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

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 facia 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

Sound Decoders……. First Time Use of a decoder… do this!

Out of the box…

After you have installed the decoder in your target locomotive, you can place the locomotive on a normal DCC layout. 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.

The decoder/locomotive will be controllable via DCC in the usual way. The decoder may be read back if required using 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, DC 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.   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 Bluetooth (BLE)

Bluetooth (BLE) connectivity, Standard NMRA DCC operation and control…. Or if required, DC mode for test of locomotives etc. We do not recommend DC operation for general locomotive running.

BLE mode control is achieved by the use of a dedicated Hornby APP for Android and IOS.

Decoders can have control handed back and forth between DCC and BLE 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.

HM7000 BLE Decoder… modes of Operation: DCC, Bluetooth or even DC analogue!?

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.

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. 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)*

DC Power: BLE Only operation Only... notes re Fixed Output DC Power Supplies.

In APP based BLE mode of operation i.e., no use of DCC controllers the track can be powered from a 15VDC power supply. The polarity of the connection is not critical. But the same polarity must be observed on the entire layout/bus to distribute power to the layout. (Recommended.)

Suitable Hornby Power Supplies.

R7337… This 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.

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 cable/harness

P9000 … As suppled 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 (R7403) to suit the P9000W power supply. *If Hornby are delayed in offering the R7403 adapter for the P9000W power supply… you can alternatively search eBay for CCTV power adapters/extenders. CCTV power distribution uses the same plug/socket as the P9000. i.e., the jack pug and inline jack socket is described as 5.5/2.1mm.*

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.)

Note: The AUX DC output on the rear of the SELECT and ELITE controllers is a "through connection" i.e., it just repeats the power going into the controller, so forms a direct connection to the controller's power unit (P9100W or P9300W.) Therefore, the AUX DC connections could be used to power the track. But even though this is possible the decoders will work perfectly OK with the DCC track signal provided by these controllers.

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WARNING… Other Power Sources… Laptop Type Power Bricks and Batteries etc…

Generally speaking, the HM700 decoders will work with any 14VDC – 16VDC regulated power supply. The decoders are however rated up to 27V, so higher voltages could be used…. Do not exceed 20V.

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!!!**

"Laptop" type power supplies usually have an output of approximately 19VDC and can supply current levels far beyond their rated/quoted output. The current overload protection maybe set to a relatively high value. 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.

DC Power: BLE Only operation Only... notes re Analogue "Train Controllers" set to maximum output:

In theory, to power the layout for HM7000 BLE operation only (where there is no DCC controller,) any 15VDC power source can be used. The power source could be derived by setting the controlled output of your "train controller" to maximum permanently. i.e., maximum voltage on the track (hopefully about 15VDC.)

Often the variable DC output supplied by a "train controller" may consist of a PWM (Pulse Width Modulation) waveform. Thes 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."

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.

Please 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 does not work well… sound distortion 100Hz modulations?

R7229/R8250

These controllers use a low frequency PWM system that can cause issues with decoder control etc.

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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.

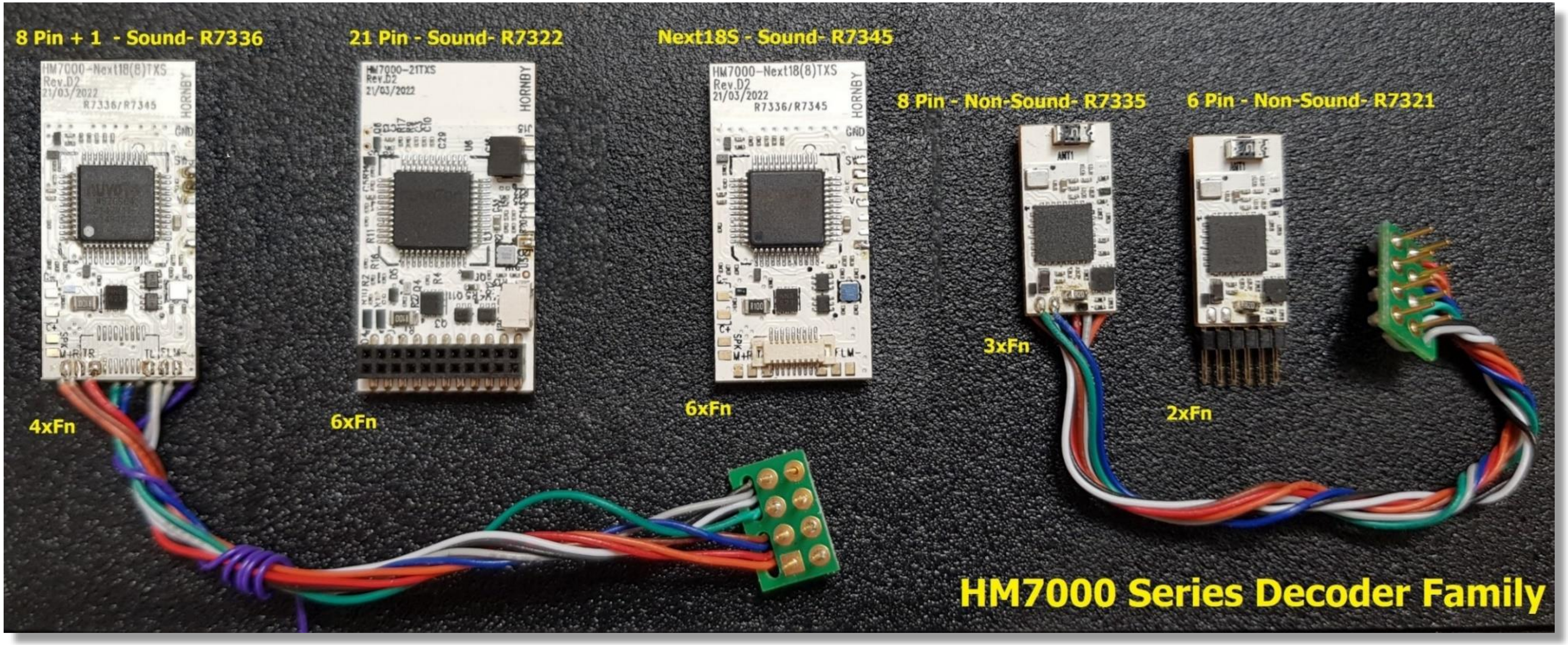
HM7000 Decoders… the basic features… an outline.

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

- *Full Bluetooth wireless control via APP based control interface.*
- *Full CV programming and Read-back via APP interface.*
- *Full Support of DCC operations.*
- *Full support of DCC operations i.e., 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 wheel slip sounds are played the locomotive will not move… fully configurable.*
- *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 on non-sound types.)*
- *The decoder supports HF0 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 … Coupling assistance …. Accessed by F26 on Sound locos. (F6 on 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 Blue Tooth 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.)*
- *Hornby Steam System support (Locomotives with ASU – Atomising Steam Unit.)*
- *Support Hornby "Stay Alive System" with "Smart Charging." Power Bank. R7377.*
- ***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… (please note all current pictures are pre-production… they will be updated later.)



