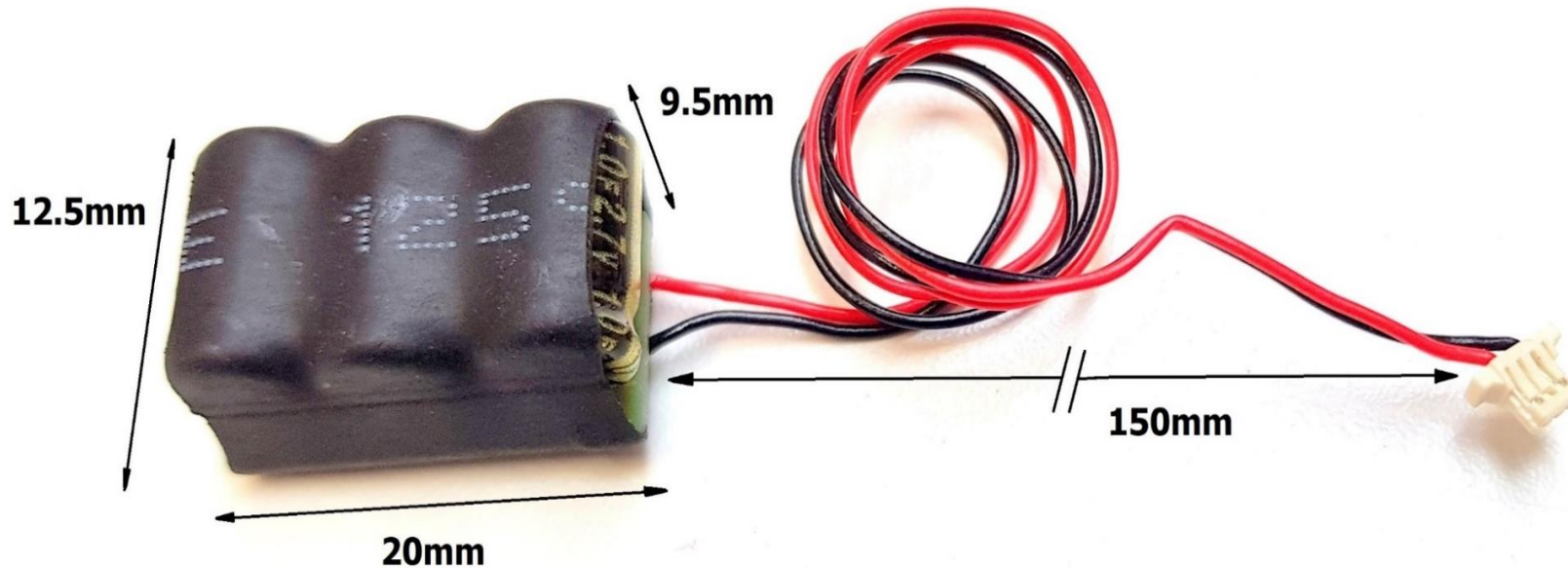
## Appendix 7: Power Bank... Hornby “Stay Alive” Implementation.... And alternative” Stay Alive” arrangements.

### Hornby R7377 Power Bank...

The HM7000 series decoders support “Stay Alive” functionality when fitted with the Hornby R7377 Power Bank. This solution supports “Smart” Charging.

### Physical...

Both the decoder and Power Bank have all the support components fitted to support charge control etc. The external R7377 Power Bank is made up of 3 super capacitors and additional charging control circuitry and is connected via a 3-pin plug directly to the decoder. (3 pins are used to ensure the connection is not mistaken for the decoder speaker connection, which is a similar but a 2-pin plug.) *Take care if working on a locomotive that the Power Bank is fully discharged or disconnected.*



### Smart Charging...

The decoder supports “smart charging.” The decoder will determine if there is power on the track before entering charge mode.

Service mode track : Power Bank will not be turn on at all.

DCC track : Power bank will be turned on forever after 1.5s

DC (Non-DCC) track : Power bank will be turned on forever after 1.5s

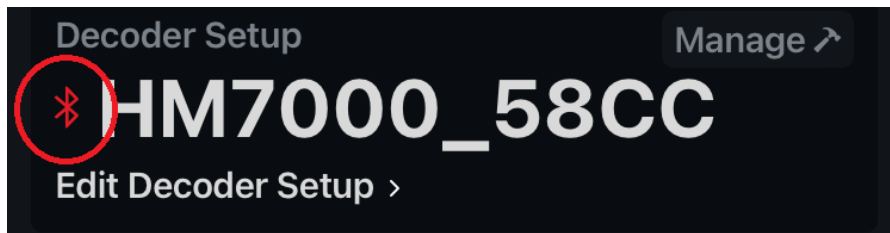
This feature ensures that the decoder can be programmed/readback on a Programme/Service Track. It is a known issue that “stay alive” systems can block successful programming functions. This is caused by the higher current demand caused by charging of the “stay alive” circuitry i.e. the current demand exceeds the current limitation of the Programme/Service Track. Programme/Service outputs are current limited on most DCC controllers.

The charge time is approximately 2 minutes. *Dependent on locomotive power load, the loco can run up to 10 seconds.*

Special Note: Power Bank fitted decoder... Resetting/Rebooting the decoder... i.e. during decoder updates etc.

If for any reason you remove the decoder/locomotive from the track, thus powering down... i.e. in the case of a deliberate decoder reset/reboot, the reset/reboot will NOT occur until the Power bank has fully discharged... Please ensure you allow enough time for the Power Bank to discharge.. This will be approximately 90 seconds.

Alternatively, you can check the **“Locomotive settings” screen in the APP** to monitor when the loco loses communication with the system... i.e. the ping status. “Pinging” is the basic way computer checks to see if a website or a device is alive and well... i.e. a simple signal is sent to the target and a simple reply is returned... if this fails the “ping” is said to have failed. See below...



The Bluetooth symbol with the red circle around it is indicating that the device has lost Bluetooth connection with the decoder.. i.e. the decoder could be in a non-powered state. The symbol turns Blue when communications are enabled (powered state.) This can be used to confirm if a Power Bank has fully discharged during a decoder reset/reboot. The connection status is also shown on the locomotive control screen.

In the lab we tend to rock the locomotive on to one set of wheels to disconnect it.. then drop the locomotive back when ready.. alternatively... A tip from the Hornby forum..... *you can just take the loco off the track however, take a length of thin plasticard and place it under all the wheels on one side of the loco to isolate it from the track. Then I keep an eye on the decoder code which is coloured blue when the decoder is connected to the app. When it changes to red, the PB has powered down and the power cycle has completed. Remove the plasticard strip and wait for the code to change back to blue before going on to the next step in the setup.*

WARNING re use of Power Banks and “EMERGENCY STOP.”

*On some DCC systems an EMERGENCY STOP event triggered by short circuit detection or other means, may cut power to the track. If the decoder has a Power Bank fitted the locomotive may not stop instantly but run on for a few seconds... this can be problematic and may cause a locomotive collision or other undesired results.*

## Non-Hornby Stay Alive systems...

It is possible to connect a “Stay Alive” capacitor to the decoder via the PCB pads marked C- and C+... there is an onboard diode and resistor fitted to the decoder to support external capacitor installation. These two connections are present for future development of the system re Hornby products etc.

We can not advise re “third party” or “home brewed” types of “Stay Alive” solution.... We do not guarantee their operation and cannot officially endorse their use.

If you decide to fit a solution you may invalidate the guarantee on the decoder for the reasons above.

## Appendix 8: Complete CV list for all decoders.

Below is the full CV listing for the HM7000 Series Decoder. Each CV is explained in detail earlier in the manual.

All CVs are writable unless otherwise stated... The CVs list is divided in to sections... i.e. Common and those unique to setting up running sounds for each locomotive type i.e. Diesel, Steam and Electric.