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

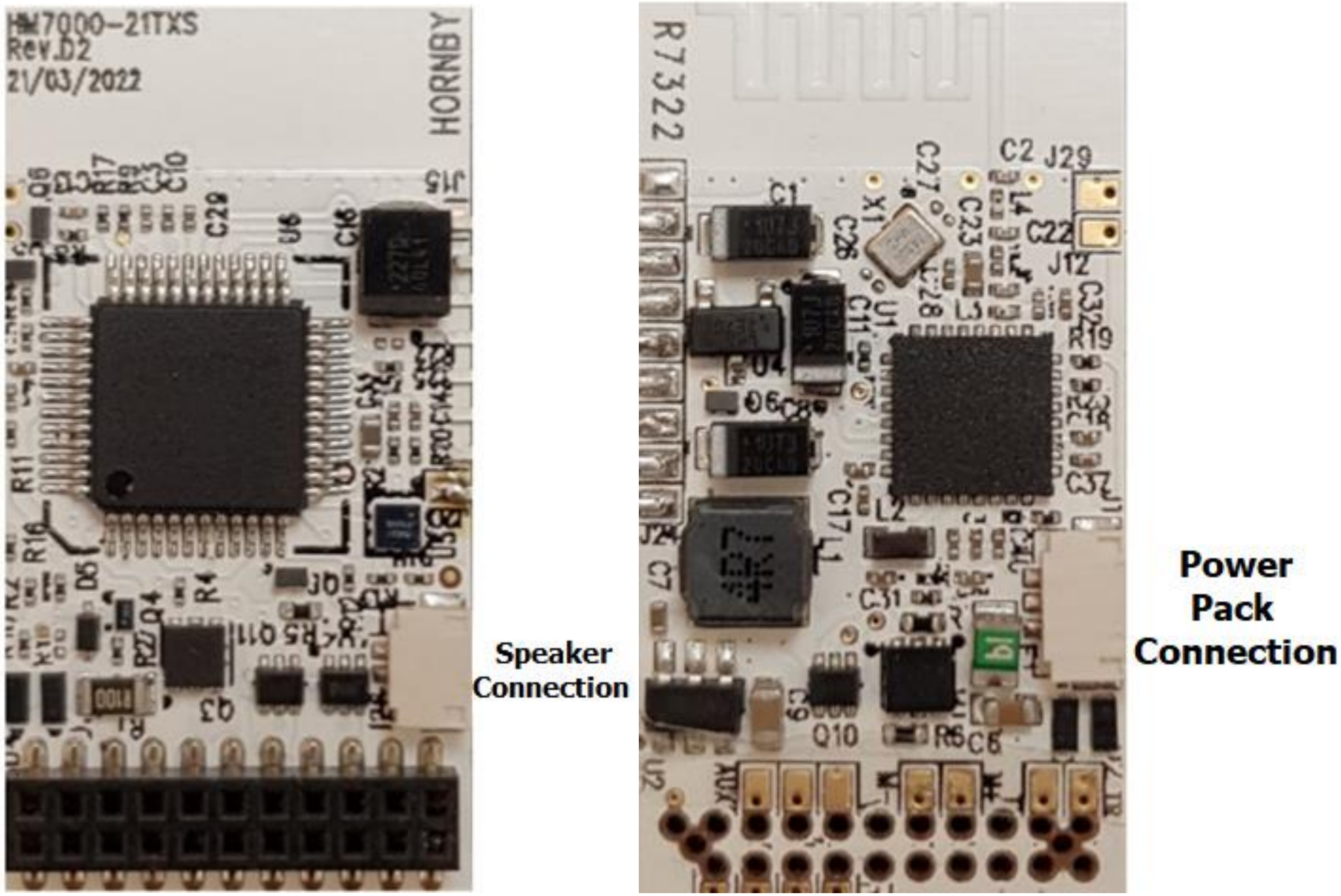
HM7000 series sound decoders all have provision for connecting a loudspeaker on the decoder pcb in the form of solder pads and a two-pin socket. Loudspeaker connections are also presented through the decoder main connector on the locomotive main PCB via solder pads and a socket where applicable. i.e., 21pin and Next 18S decoders.

HM7000 series decoders all have provision for connecting an R7377 Power Bank to give "stay alive" functionality via a 3-pin socket on the decoder pcb.

When talking about decoder hardware please refer to the table re reference conventions… see Function and hardware naming…Conventions…

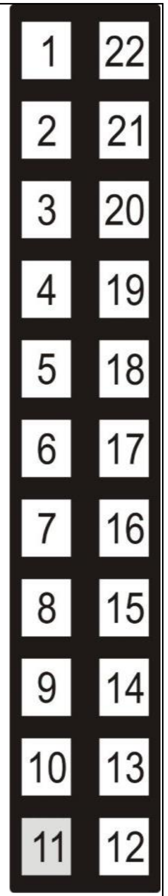
Sound Decoder Types and Connection

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



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

Pin #	Name	Function	Colour
1	AUX7	Logic output/input HFO9d… *Controlled by BLE MCU*	
2	AUX8	Logic output/input HFO10d… *Controlled by BLE MCU*	
3	AUX 6	Logic output/input HFO8d… *Controlled by BLE MCU*	
4	AUX 4	Logic output/input HFO6d… *Controlled by BLE MCU*	
5	N/C	No Connection	
6	ZBDATA/AUX10	SWS Prog/Debug of BLE MCU … alternate AUX10d… *Controlled by BLE MCU*	
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… *Controlled by BLE MCU*	
14	AUX 2	HFO4…	Violet
15	AUX 1	HFO3…	Green
16	V+	Decoder Positive **(HFO Common)**	Blue
17	AUX 5	Logic output/input HFO7d… Digital Output *Controlled by BLE MCU*	
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.

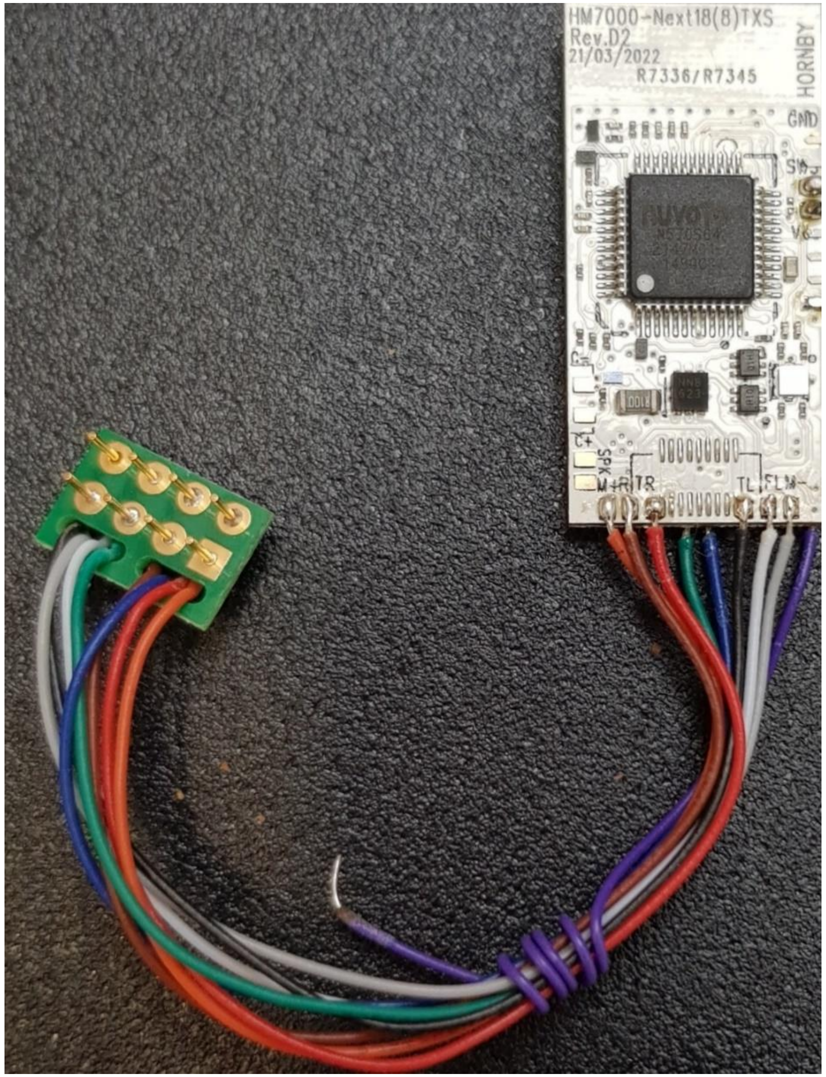
Note: In the design of the decoder there are two MCUs i.e., the NMRA part and the Bluetooth (BLE) part. HFOs are split over the two MCUs. HFOs served by the BLE MCU are digital only types. (In Blue)

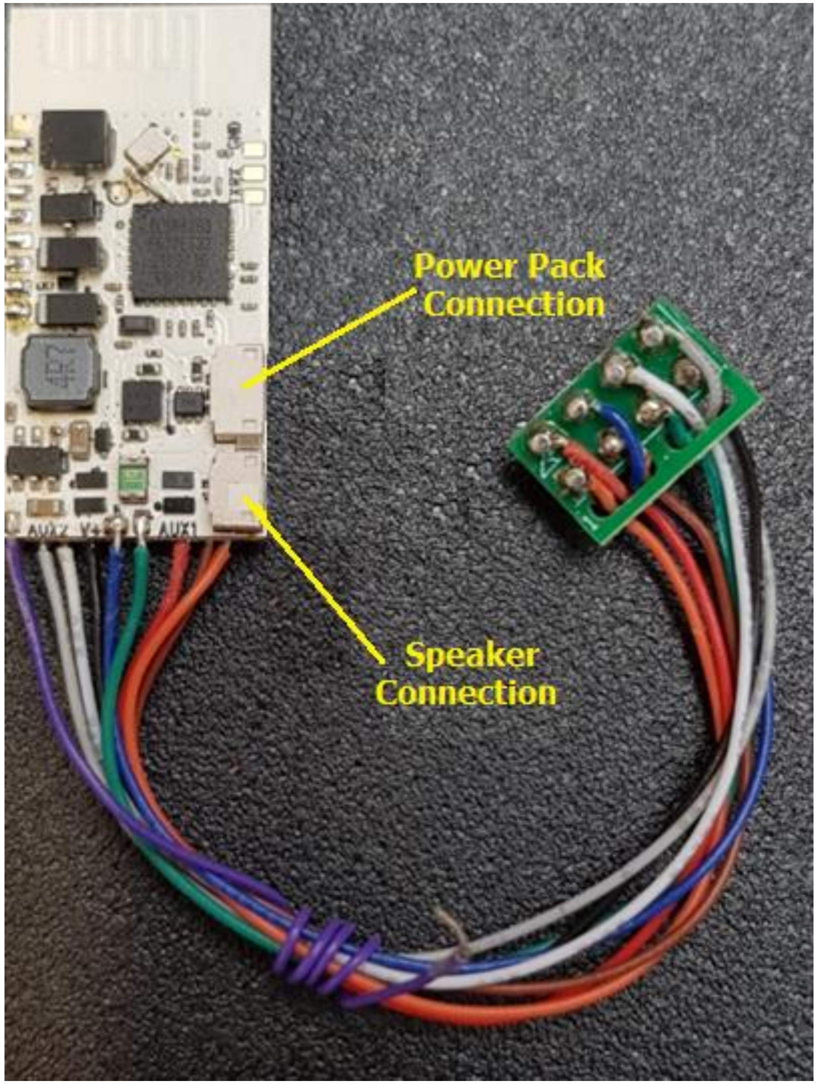
Note: This type of connector comprises of a socket on the decoder pcb that plugs into the corresponding plug pins mounted on a pcb fitted in the locomotive.

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.

8 Pin BLE Decoder ... HM7000-8TXS ... R7336......





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 **(HFO Common)**	Blue
8	Power	Right Rail pickup	Red
Flying wire	AUX2	HFO4…	Purple

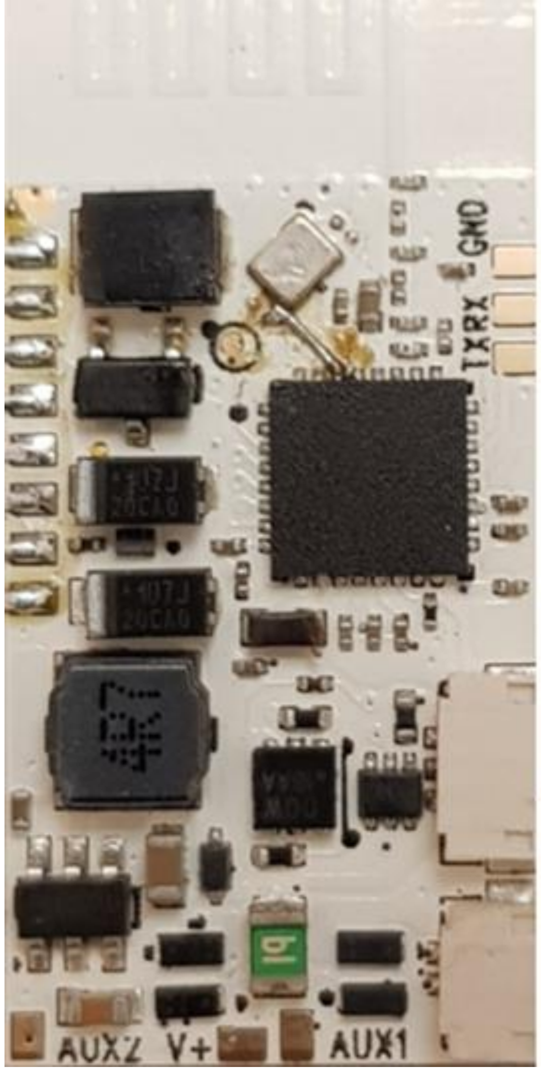
View looking down at the locomotive decoder socket
Pin 1 may be designated by a star, a square or spot
printed on the locomotive pcb.

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.

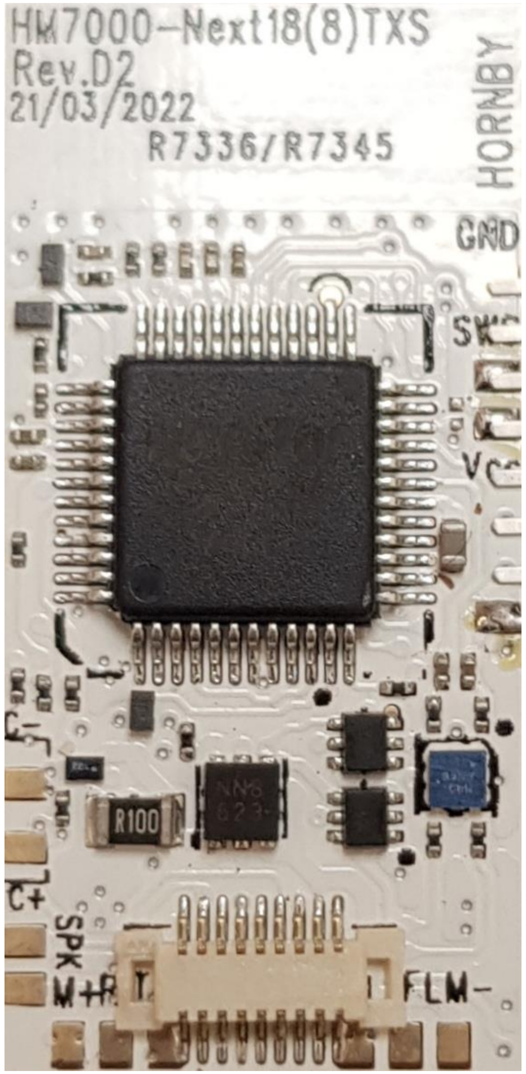
Note: On Sound Decoders… Speaker connection is made by a 2-pin socket mounted on the pcb.

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… *Controlled by BLE MCU*
5	Ground -	Decoder Ground, tapped at internal rectifier. Common with pin14
6	V+	Decoder Positive **(HFO Common) Electrically** 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… *Controlled by BLE MCU*
14	Ground -	Decoder Ground, tapped at internal rectifier. Common with pin5
15	V+	Decoder Positive **(HFO Common) Electrically c**ommon 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.

..

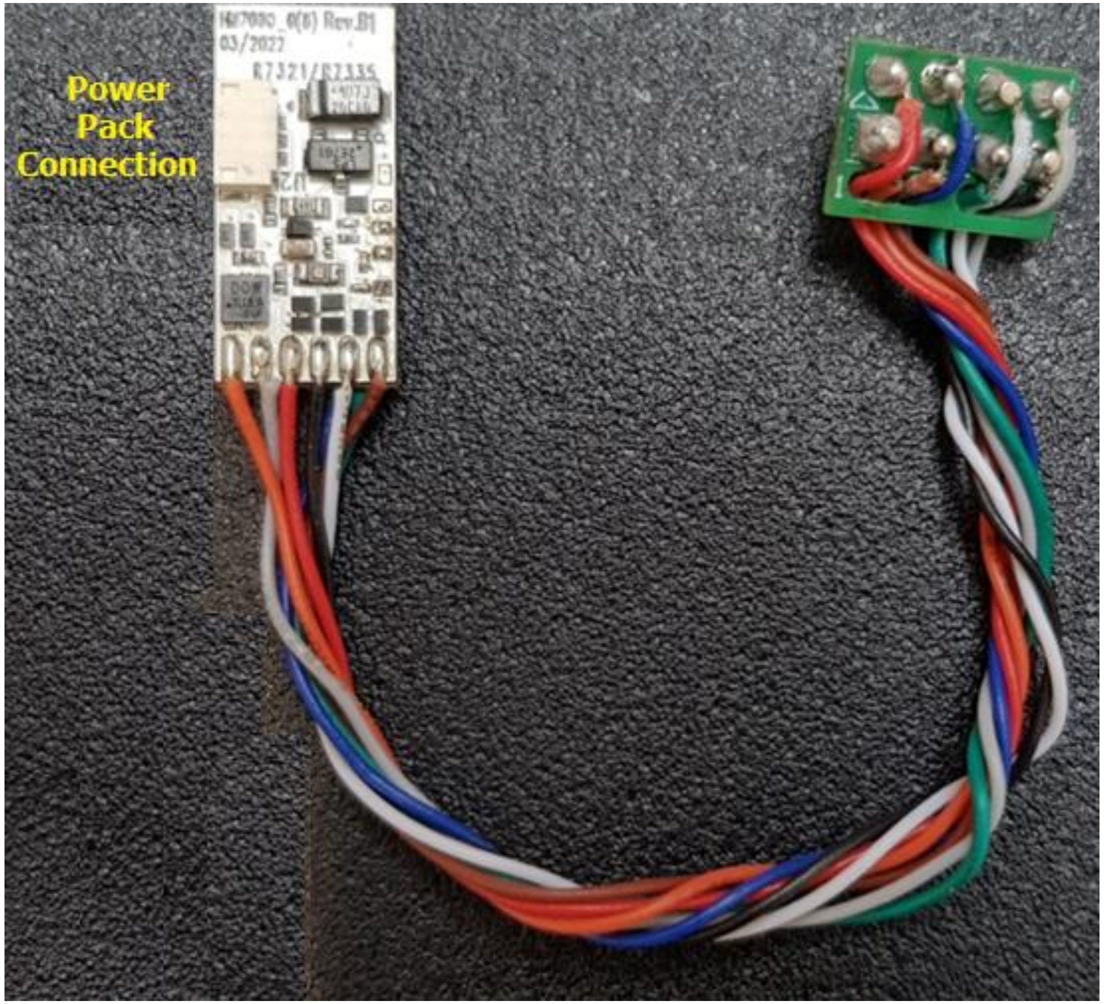
Non-Sound Decoders do not at this time support ABC i.e., ADCC operation (See ABC- ADCC later in this manual.)