### Common CVs to all sound decoder types.

CV #	CV Name	Default Value	Range	Comments
1	Primary Address	3	1-127	
2	Vstart	2	1-255	
3	Acceleration Rate	15	0-255	
4	Deceleration Rate	15	0-255	
5	Vhigh	255	0-255	
6	Vmid	72	0-255	
7	Manufacturer Version No.	254	0-255	Not used in HM7000 decoders see... <a href="#">CV7... Manufacturer Version number</a>
8	Manufacturer ID	48	48	Assigned by NMRA... READ ONLY. However, Writable for reset functions... <a href="#">CV8... Manufacturers ID</a>
10	BEMF Feedback Cut-out	127	1-127	Speed Step
12	Power Source Conversion	0		0: NMRA 1: DC 2: Radio (BLE)
17	Extended Address	192	1-255	These two bytes form the Extended Address.
18	Extended Address	100	1-255	These two bytes form the Extended Address.
19	Consist Address	0	1 - 127	
27	Decoder ADCC Rail Select for Auto Stop Configuration etc. Rail for detection of positive bias.	0	0 - 3	Enables Asymmetrical DCC Automatic Brake Control (ABC) and sets rail symmetry for detection. <b>This is the rail opposite the diode matrix.</b>  0 = No ADCC 1 = ADCC Right Rail 2 = ADCC Left Rail 3 = ADCC Both rails  See, <a href="#">Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)</a>
29	Configuration Data #1	2	1-255	<a href="#">CV29... Decoder Configuration</a>

Control Processor Firmware version		APROM	Subject to Change	
47	Firmware Version Major	STC	1-255	Control Processor Firmware Version... READ ONLY The format of the software version of the decoder is: "v[Major]. [Minor].[Patch]"
48	Firmware Version Minor	STC	1-255	
49	Firmware Version Patch	STC	1-255	

Lighting Configuration				
51	Lighting Effect F0 - (Front)	0	0-7	Lighting Control 0: Constant bright light 1: Random flicker (fire box) 2: Mars light 3: Flashing light 4: Single pulse strobe 5: Double pulse strobe 6: Rotary beacon 7: Gyra light
52	Lighting Effect F0 - (Rear)			
53	Lighting Effect F1			
54	Lighting Effect F2			
55	Lighting Brightness F0 - (Front)	8	0-8	0: Dim level minimum 8: Dim level maximum
56	Lighting Brightness F0 - (Rear)			
57	Lighting Brightness F1			
58	Lighting Brightness F2			

AFC Sound Selection .... Sounds while the locomotive is stationary See <a href="#">F28... Enable/Disable Auto Function Control (AFC) of Spot Sound Play ... CV59 – CV66</a>				
59	Play Mode while running	0	0 - 1	0 = Sequential 1 = Random
60	Loco Running Spot Sound Select F2 – F7	0	0 - 255	
61	Loco Running Spot Sound Select F8 – F15	0	0 - 255	
62	Loco Running Spot Sound Select F16 – F20	0	0 - 31	
AFC Sound Selection .... Sounds while the locomotive is stationary				
63	Play Mode while stationary	0	0 - 1	0 = Sequential 1 = Random
64	Loco Stationary Spot Sound Select F2 – F8	0	0 - 255	
65	Loco Stationary Spot Sound Select F2 – F8	0	0 - 255	
66	Loco Stationary Spot Sound Select F2 – F8	0	0 - 31	

**Speed Table Configuration... CV67 to CV94** [Explanation of the Speed Step Curve Graphs.](#)

<b>Multi decoder Locomotives... Function Mask Select...</b> See <a href="#">CV119... Function Mask Select for multi decoder locomotives...</a>		
119	0 - 2	Function mask select.

<b>Special Decoder Functions</b>				
120	Shunting Percentage	1	0 - 2	Percentage of current NMRA speed 0: 25% 1 : 50% 2 : 75%
121	Creep speed	1	1 - 15	
122	Creep pre-set duration (Seconds)	0	0 - 10	CV122 = 0 for Continuous Operation. CV122 = 1-10 allows sets duration from 1 to 10 seconds.
123	Brake deceleration rate	5	0 - 255	CV123 = 1 will result in an instant stop.

<b>ABC Configuration</b> <a href="#">Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)</a>				
125	ABC Control Function	0	0 - 3	<a href="#">Appendix 4: Setting up Asymmetrical DCC Control... (ADCC)</a>
126	ABC Stop Hold time	1	0 - 255	
127	ABC Constant Braking Distance	25	0 - 255	

<b>Motor Control Algorithm... CVs affected by the Auto-Calibration Procedure. CV149 = 0 to arm process. (CV149 returns to = 2 after process has completed.) Values are examples only.</b>				
143	Incidence of BEMF reversals re motor type...	0		Populated by Auto-Calibration
144	Source of Motor Control settings	0	0 - 1	Value 0 = Internal motor control values for motor control Value 1 = Use the control parameter as defined in CV150, CV151, CV152
145	Calibration result of the motor speed rise time	200		Populated by Auto-Calibration
146	Calibration result of the motor speed fall time	3		Populated by Auto-Calibration
147	Calibration result of most suitable motor BEMF Scale	3		Populated by Auto-Calibration
148	Reserved.			
149	Set Motor Control Algorithm/Auto calibration enable	2	0 - 2	0 : Arm Auto-Calibration process 1: Use PID Motor Control Algorithm 2: Use PA motor control algorithm

Please refer to [Stage 1 ... Motor Control Algorithm base CVs: initial state and function.](#) for more details.



Motor Control Algorithm... CVs used for PA adjustment after Auto-Calibration. CV149 = 2 <a href="#">2, Stage Two ... adding the PA Control factors...</a> CV149 = 2				
150	Number of additional BEMF sampling times in tuning mode	0	0 - 40	Defines the additional BEMF sampling times in tuning mode (CV144=1)
151	Additional PWM Output Time in PA mode	1	1 - 20	Defines the additional PWM output time in tuning mode (CV144=1)
152	PA Mode Error Amplification	9	0 - 9	Active strength of PWM correction in response to the resulted motor BEMF in comparison to the desired motor BEMF value during control

Motor Control Algorithm... CVs used for PID adjustment. CV149 = 1 <a href="#">3, Stage 3 ...PID Control Algorithm... (Manual Tuning)</a> CV149 = 1				
153	Algorithm P Value	4	0 - 255	Manual input or Auto-Calibration.
154	Algorithm I Value	8	0 - 255	Manual input or Auto-Calibration.
155	Algorithm D Value	1	0 - 255	Manual input or Auto-Calibration.

Sound Volume Configuration... <a href="#">Sound Decoders... adjusting sound volumes etc.</a>				
158	Global volume set	35	0 - 127	Write a value to this CV sets "Spot Sound" volumes (F1-F28) to the same volume level. Effects CV162 to CV168
159	Volume of F0 (Special Case)	35	0 - 127	This applies to non-locomotive decoder profiles only i.e., like the original Vent Van projects etc.
160	ELECTRIC Volume of Locomotive Motors	35	0 - 127	Applies to both acceleration/deceleration phases of operation. Applies when the locomotive is Stationary.
161	DIESEL and STEAM Volume of locomotive Engine	35	0 - 127	Applies to both acceleration/deceleration phases of operation. Applies when the locomotive is Stationary.
162-180	Volume of F2 - F20.	35	0 - 127	Volume of all Spot Sound Play

181-199	Reserve for future use			
---------	------------------------	--	--	--

Sound IDs and Versions... SPIROM		Subject to change.		
<b>200</b>	Sound ID (High Byte)	STC	0-255	2 Bytes = 16-bit value for the ID of the sound file... READ ONLY
<b>201</b>	Sound ID (Low Byte)	STC	0-255	
<b>202</b>	Sound Version (High Byte)	STC	0-255	2 Bytes = 16-bit value for the version of the sound file... READ ONLY
<b>203</b>	Sound Version (Low Byte)	STC	0-255	

Horns and Whistle play... F2 and F3 Configuration... <a href="#">Horn and Whistle Selection re F2 and F3... Configuration... CV205 to CV208...</a>				
<b>205</b>	Sound Selection for F2	***	0-255	F2 sound selection, maximum 8 sounds, default 0xff to play all 8 sounds.
<b>206</b>	F2 Play Mode	0	0-1	F2 sound play mode, 0=sequential, 1=random.
<b>207</b>	Sound Selection for F3	***	0-255	F3 sound selection, maximum 8 sounds, default 0xff to play all 8 sounds.
<b>208</b>	F3 Play Mode	0	0 - 1	F3 Sound play mode 0=sequential, 1=random

\*\*\* Depends on Locomotive type.