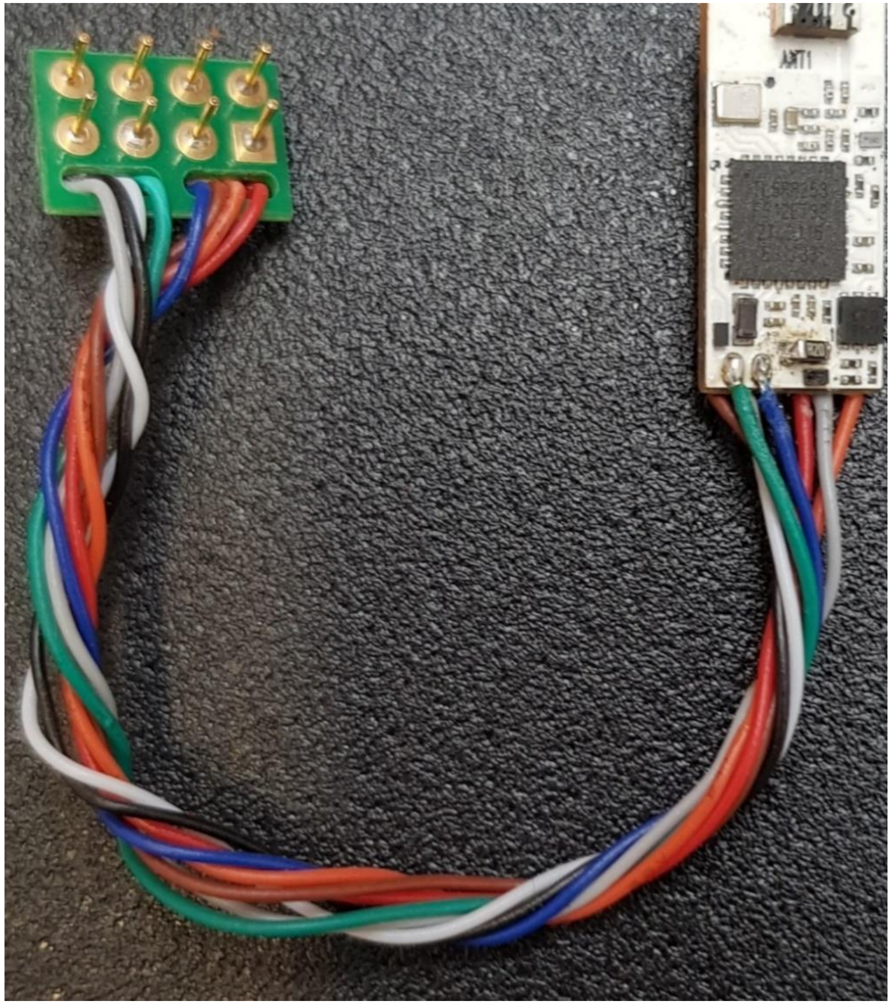
..

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.





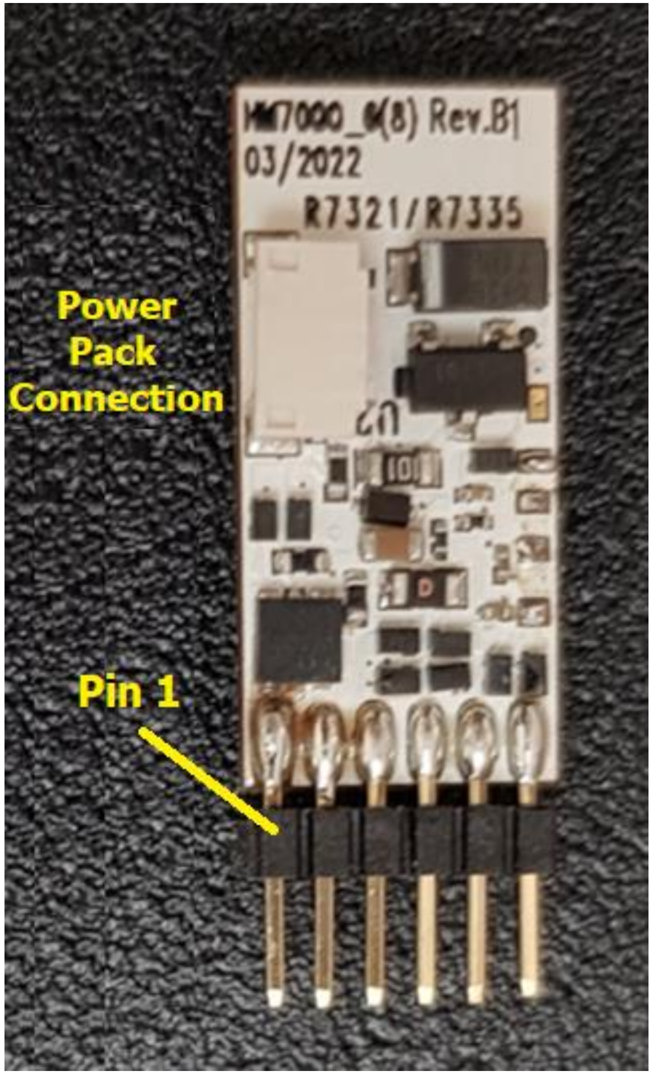
Dimensions	**8mm x 21.5mm x4 mm**
Termination	**NEM 652 8 pin**

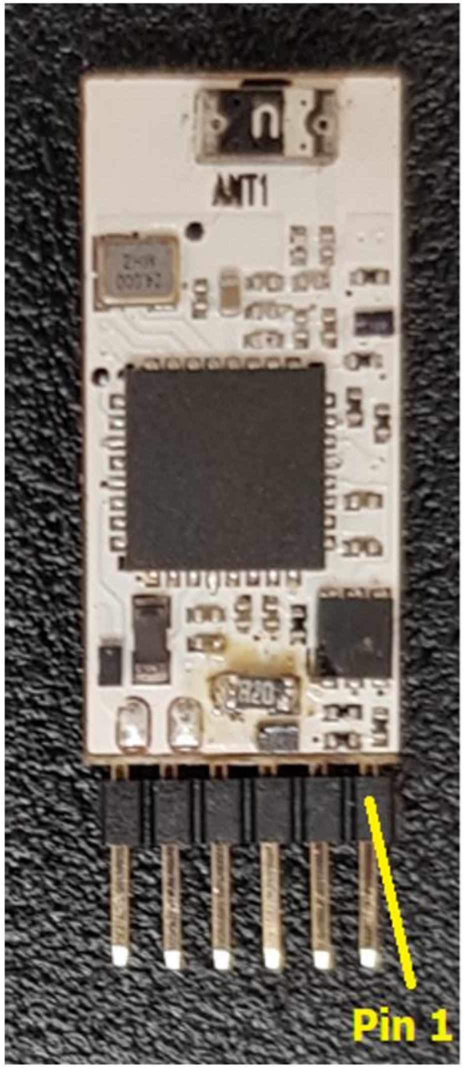
Pin #	Name	Function	Colour
1	MTR +	Motor Right/Positive	Orange
2	F0r	HFO2…	Yellow
3	AUX1	HFO3…	Green
4	Power	Left Rail pickup	Black
5	MTR -	Motor Left/negative	Grey
6	F0f	HFO1…	White
7	V+	Decoder Positive **(HFO Common)**	Blue
8	Power	Right Rail pickup	Red

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.



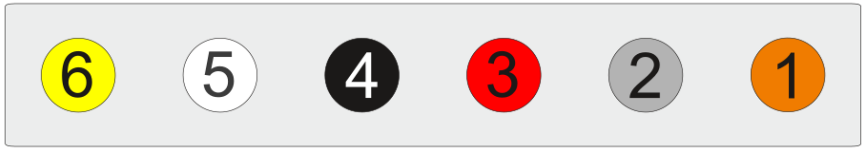


Dimensions	**8mm x 22.5mm*** x 4mm *** including pin length, pcb length is 17mm**
Termination	**NEM651n 6 pin**

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.

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



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.

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.

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

Functions F1 to F20 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.

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

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 then 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 then start. Applies to the diesel engine mode only.

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.

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.

F6… Activate “Creep Mode” … Coupling assistance.

F7… Apply Brake action (overrides current deceleration level.)

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 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	

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 its “node” is re-established and automatically reconnects to the APP

If the locomotive loses power, falls off the track, etc, the locomotive/decoder will automatically “re-establish” connection returned to the track.

Adding other HM7000 devices to your layout is easy and does not have to be expensive. The “nodes” of the Mesh can be made up of locomotives, PACs and other trackside accessories…. The more “nodes” the better... i.e. this will improve the security of the BLE system.

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 - 128

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.

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	For readback test only

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.

CV19… Consist setup

This CV contains a secondary address which can be shared by other decoders to support “Consisting” or “Double heading” etc. i.e., it becomes a common secondary address.

Default Value	Range	Comments
0	1-255	Default = 0 (Not part of a consist)

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. If the seven-bit address in bits 0-6 is "0000000" the unit is not in a consist.

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. 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… Opposite Direction = + 128

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.

There are several CVs associated with the configuration of ADCC operations... i.e., CV27 and CV125-CV127.

Please refer to Appendix 4: Setting up Asymmetrical DCC Control… (ADCC) for a full description of ADCC operations and configuration.

CV27 is used to select which rail the ADCC condition is present.

Default Value	Range	Comments
0	0 - 3	0 = No ADCC 1 = Left Rail ADCC Present 2 = Right Rail ADCC Present 3 = Both Rails

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 Bit4 are enabled i.e.   2 + 16 = 18 ... 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 127 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 65-94.

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

Detail…

Bit4 set to 0 directs the decoder to use the basic speed curve set by Vstart, Vmid and Vhigh. Bit4 set to "1" (default) directs to use the complex speed step curve defined in CVs 65 through to CV94.

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 1 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. Control Processor Firmware Version (CV47-49)

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.

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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

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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.

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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… Speed Table Configuration

This range of CVs allow the user to configure the "throttle" response of the locomotive/decoder. The table of values describe a "Speed Curve."

For a more complete description of "Speed Tables" … See… for Appendix 6: All about Motor Control and Tuning... Speed Curves. PIDs and Things... … CV143 to CV155 explanation regarding "Speed Tables".

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

Range is 1-255 for all CVs listed above.

If this user defines speed table is to be implemented CV29 bit4 must be enabled in order to select the table.

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
Shunting Mode	F25	F5	Engage Shunting Mode
Coupling Assist (creep) mode	F26	F6	Engage Creep
Brake while decelerating	F27	F7	Apply Brakes
Random Automatic Spot Sound Play (AFC)	F28		Enable/Disable AFC operation
Push Button Control of motor		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… This is a momentary function on the controller.

A set period maybe useful for coupling etc.

CV#	CV Name	Default Value	Range	Comments
121	Creep speed	1	1-127	
122	Creep pre-set duration	2	1 - 10	Values of 1 – 10 Seconds - sets creep time out.

“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.

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 CV4

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,

In use 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.)

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								
				Bit#	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
				ADD:	**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

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

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								
				Bit#	*7*	*6*	*5*	*4*	*3*	*2*	*1*	*0*
				ADD:	**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.

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…

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

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

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 declaration 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.

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.

This CV can be used to set all volumes to a common level. We recommend that individual volume levels can then be set via their own individual volume level CVs.

WARNING: The decoder is fitted with a 1.68W amplifier. This amplifier is quite capable of destroying standard sugar cube speakers (1W rating typical) if set to higher volumes. We have chosen to use a higher power amplifier to allow users to fit their own “high power” speaker arrangements to the locomotive and have enough volume to drive these types. We recommend that you do not exceed a volume setting of greater than 125 when using the Hornby Sugar Cube speaker. The practice of fitting/supplying lower power speakers when compared to the onboard amplifiers output power is common practice in the DCC in the world model of sounds.

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
50	0-255	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
50	0-255	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.

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
50	0-255	Volume F0 only… Special Case for sound only decoders

CV160... ELECTRIC motors volume

ELECTRIC locomotives only

Default Value	Range	Comments
50	0-255	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
50	0-255	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 be 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…

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CV#	CV Name	Default Value	Range	Comments
162-180	Volume of F2 - F20	50	0-255	Volume control from F2 to F20

Each Spot sound by F#… "Volume configuration" CV table…

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.

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		

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.				
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	

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 "Sound 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	255	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	255	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… 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… i.e., CV205 refers to F2 and CV207 refers to F3.

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.

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.

CV205/207 Horn/Whistle Selection re F2 and F3		
Horn/Whistle Reference	**Bit#**	**ADD**
F2a F3a	0	1
F2b F3b	1	2
F2c F3c	2	4
F2d F3d	3	8
F2e F3e	4	16
F2f F3f	5	32
F2g F3g	6	64
F2h F3h	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 3rd notch to the 4th notch and back again.

3 Notch Diesel… Configuration… CV210 to CV215

CV#	Description	Default	Range	Explanation
	Idle			Applies to SS of < **DTT1**
CV210	Trigger Threshold 1 (**DTT 1**)	5	5-15	Applies when SS > **DTT1** but < **DTT2**… Plays Notch 1
CV211	Trigger Threshold 1 Window (**DTTW 1**)	5	5-9	**DTTW1**… Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
CV212	Trigger Threshold 2 (**DTT 2**)	30	25-45	Applies when SS > **DTT2** but < **DTT3**… Plays Notch 2
CV213	Trigger Threshold 2 Window (**DTTW 2**)	5	5-14	**DTTW2**… Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
CV214	Trigger Threshold 3 (**DTT 3**)	60	60-80	Applies when SS > **DTT3…** Plays Notch 3
CV215	Trigger Threshold 3 Window (**DTTW 3**)	5	5-15	**DTTW3**… 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 4th "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 4th 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.

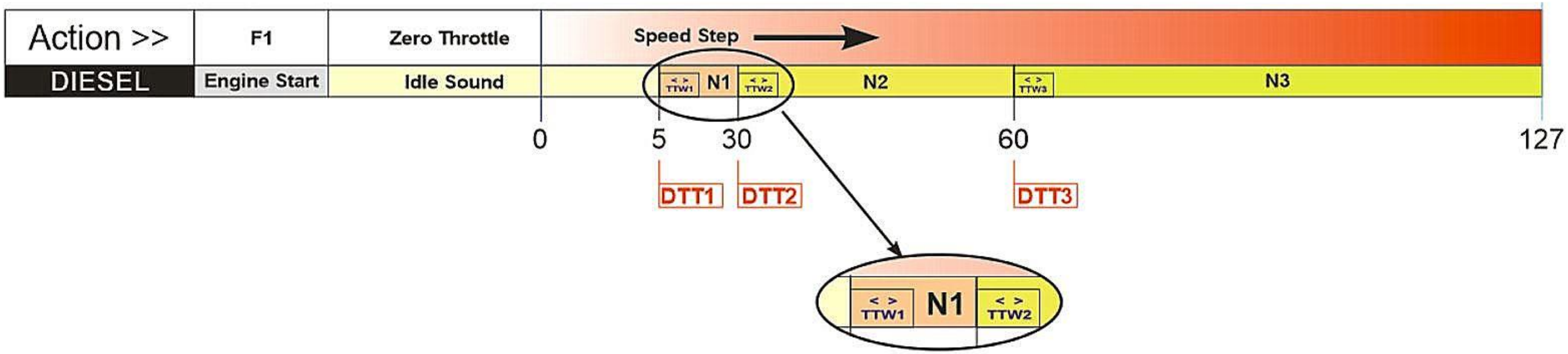
When the speed step transmitted from the controller falls into the range between the DTT and DTT + DTTW the engine sound will NOTCH up and then immediately NOTCH down. Please note that once the speed step transmitted is in this range no further automatic NOTCH Up/Down action will occur until, after the 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 < **DTT1**
CV210	Trigger Threshold 1 (**DTT 1**)	5	5 - 15	Applies when SS > **DTT1** but < **DTT2**… Plays Notch 1
CV211	Trigger Threshold 1 Window (**DTTW 1**)	5	5 - 9	**DTTW1**… Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
CV212	Trigger Threshold 2 (**DTT 2**)	20	20 - 30	Applies when SS > **DTT2** but < **DTT3**… Plays Notch 2
CV213	Trigger Threshold 2 Window (**DTTW 2**)	5	5 - 14	**DTTW2**… Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
CV214	Trigger Threshold 3 (**DTT 3**)	45	40 – 50	Applies when SS > **DTT3** but < **DTT4**… Plays Notch 3
CV215	Trigger Threshold 3 Window (**DTTW 3**)	5	5 – 14	**DTTW3**… Forces Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3
CV216	Trigger Threshold 4 (**DTT 4**)	65	65 - 70	Applies when SS > **DTT4**… Plays Notch 4
CV217	Trigger Threshold 4 Window (**DTTW 4**)	5	5 - 14	**DTTW4**… 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