Sound Play Configuration DIESEL Engines... Idle + 3 Notches... Earlier TTS projects etc. <a href="#">3 Notch Diesel... Configuration... CV210 to CV215</a>				
	Idle			Applies to SS of < <b>DTT1</b>
<b>210</b>	Trigger Threshold 1	5	5-15	Applies when SS > <b>DTT1</b> but < <b>DTT2</b> ... Plays Notch 1
<b>211</b>	Trigger Threshold 1 Window	5	5-9	<b>DTTW1</b> ... Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
<b>212</b>	Trigger Threshold 2	30	25-45	Applies when SS > <b>DTT2</b> but < <b>DTT3</b> ... Plays Notch 2
<b>213</b>	Trigger Threshold 2 Window	5	5-14	<b>DTTW2</b> ... Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
<b>214</b>	Trigger Threshold 3	60	60-80	Applies when SS > <b>DTT3</b> ... Plays Notch 3
<b>215</b>	Trigger Threshold 3 Window	5	5-15	<b>DTTW3</b> ... Forces Notch to Decrease back to Notch 2

Sound Play Configuration DIESEL Engines... Idle + 4 Notches... Later TTS projects etc. <a href="#">4 Notch Diesel... Configuration... CV210 to CV217</a>				
	Idle			Applies to SS of < <b>DTT1</b>
<b>210</b>	Trigger Threshold 1	5	5 - 15	Applies when SS > <b>DTT1</b> but < <b>DTT2</b> ... Plays Notch 1
<b>211</b>	Trigger Threshold 1 Window	5	5 - 9	<b>DTTW1</b> ... Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
<b>212</b>	Trigger Threshold 2	20	20 – 30	Applies when SS > <b>DTT2</b> but < <b>DTT3</b> ... Plays Notch 2
<b>213</b>	Trigger Threshold 2 Window	5	5 - 14	<b>DTTW2</b> ... Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
<b>214</b>	Trigger Threshold 3	45	40 - 50	Applies when SS > <b>DTT3</b> but < <b>DTT4</b> ... Plays Notch 3
<b>215</b>	Trigger Threshold 3 Window	5	5 – 14	<b>DTTW3</b> ... Forces Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3
<b>216</b>	Trigger Threshold 4	65	65 - 70	Applies when SS > <b>DTT4</b> ... Plays Notch 4
<b>217</b>	Trigger Threshold 4 Window	5	5 – 14	<b>DTTW4</b> ... Causes Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3

DIESEL Start Delay after Brake release... <a href="#">CV225... Start delay after Brake release ... Diesel Locomotives Only</a>				
<b>225</b>	Delay Time	25	0 - 255	1 = 100mS Default = 2.5S

Steam Locomotives... Running Sounds set up. Uniquely allocated CVs.

<b>Chuff/Puff System... Puff adjustment... applies to ASU/Sensor equipped Steam Locomotives</b>				
<b>211</b>	Puff Strength... During Chuff ... High level steam	127	0 - 127	
<b>212</b>	Puff Strength... During Idle ... Idle Steam	50	0 - 127	

<b>Steam Wheel Slip Simulation Configuration... Applies to all Steam Locomotives. <a href="#">Automatic Wheel slip behaviour simulation ... CV213 and CV216</a></b>				
<b>213</b>	Wheel Slip Automatic Mode Enable	0	0-1	0 = Manual 1= Auto
<b>214</b>	Wheel Slip Triggering Step Difference	7	5-15	Overshoot value... i.e., how many speed steps you can apply before wheel slip engages
<b>215</b>	Wheel Slip Deactivating Speed (Low Range)	2	0-5	SS of the locomotive below which the wheel slip operation will be disabled in automatic mode.
<b>216</b>	Wheel Slip Deactivating Speed (High Range)	25	15-75	SS of the locomotive above which the wheel slip operation will be disabled in automatic mode.

<b>Chuff/Puff Piston Sync Configuration... applies to ASU/Sensor equipped Steam Locomotives</b>				
<b>221</b> <b>238</b>	Chuff Band select/Pulse Frequency		0 - 255	Will be Read Only.... Future use... Reserved

Electric Locomotives... Running Sounds set up. Uniquely allocated CVs.

<b>Sound Play Configuration ELECTRIC Locomotive... <a href="#">ELECTRIC LOCOMOTIVES... Engine Running Sound Playback...</a></b>				
	Automatic Idle			Applies to SS of > 0 but less than <b>ETT1</b>
<b>218</b>	ELECTRIC Trigger Threshold 1 ( <b>ETT 1</b> )	3	1-127	Applies when SS > <b>EET1</b> but < <b>ETT2</b>
<b>219</b>	ELECTRIC Trigger Threshold 2 ( <b>ETT 2</b> )	30	1-127	Applies when SS > <b>ETT2</b> but < <b>ETT3</b>
<b>220</b>	ELECTRIC Trigger Threshold 3 ( <b>ETT 3</b> )	60	1-127	Applies when SS > <b>ETT3</b> but < <b>ETT4</b>
<b>221</b>	ELECTRIC Trigger Threshold 4 ( <b>ETT 4</b> )	80	1-127	Applies when SS > <b>ETT4</b> but < <b>ETT5</b>
<b>222</b>	ELECTRIC Trigger Threshold 5 ( <b>ETT 5</b> )	100	1-127	Applies when SS > <b>ETT5</b>

## Appendix 9: Decoder Operational, Electrical and Physical Specifications

### Sound Decoders Specification.

	HM7000-21TXS	HM7000-8TXS	HM7000-N18TXS
<b>Operational Modes</b>	All Decoders		
Bluetooth BLE Supported	All Decoders		
DCC Supported	All Decoders		
DC Supported (Motor Control Only)	In DCC mode only... In Bluetooth mode the decoder waits for a valid Bluetooth Signal		
<b>Electrical Limits</b>			
Track Voltage Maximum	27V All Decoders		
Motor Current Maximum Continuous	1000mA (All Decoders)		
Motor Current Peak	1500mA (All Decoders)		
Function Output HFO1, 2, 3 and 4 Voltage and Maximum Current	-14VDC @ 100mA each... (All Decoders)		
Function Output HFO 5 and 6 Voltage and Maximum Current	Digital	N/A	Digital
Decoder SUM Current Maximum Continuous	1000mA (All Decoders)		
Audio Amplifier Maximum Output & Speaker Impedance	Class D Power 1.68W @ 8Ω		
Number of Sound Channels	3		
<b>Physical</b>			
Dimensions	15.5mm x 29.5mm x 4.9mm	14mm x 28.5mm x 4.9mm	14mm x 28.5mm x 4.9mm
Termination	21MTC	NEM 652 8 pin + flying lead	Next18-S

Check Decoder Types for full information re the availability of HFO/AUX connections per Decoder... note they are not all the same!!!