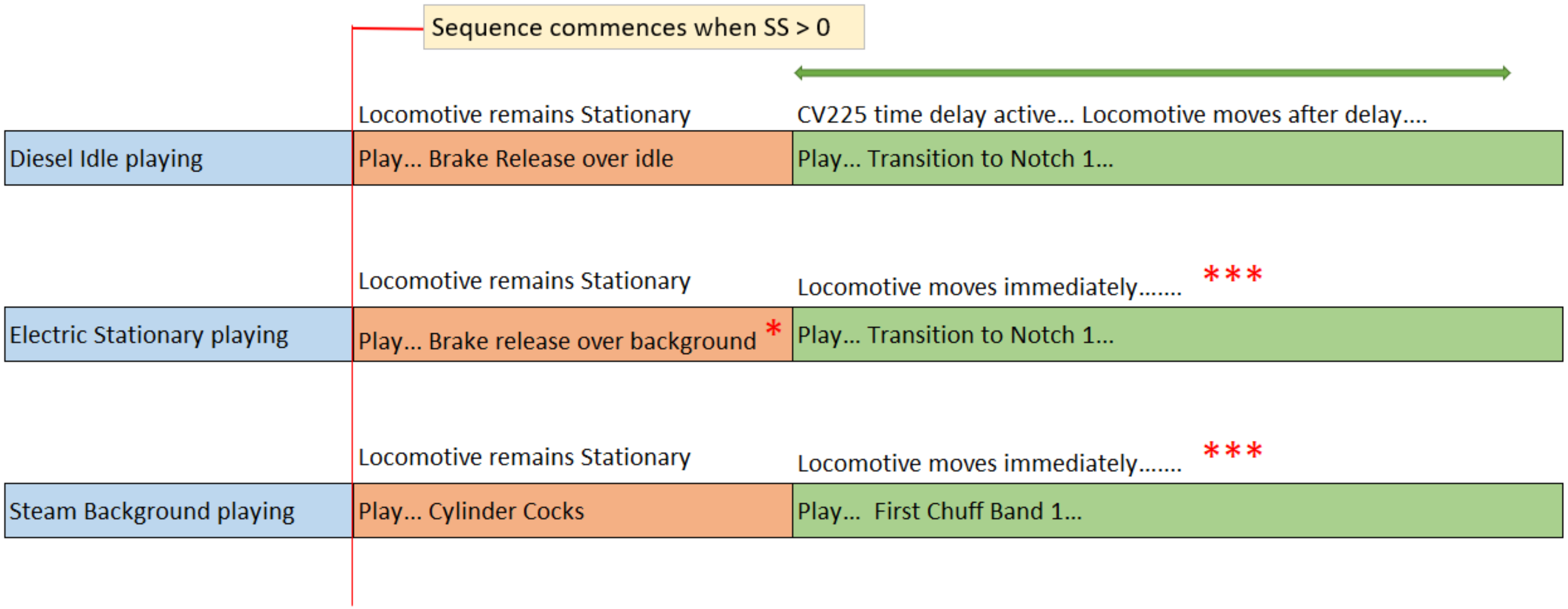
CV225	Default	Range
Start delay before Brake Release	25	0-255

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 simlar 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.

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 Speed)

NOTCH 3 (Revs Increase Speed)

NOTCH 4 (Revs Increase Speed)

NOTCH 5 (Max rev Speed)

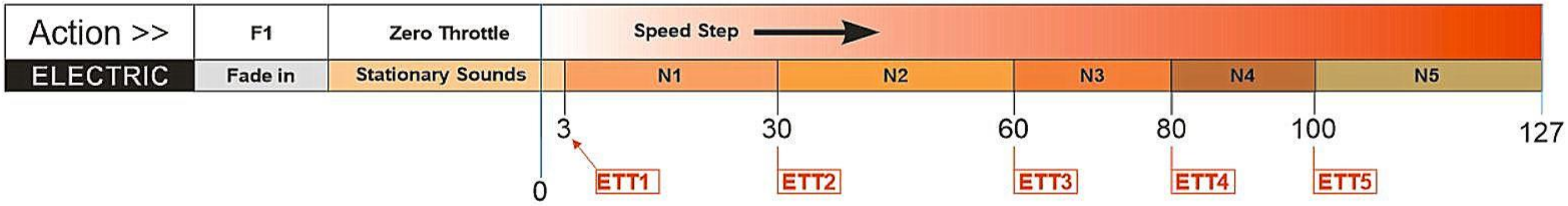
The way that the locomotive engine sound responds is controlled by the throttle on your controller i.e., as you increase the actual speed of your locomotive on the track, so the sound responds accordingly.

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

CV#	Description	Default	Range	Explanation
	Automatic Idle			Applies to SS of > **ETT1**
CV218	ELECTRIC Trigger Threshold 1 **(ETT 1)**	3	1-127	Applies when SS > **EET1** but < **EET2**
CV219	ELECTRIC Trigger Threshold 2 **(ETT 2)**	30	1-127	Applies when SS > **EET2** but < **EET3**
CV220	ELECTRIC Trigger Threshold 3 **(ETT 3)**	60	1-127	Applies when SS > **EET3** but < **EET4**
CV221	ELECTRIC Trigger Threshold 4 **(ETT 4)**	80	1-127	Applies when SS > **EET4** but < **EET5**
CV222	ELECTRIC Trigger Threshold 5 **(ETT 5)**	100	1-127	Applies when SS > **EET5**

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.

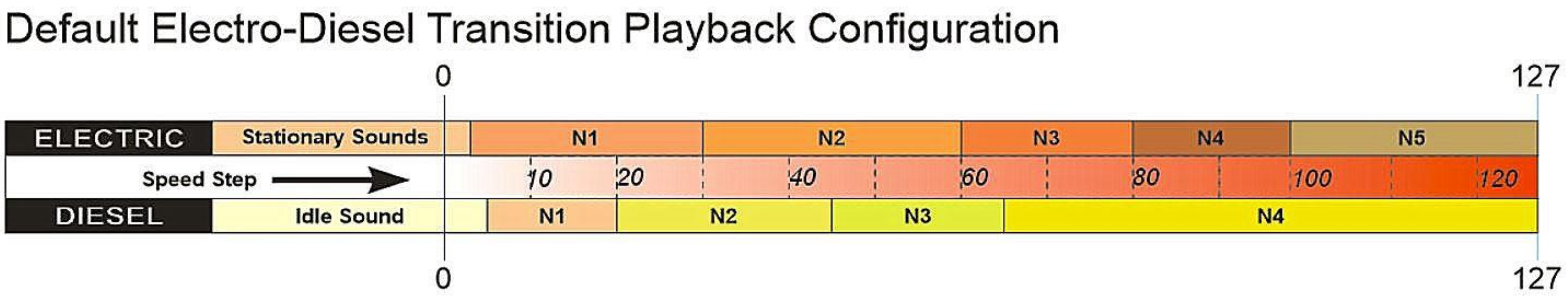
Note that on this type of locomotive the diesel has 4 Notches, and the ELECTRIC has 5 Notches. This is explained further below.

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 4th 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.



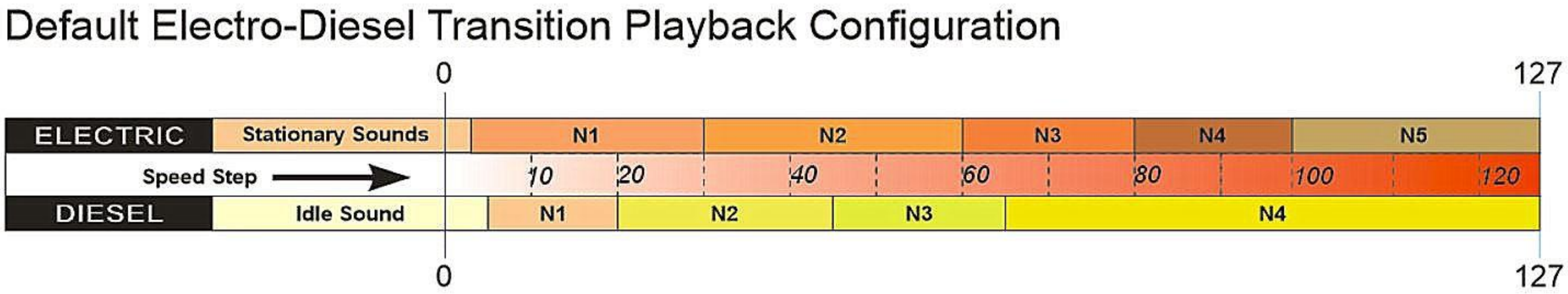
On the operation of F5 the transition between ELECTRIC/DIESEL/ELECTRIC will be made. The transition is made by playing two different sounds concurrently that contain the appropriate sounds for the transition i.e., the diesel engine running down and turning off and electric motor starting and running 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.



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…

e.g., If the DIESEL is running with “Notch 4” playing and a transition made to ELECTRIC, either “Notch 4” or “Notch 5” of the ELECTRIC will be selected... this is because the speed step is in control and Notch 4 of the DIESEL spans across “Notch 4” and “Notch 5” of the ELECTRIC.

e.g., If the ELECTRIC is running with “Notch 2” playing and a transition made to DIESEL, either “Notch 1” or “Notch 2” of the DIESEL may be selected... this is because the speed step is in control and Notch 2 of the ELECTRIC spans across “Notch 1” and “Notch 2” of the DIESEL.

Please study the diagram above for help with these explanations.

STEAM LOCOMOTIVES… Engine Running Sound

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 F17 to force constant rate "deceleration" sounds... as above these will change depending on the RSS value.

Automatic Wheel slip behaviour simulation … CV213 and CV216

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

Wheel slip can be initiated automatically 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 to 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.

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 a 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 + 16 + 0 + 4 + 0 + 1 …. which is equivalent to 53 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.

Online there are other resources… 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 or Appendix 1 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...

Definitions...

Short Address… this a locomotive address in the range 1 - 127

Long Address… this is a locomotive address above 128. 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.

..

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….

Hexadecimal?!?!?!