## Non-Sound Decoders Specifications

	HM7000-8	HM7000-6
<b>Operational Modes</b>		
Bluetooth BLE Supported		All Decoders
DCC Supported		All Decoders
DC Supported (Motor Control Only)	In DCC mode only...	In Bluetooth mode the decoder waits for a valid Bluetooth Signal
<b>Electrical Limits</b>		
Track Voltage Maximum		27V (All Decoders)
Motor Current Maximum Continuous		1000mA (All Decoders)
Motor Current Peak		1500mA (All Decoders)
Function Output HFO1, 2 Voltage and Maximum Current		-14VDC @ 100mA (All Decoders) Note: HM7000-6 only supports HFO1 & HFO2
Decoder SUM Current Maximum Continuous		1000mA (All Decoders)
<b>Physical</b>		
Dimensions	8mm x 21.5mm x 4 mm	8mm x 22.5mm*** x 4mm *** including pin length, pcb length is 17mm
Termination	NEM 652 8 pin	NEM651 6 pin

Check Decoder Types for full information re the availability of HFO/AUX connections per Decoder... note they are not all the same!!!

To be added...

HM7000-18 R7401 ... Next18 Non-Sound Decoder

HM7000-21 R7402 ... 21pin Non-Sound Decoder

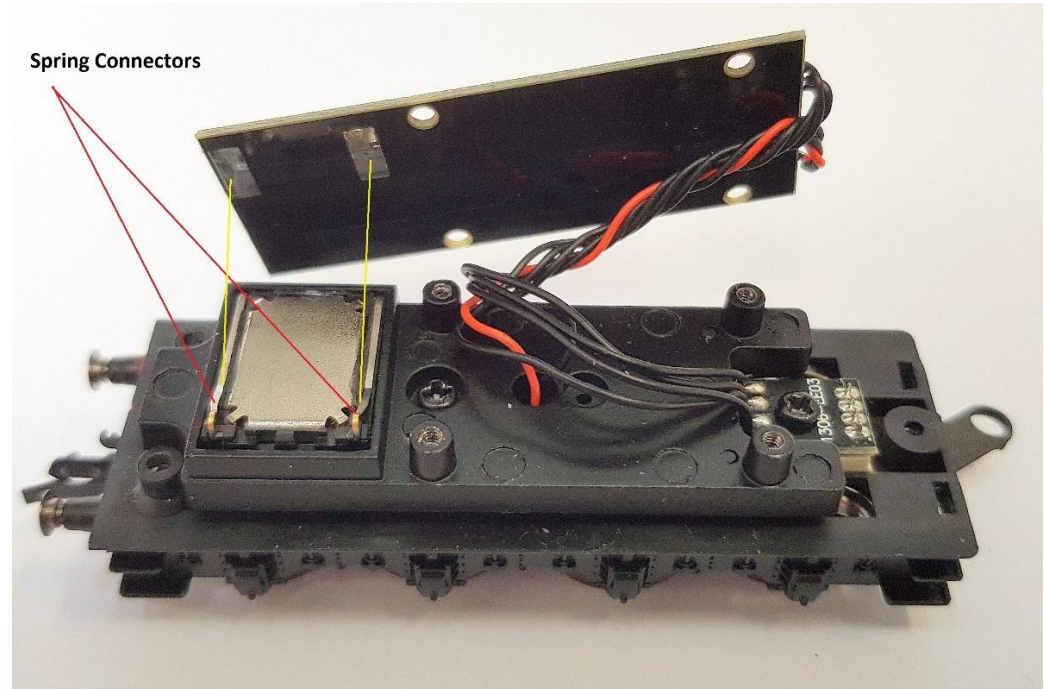
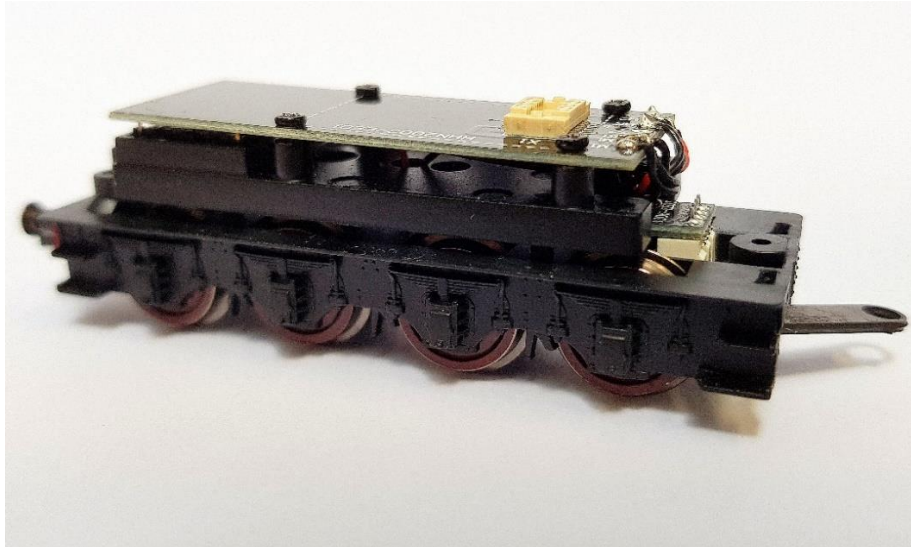
... physical size to be confirmed.

## Appendix 10: Speakers.... Sugar Cubes and the rest...

In this Appendix we will discuss the fitting, installation and wiring of different speaker arrangements. These include where Factory Fitted Speakers are present as in TT locomotives or locomotives with speaker boxes preinstalled/moulded in to the locomotive chassis. Where a locomotive has a preinstalled speaker arrangement there is no need to assemble/install the speaker driver and enclosure supplied with the decoder (unless you really want to!)

### TT Locomotives... with factory fitted speaker.

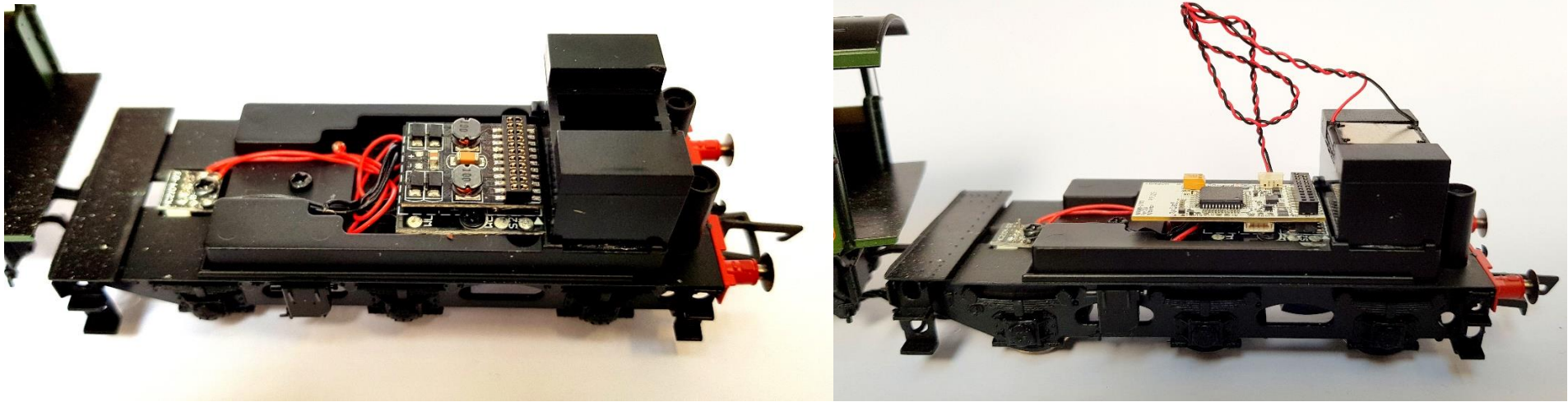
Later TT locomotives come fitted with a sugar cube speaker, please check your locomotive documentation.



The above pictures illustrate the pre-fitted speaker arrangement found in a typical TT steam locomotive. The speaker driver is sealed to an internal speaker box. Spring contacts on the speaker driver make contact with the underside of the tender motherboard. Speaker connection to the decoder is provided via the Next18s decoder socket. TT Diesel locomotive will have a similar arrangement re speaker connection.

00 Locomotives... with factory fitted speaker box/sugar cube.

Some 00 gauge locomotives may come with preinstalled “sugar cube” type speaker boxes.



The above picture shows a 9F tender with factory fitted speaker box. The speaker driver is mounted in the box with its adhesive seal and connected to the decoder via the flying lead and plug.

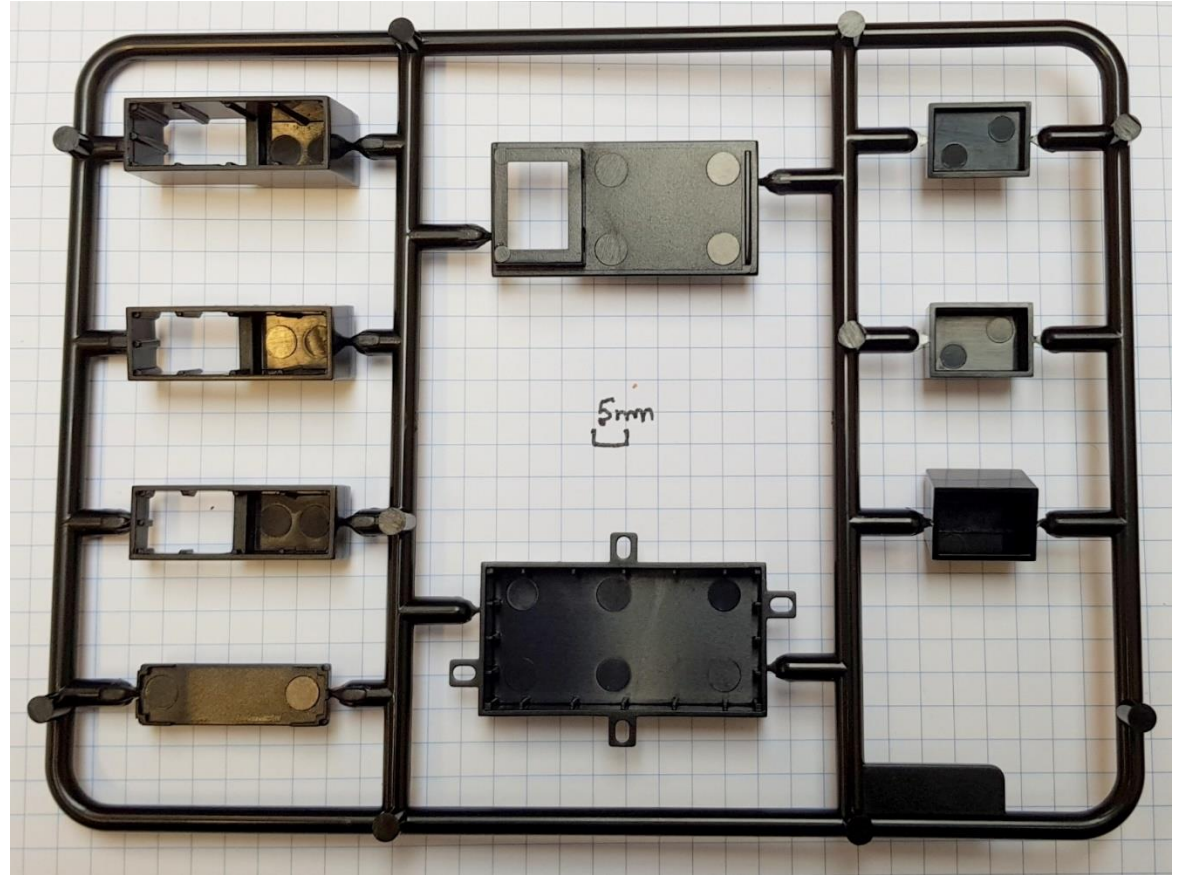
Other types of 00 locomotive may will have similar arrangements.

However, if no speaker box/sugar cube is preinstalled in your locomotive, you may want use the speaker driver and box/sugar cube enclosures supplied with the decoder. See next.



## DIY... Sugar Cube Speakers

Included in the decoder packaging are the components to build a suitable “sugar cube” type speaker to fit your loco. This consists of a speaker driver unit and a plastic sprue with a selection of 8 differently sized speaker enclosures/boxes i.e. a kit of parts.



The “Speaker Driver” measures 11mm x 15mm and is supplied with a 150mm flying wires which terminate in a two pin plug. The impedance of the driver is 8Ω with a power handling of 1.2W maximum. See later for more information re the decoder amplifier and speaker characteristics etc.

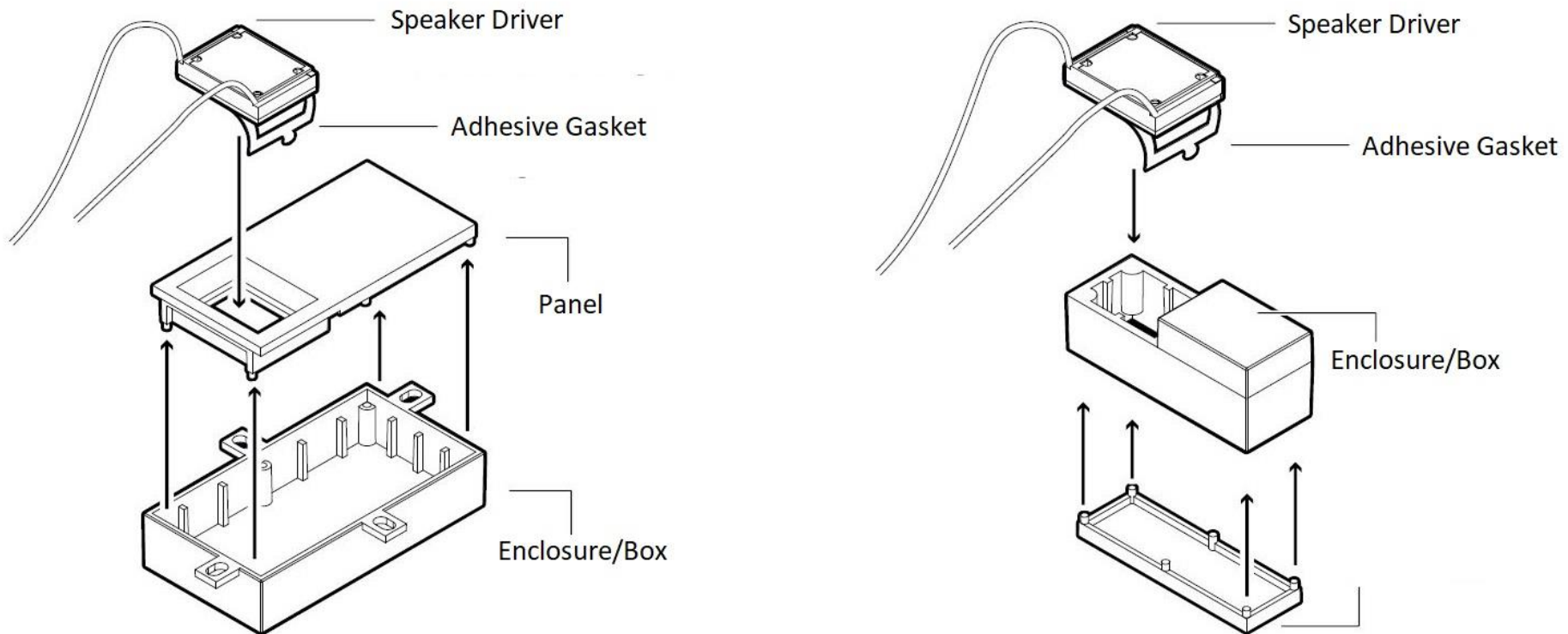
The sprue has a range of enclosure types. Three of them are simple cubes, the rest are larger and require two part assembly i.e. they have an enclosure and a sealing panel.