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

The thinking process is very similar to the explanation of Binary in Appendix 1.

Long Address Example…

Using a Long Address 9999 as an example…

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...

MSB rule….

CV17 contains the **msb + C0 ***.**.. i.e., **100111**+**1100000** = 11100111…

******* It is standard practice when *calculating the value for CV17 to add Decimal value **192** to the final result... this is **CO** in hexadecimal.*

LSB rule…

CV18 contains the lsb i.e., ... 00001111   When reading CV18 back you will see a Decimal value of 15.

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.)

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

The Hardware Function Outputs… HFO … electrical information.

There are two types of HFO.

Analogue High-level switches… HFO1 to HFO4… FO, F1 and F3…. HFO3 = F1 HFO4 = F2

You can think of the first 4 HFOs (i.e., HFO1 to HFO4) actually consist of transistor negative going switches. Typically, a LED will be connected with its associated series resistor to one of the HFO, the other LED connection will be to the common positive of the decoder. The positive connection is either supplied via a pin on the decoder plug/socket or is created externally using a rail connection as a common... see later re connecting LEDS. In operation current flows from the positive connection to the LED and its resistor and is switched on when the HFO is activated i.e., the transistor conduct and completes the current path to the negative/common of the decoder.

Digital Low-Level connections… HFO5 to HFO12***… F3 upwards… (AUX3 upwards)

These HFOs are designated as digital level outputs (3.3V logical high) and are designed to interface with electronics on the locomotive's motherboard for control of various locomotive features. Some users with an understanding of CMOS logic etc will understand these concepts and may well be able to design circuitry to operate with this type of HFO. These digital outputs give a high state in reference to decoder ground. (Pin20 on MTC 21 decoders. Pin14 on Next18S types.)

*** Some decoders on the market support 12 HFO connections.

Decoder Current Limits

Remember... The decoder has a total current rating which applies to the sum of the HFOs and motor current i.e., any current drawn from an HFO is part of the total current capability of the decoder. It can be seen that loading the HFOs up with different loads will subtract current available for the locomotive motor. In practice when using LEDs connected to HFOs this is not a problem. You just need to be aware of this decoder limitation. This rule applies to any decoder on the market.

Each AUX output (Analogue High Level HFO) has a current capability of 100mA. However, see note above if you intend to connect "heavy" loads to the HFOs. The theoretical maximum would be a maximum current draw of 400mA possible from all HFOs in sum total but, this would be totally impractical for normal decoder usage.

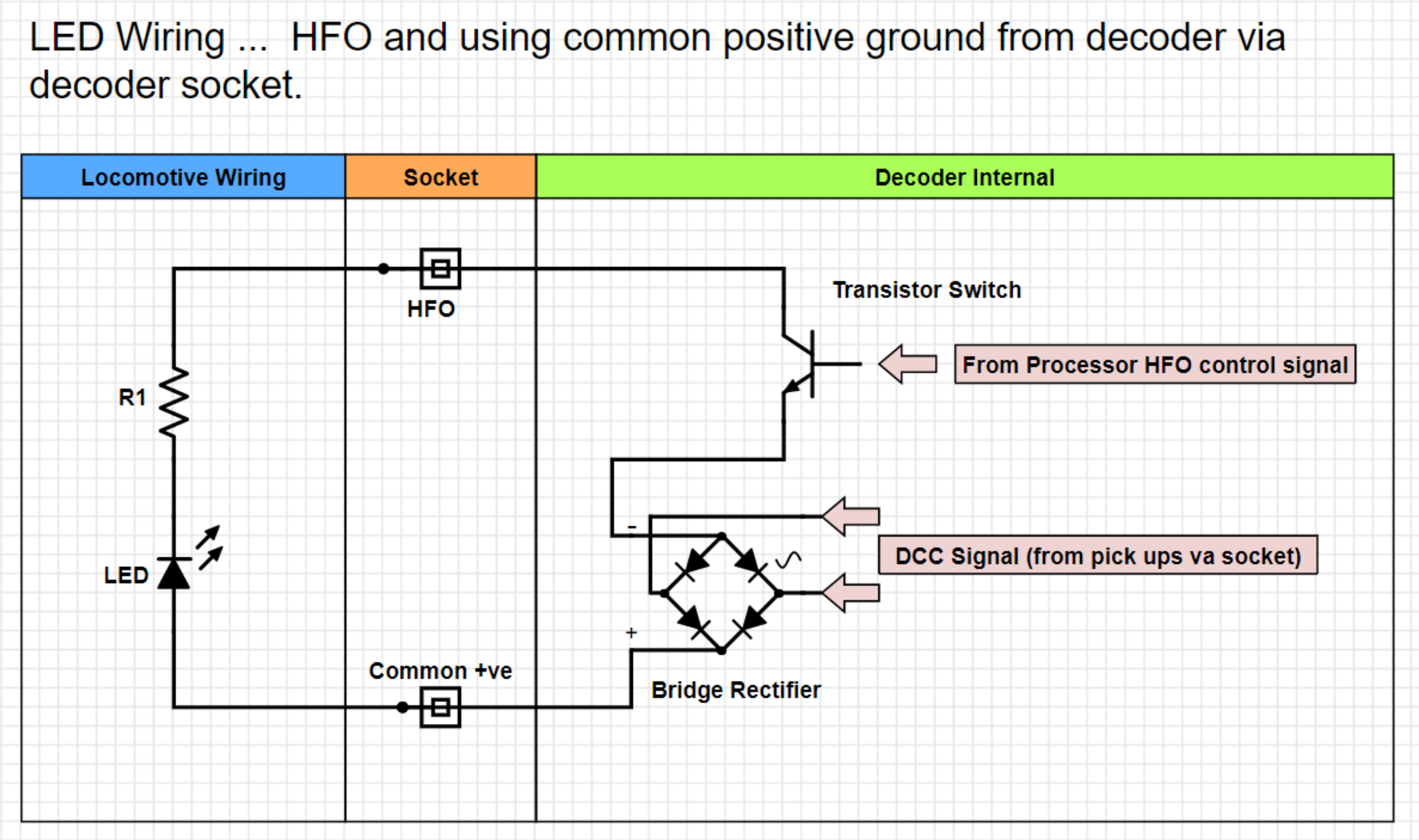
Any item to be connected to the HFO must NOT exceed the 100mA rating. It is recommended that you leave some headroom when selecting the item to be connected i.e., do not go above 80mA.

A final Warning!! HFOs are not protected against current overloads. DO NOT Overload your HFOs... you can damage your decoder!!!!!!!

Load Type... LEDs

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.



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.

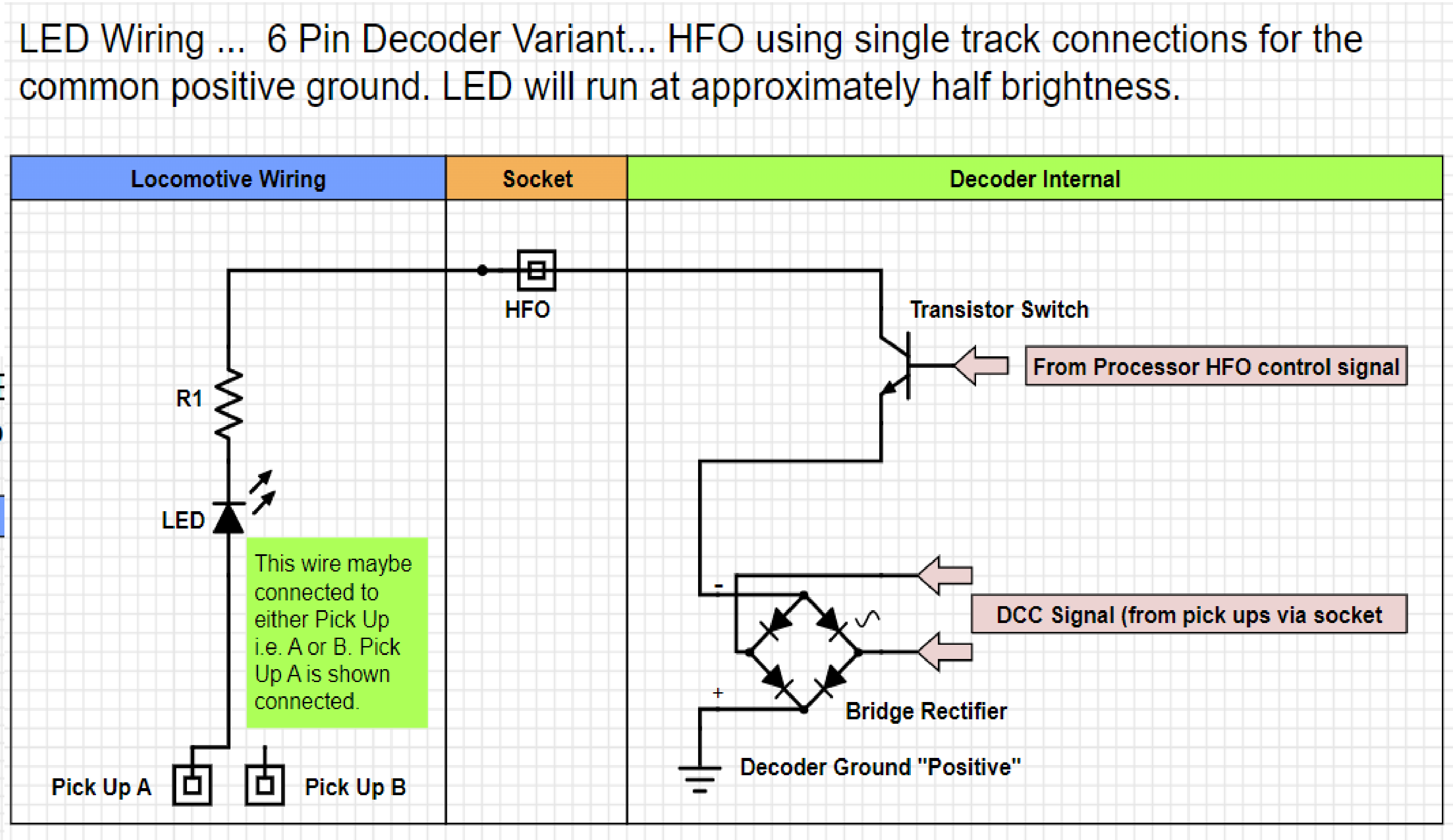
When the transistor turns on... current can flow through the LED and resistor, through the transistor to the negative side of the Bridge Rectifier thus, it illuminates.