## Assembling the Sugar Cube kit...

The kit contains two types of enclosure. The simple “box” type and the two part enclosures type as shown below.

### Speaker Driver Installation...

The speaker driver is simply stuck to the open side of the simple “box” type... For the larger two part enclosure please refer to the diagram below.



The “Speaker Driver” has a white tab which is peeled off to expose the adhesive gasket, which must be sealed to the enclosure. **WARNING:** After a few minutes the seal becomes permanent.

#### IMPORTANT:

If for what ever reason you need to remove the “Speaker Driver” from the enclosure after initial assembly, be aware that the adhesive gasket is designed for single use... i.e. the gasket may not work well enough to hold the “Speaker Driver” in place if the “speaker driver” is reapplied to another enclosure. Also, please note that it is possible to damage the speaker driver when attempting to uninstall it... use a scalpel or similar tool to break the gasket seal.

If the speaker driver is to be reused, the only way of refitting it is to apply a sealer to the sides of the unit to ensure a good seal between it and the enclosure/box. You could use silicone sealer, Kapton tape cut to fit etc. i.e. place the tape around the edge of the sugar cube assembly.

**Do not cover the back of the speaker driver. Doing so will reduce the fidelity of the entire sugar cube assembly.**

#### Connecting the Speaker Driver to the decoder...

All sound decoders have a two pin socket fitted to the decoder circuit board to accommodate a speaker connection.



However, actual connection to decoder may be implemented differently on some locomotives. i.e. locomotives with 21 pin connectors may use pins 9 and 10 to connect to the locomotive pcb directly i.e. the speaker is connected/plugged in to the locomotive pcb and make its connection back to the decoder through the 21 pin socket/plug..

Next18 decoders may use pins 7 and 16 to carry out a connection in a similar manner to the pcb.

..

Next18 and 8 pin decoders also have solder pads available on the pcb for connection of a speaker...these solder pads can be found on the opposite side of the decoder pcb from the speaker socket, they are labelled SPK ....

Please check the information in section [Sound Decoder Types and Connection](#) for more information re speaker connection arrangements for each type of HM7000 decoder.

#### Supplied Speaker Driver and Audio Amplifier Specification...

The basic specification of the supplied speaker driver and amplifier is...

Speaker Driver – HM7000 pack	
Parameter	Value
Impedance	8Ω
Rated Input Power	800mW
Maximum Input Power	1.2W

The decoder has a built in amplifier which drives the speaker connection. The amplifier is rated output is **1.68W maximum**. Amplifier power rating and speaker power handling pairing is dependent on what is commonly available on the market.

Other manufacturers offer decoders with amplifier outputs in excess of the supplied speakers apparent power handling. This practice of fitting/supplying lower power speakers compared to the onboard amplifiers output power is common practice in the DCC world of model of sounds

The HM7000 decoder amplifier is designed to have enough power to drive third party speaker systems/arrays. Therefore, depending the connected speaker arrangement with our onboard amplifier certain things should be borne in mind. i.e. The amplifier can damage some speakers (check the power rating of your speaker!) if volume levels are set to extreme levels. You may hear distortion of you push your speaker too far... you will know when you have the limit re volume... this is common to all decoder sound systems using miniature speakers.

### What is speaker “Impedance?”

“Impedance” is measured in ohms i.e. in the same way resistors have a resistance measured in ohms The use of the word “Impedance” as opposed to “Resistance” in regard to speakers is to indicate that the figure in ohms is related to an AC signal. i.e. the audio fed to the speaker is an AC signal.

The loud speaker has a speaker coil... being a coil, it’s apparent electrical resistance will change depending on the audio frequency applied to it. When a speaker is quoted as having an 8Ω impedance it actually means, it is 8Ω at a specific frequency... usually about 1KHz. Fortunately, measuring the “impedance” of a speaker with a multimeter set to ohms, will give a reading close to the “Impedance” quoted for the unit. That as much as really need to know in practice!!

### Using other speaker types with your HM7000 decoder...

The HM7000 sound decoder can be used with any 8Ω impedance speaker arrangement. Also, it is possible to use higher impedance speakers, but there will be some drop in volume. The decoder’s onboard amplifier has enough power capability to drive a large range of speaker arrangements.

As stated, If using higher impedance speaker arrangements there is likely to be a drop in volume available Within limits, the volume drop can be compensated for by editing the “sound volume CVs.”

### Two speakers???

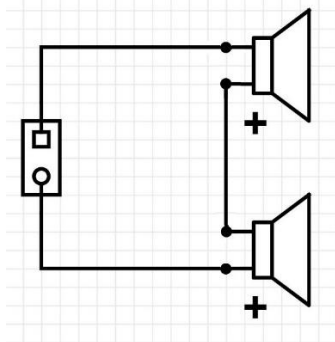
In some installations it is desirable to have multiple speakers connected the decoder’s output. E.g. in Class 800, Class 43 and similar locomotives. This may be to give a better sound spread over the locomotive, or maybe to allow the use of two different speakers with differing frequency response characteristics... e.g. using a large speaker which will have better bass response with a small speaker with a superior high frequency response..... a sort of tuned system.. There is much experimentation in this area.

Multiple speakers may be connected in series or parallel. However, it is important that the total speaker impedance presented to the decoder is not less than 8Ω.

Connecting many speakers together fed from a common source is referred to as a “speaker array.” Next we will examine various ways to connect multiple speakers i.e. an array..... These diagrams (below) show methods of connecting two speakers to a decoder.

It is possible to connect more than two speakers in an array. However, for the scope of this article we will only cover two speaker arrangements in detail.

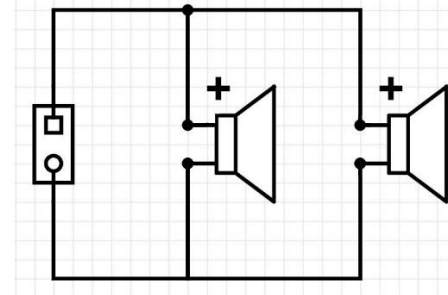
Two speakers is probably the most common arrangement.....



#### Two Loudspeakers in Series...

This speaker arrangement is probably the most likely one to be used when installing two speakers in a locomotive.

If each speaker has an impedance of  $8\Omega$  the overall impedance presented to the decoder will be  $16\Omega$



#### Two Loudspeakers in Parallel...

This speaker arrangement is probably not the most common arrangement for two speakers.

If each speaker has an impedance of  $8\Omega$  the overall impedance presented to the decoder will be  $4\Omega$ .

Depending on the decoder,  $4\Omega$  may be too small of an impedance to suit the decoder audio amplifier, therefore the arrangement shown in the lefthand schematic is the more likely way that two speakers will be connected... i.e. series.

the most likely one to be used when installing two speakers in a locomotive.

If each speaker has an impedance of  $8\Omega$  the overall impedance presented to the decoder will be  $16\Omega$

More than two speakers???

Many speakers in series or parallel in an array is possible. In some cases both methodologies could be combined in order to keep the overall impedance of the system at the required level.

Some basic rules re calculating Impedance in arrays with multiple speakers...

For Speakers in series...

Just add all the speaker impedances together... e.g. two  $8\Omega$  speakers connected in series will give a total impedance of  $16\Omega$

For Speakers in Parallel...

**To keep thing simple we will assuming all speakers in the array have the same base impedance.**

Just divide the impedance of one speaker by the number of speakers connected in parallel... e.g. two  $8\Omega$  speakers connected in parallel will have a total impedance of  $4\Omega$

Speaker Arrays.... Going Further...

You can mix parallel and series arrangements together and use different speaker impedances. Calculations of total impedance can get complex....

This is a useful link.... <https://www.speakerimpedance.co.uk/>

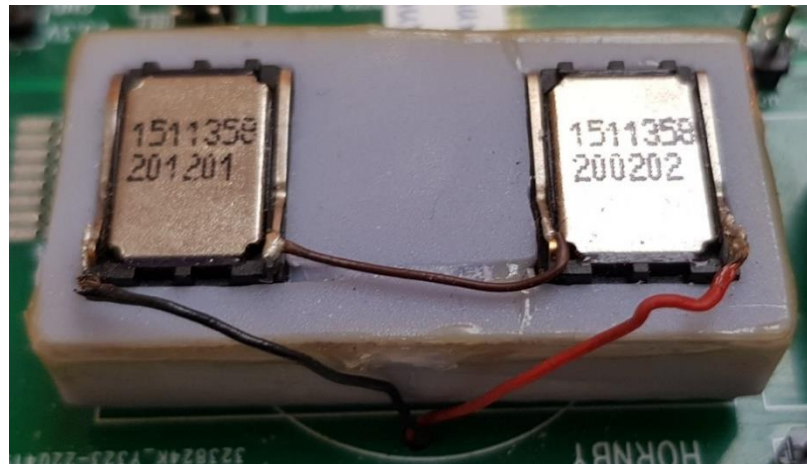
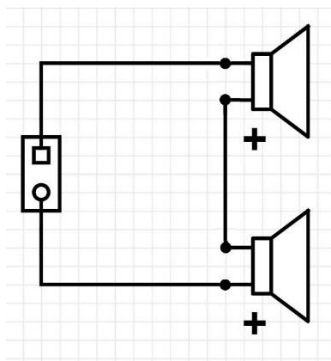
## Speaker Polarities...

Connecting many speakers together... the terminals on the speaker drivers may be labelled with a red dot or maybe a “+” sign. This indicates the so called positive connection of the speaker coil. Basically, all it means is that when a positive voltage is applied to this connection the loudspeaker diaphragm/cone moves forwards. When you have many speakers in an array, it is important that all the cones work in unison i.e. you do not want one of them going in the opposite direction to the rest.

Just to be awkward, sometimes there is no polarity indication on the speaker!!! However, there is a simple rule re connecting multiple speakers together. Imagine there is a red dot on the same physical terminal on all of the speakers in your array... it does not matter which terminal you apply this rule to. The purpose of this exercise is to make sure all the speaker cones are going forwards and backwards in unison.... Which termination on the speaker is actually positive is unimportant.

Take a look at the diagram and picture below...

In the diagram on the left we show a pair of speakers connected in series. In the picture on the right we show you what this physically could look like.



In the picture, as you can see there is no convenient “red dot,” so we took the decision to allocate the right hand terminal on each speaker driver to be the “positive” i.e. when both speakers are viewed as shown. The actual polarity is not critical, the allocation could have been the opposite way round... it will work just fine either way.

## Appendix 11: Recommended Power Supplies for HM7000 Decoders

### Introduction... the recommended power supplies...

The decoders can be powered by either a standard DCC NMRA track signal from your DCC control system or from DC power supply. Using A DCC standard power source is straight forward and should not present any issues. However, when running under BLE control only i.e. when using a DC power supply certain factors must be taken in to account. For simplicity we therefore only recommend that the following power supplies when running in DC mode (BLE control) ...

- **Hornby P9000W** (Supplied with R8250 and R7229 train set controllers.)
- **Hornby P9100W** (Supplied with the SELECT DCC controller.)
- **Hornby P9300W** (Supplied with the ELITE controller.)

**These power supplies are normally connected directly to the track/bus.**

### Recommended Power Supplies in detail...

#### P9000W...

As supplied with R7229/R8250 Analogue Controllers... These power supplies utilise a different size plug arrangement from the ELITE/SELECT power supplies above. An adapter cable is available HM7080 (R7403) to suit the P9000W power supply. *(the jack pug and inline jack socket is described as 5.5/2.1mm.)*

#### Rated Output

The quoted running current limit is a maximum of 500mA... this unit will supply 950mA under maximum overload conditions. Above 950mA overload the unit will continue too supply current but at reduced voltage... i.e. the power delivered in Watts remains constant until the output voltage reduces to about 12V, at which point the unit will cut out and go into “pulse mode” at a reduced voltage. This is how the PSU detects when after an overload condition, the load is now “safe” and Ok for the PSU to restore normal operation.

If using the P9000W power supply please note, it is only rated at 0.5 Amps, which makes it very limited in power capability for running HM7000 decoders (especially sound types.)



P9100W...

This is the standard SELECT/HM6000/eLink 1 Amp power supply. This can be used to power the track directly using the R7324 adapter ...

#### *Rated Output*

The quoted running current limit is a maximum of 1A... this unit will supply 1.4A under maximum overload. Above 1.4A overload the unit will continue to supply current but at reduced voltage... i.e. the power delivered in Watts remains constant until the output voltage reduces to about 8V, at which point the unit will cut out and go into "pulse mode" at a reduced voltage. This is how the PSU detects when after an overload condition, the load is now "safe" and Ok for the PSU to restore normal operation.

R7337/P9300W...

This is an ELITE/SELECT power supply (P9300W 4 Amp power supply) bundled with an adapter cable (R7324 .. harness) to facilitate connection of the power supply to the power track.

#### *Rated Output*

The quoted running current limit is a maximum of 4A... this unit will supply approximately 5A under maximum overload. Above 5A overload the unit will continue to supply current but at reduced voltage... i.e. the power delivered in Watts remains constant until the output voltage reduces to about 8V, at which point the unit will cut out and go into "pulse mode" at a reduced voltage. This is how the PSU detects when after an overload condition, the load is now "safe" and Ok for the PSU to restore normal operation.

The output connection of the P9300W can be adapted for direct track connection using Cables/Adapter... R7324 ... (Adapter cable/harness)

Notes...

The AUX power outputs on the SELECT and ELITE controllers are DC. They could be used to power HM7000 decoders. However, these protected outputs are normally used for powering accessories . The protection takes the form of thermal resettable fuses.

SELECT... 900mA

ELITE... 1A

**Please take care not to cross connect an AUX DC output to the TRACK output (or BOOST output) of the controller... damage will definitely occur.**

## WARNING... Other Power Sources... Laptop Type Power Bricks and Batteries etc...

Generally speaking, the HM700 decoders will work with any 14VDC – 16VDC regulated DC power supply, therefore there is a temptation to use a third party power supply solution. However, we do not recommend using third party DC power supplies. Also, clearly a battery system might be attractive... we can't recommend this either due to lack of internal "built in" over current protection.

We have no control over the overcurrent protection systems of these types of power supply/battery system.

Hornby power supplies differ in their protection re over-current from most other types of regulated power supply. In overload conditions, Hornby power supplies will reduce their output voltage as the current increases, thus maintaining a constant power output.. This type of protection system is safer than over current protection systems that supply a current level exceeding the quoted level for the power supply before "cutting out." This is most evident in Laptop type power supplies.

*Laptop PSUs can supply current levels far beyond their rated/quoted output... we can't recommend them.*

*In the lab, we have seen overload current values as high as 150% over the rated current output before the unit cuts out... This means the power output increases as the overload increases. i.e. unlike Hornby PSUs there is no constant power limit. The worst case we have seen is an older type "Laptop" PSU rated at 9A which gives a very powerful 180W of possible power... however, under overload conditions it did not cut out until nearly 15A was measured... that came out about 270W of power.... Plenty enough to heat things up significantly under a short.*

## Additional Overload Protection...

With the smaller power supplies it is reasonable to assume the internal overload protection is sufficient. As the layout grows and you wish to run more locomotives you may want to increase the current rating of your PSU.

The Hornby "high power" PSU solution is the P9300/R7337. This unit has constant power over load capability and should represent a limited risk to a severe overload condition. Especially if the unit is connected to a power bus arrangement.

If you require more current capability for your layout in order to run many locomotives you may have to consider sectionalising your layout into "Power Districts." This is subject well covered elsewhere and will not be discussed here.

It is always worth considering adding external protection to your layout in the form of PSU fusing and other methods. Fuses are the simplest to consider... just choose a fuse rating at 75% of the rated output of your PSU. 75%??? This is because fuses actually blow at a higher value than their rating.

Alternative methods of protection include incandescent lamp protection, which consist of light bulbs (NOT LEDs) in series with the connection to the track. This is traditional protection plan. Again this subject is covered on the internet. Some companies offer a suitable over current protection system.

If you intend to use a single “high power” PSU ..... **NOT RECOMMENDED!!!!**

Please ensure that connection to the track/bus is fused and current limited. etc. **BEWARE!!! SHORT CIRCUIT SCENARIOS ON AN UNPROTECTED POWER FEED CAN CAUSE FIRE!!** Also, at a voltage output of 19VDC the maximum speed of the locos may be too great. Also, depending on how they are run, there could be stresses on the motors that could lead to issues in the longer term.

Where practical, batteries may be an option, i.e., these provide a completely smooth power source which is ideal on paper. If using batteries please ensure adequate fuse/overload protection is used in case of track shorts etc... **WE DO NOT WANT A FIRE!!!**

Analogue “Train Controllers” set to maximum output???

Not recommended!!!!

In theory, to power the layout for HM7000 BLE operation only (where there is no DCC controller,) any 15VDC power source can be used. For those coming from “plain old analogue DC” to the world of Bluetooth control... i.e. skipping DCC operation altogether... it is tempting to power your layout from your DC train controller. Unfortunately, this approach does not always work....

Therefore, we do not recommend this practice for two reasons....

- Analogue Controllers can produce voltages of 200V plus when shorted... this will damage decoders. E.g. HM2000 and similar types..
- The nature of the control DC waveform of some of these types of controllers is not compatible with the digital electronics that make up the decoder. Decoders sometimes just do not work. E.g. HM2000 and similar types.

Often the variable DC output supplied by a “train controller” may consist of a PWM (Pulse Width Modulation) waveform. These waveforms can be quite low frequency and may create issues when used to power HM7000 decoders.

This may apply to many of the lower end train controllers which employ PWM frequency ranges of 50Hz upwards with 100Hz most common. Please check you analogue “train controllers” specification for more information re the unit’s output.

If using a DC “train controller,” the output will have to be set to approximately 14VDC permanently, thus making other analogue only locos non-controllable. Generally, this will be “full throttle.”

..

AUX DC and AC outputs on these types of Analogue controller are not suitable... basically they are very crude DC power sources being full wave rectified AC only if lucky. AC only type outputs have there own drawback... and are definitely not recommended. The Hornby HM2000 is typical of this type of controller.

### Special Note: Using HM6000 Circuit Outputs for BLE.

Testing has shown that when using HM6000 set to maximum output, HM7000 sound decoders can give unpredictable behaviour in the form of decoders becoming unresponsive or sounding distorted.

Non-sound decoders tend to work more reliably. However, if you wish to use the track (circuit) outputs to power your BLE decoder i.e. you wish to swap between running BLE decoders only and standard analogue locomotives by using the HM6000 in both cases, you will need to change PWM frequency of the HM6000 track output when running BLE HM7000 decoders.

This is done on a Circuit 1 and Circuit 2 set up in the HM6000 APP. See Edit device screen.

We recommend that you use the power supply that came supplied with the HM6000 unit directly connected to the track and remove the HM6000.

### DC-Controllers not recommended.

#### HM2000

The Hornby HM2000 analogue controller controlled output does not work well... sound distortion 100Hz modulations? Also there is a risk of unexpected decoder control behaviour and/or decoder damage on track shorts etc.

We do not recommend the AUX outputs of the HM2000...

#### R7229/R8250

These controllers use a low frequency PWM system that can cause issues with decoder control etc.

..

There are many analogue controllers on the market and in use, clearly, we have not tested all of them. They may work OK... we suggest checking the forums for user information and user comments re any particular controller... keep watching the forums for any discussion.

## Appendix 12: Need Help?

**Note: The decoder version number is held in CV47, CV48 and CV49 of the decoder.**

For faulty goods/returns etc... Please contact your dealer for advice.

User technical support etc...

Customer Helpline... Tel. +44 (0)1843 233525

All contact information and Forum access can be found here...

<https://uk.hornby.com/support-and-advice>

The Hornby Community with access to Forums etc can be found here:

<https://uk.hornby.com/community>

For Function Lists for each locomotive Profile, Reference Manuals and other support information please go here:



<https://support.hornby.com/hc/en-gb/sections/6430190965522-Additional-Manuals>

## Appendix 13: This Manual - Revisions and Changes

The table below lists the published revisions of this manual. This includes a general summary of any changes or additions.

**Note: The decoder version number is held in CV47, CV48 and CV49 of the decoder.**

Revision	Date	General Description Changes	Notes
<b>R1.0.0</b>	140323	Initial Release	Some areas of the manual omitted at the moment until features become available.
<b>R1.2.0</b>	N/A	Intermediate	Internal Reference update... Not publicly released.
<b>R1.3.0</b>	151123	Corrections, Additions and further Updates and cross indexing..	<p><b>All Updates</b></p> <p>Contents list</p> <p>UPDATED: page 24 ... Mounting 21MTC Decoders... There are two modes of mounting: “Compact” and “Rotated”</p> <p>UPDATED: page 49 ... CV19 Consist setup</p> <p>UPDATED: CV7 description re CV47, CV48 and CV49</p> <p>UPDATED: pages 50, 51, 52 ....Text changes to bit4 and general layout</p> <p>CORRECTED: page 54 ... Bit4 set to <b>0 (default)</b> directs the decoder to use the basic speed curve set by Vstart, Vmid and Vhigh. Bit4 set to “1” directs to use the complex speed step curve defined in CVs 65 through to CV94.</p> <p>ADDED: page 59.... CV119... Multi Decoder masks.</p> <p>UPDATED: page 60.... CV67 to CV94: New text link</p> <p>UPDATED: pages 61.... CV119 Layout update</p> <p>UPDATED: page 64.... “Creep Mode” Functionality Changed... CV122 = 0 ... Continuous Operation</p> <p>UPDATED: pages 67, 68, 69.... All Default CV values changed to 35 and other text updates.</p> <p>UPDATED: page 82, 83, 84, 85, 86, 87, 88. 89</p> <p>UPDATED: pages 112, 113, 114, 115, 116, 117... these pages contain new text and graphs.</p> <p>UPDATED: Appendix 2: Rewrite with corrections</p> <p>UPDATED: Appendix 3: Using AUX Outputs...</p> <p>UPDATED: Appendix 4: Setting up Asymmetrical DCC Control... (ADCC) ... New Content.</p> <p>UPDATED: Appendix 7: Power Bank... Hornby “Stay Alive” Connection and Implementation</p> <p>UPDATED: Appendix 8: Complete CV list for all decoders</p> <p>ADDED: Appendix 10: Speakers.... Sugar Cubes and the rest...</p> <p>ADDED: Appendix 11: Recommended Power Supplies for HM7000 Decoders</p> <p>UPDATED: Appendix 13: This Manual - Revisions and Changes</p>