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 470Ω and 1KΩ. Resistors are explained 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 Halfwave and Full wave Rectification… each has its advantages.



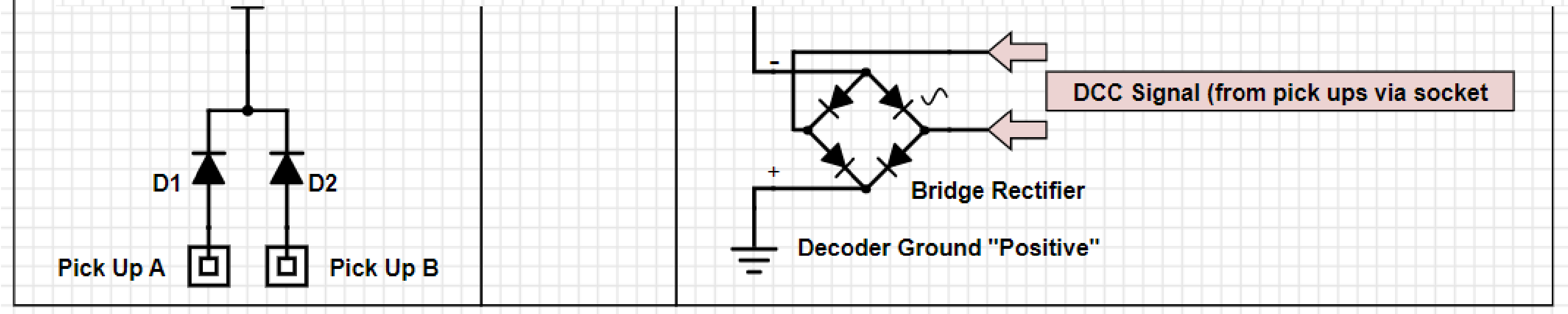
Method 1… Half Wave Method

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 time when compared with a normal +ve Common connection.



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.

LED Current Draw…

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

While lower or higher currents may be desired for some types of LED than the 10 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

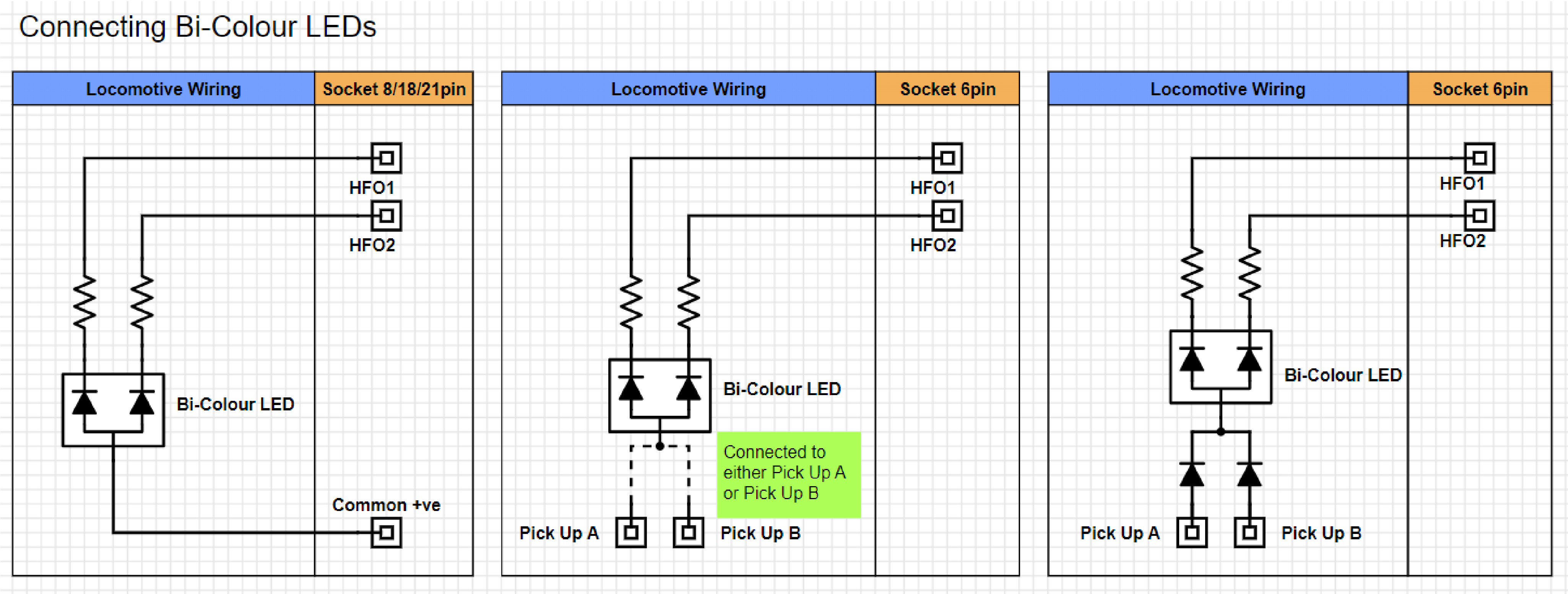
Below are some typical examples of "forwards voltages" and typical current levels that apply to different colour LEDs. The forward voltage of a LED is specific to that LED and can be checked in the specification of the LED to be used. However, the guide below will apply for the purposes of calculation 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 mid also that all resistors are manufactured with a value tolerance (or accuracy) ... usually 5%... so again, you can see that these values are not supper 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…

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.



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…

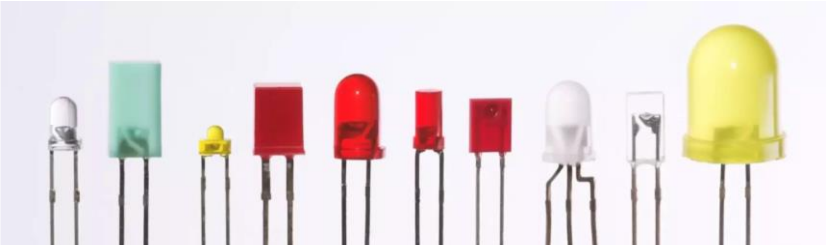
Physically, LEDs come in to two main types… Through Hole (TH) mounting and Surface Mounting Devices... (SMD.) TH LEDs are designed to be mounted on a printed circuit board with connection wires soldered to the underside of the pcb. The fact that they have actual wire connections can make them flexible 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!

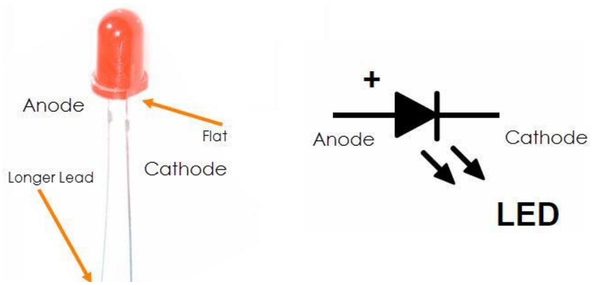
Through Hole Mounting…. A few pictures and diagrams referring to LEDS… for information.

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

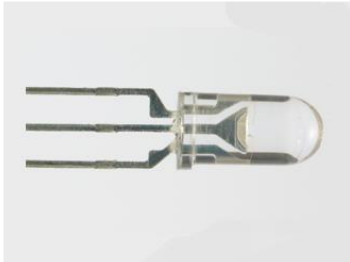
TH Mono Colour LED Package…. Note that with these types of LEDs the Anode connection is the longest lead. (Not shown!!) (Can you spot the Bi-Colour LED?!?!



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



Basic Bi-Colour LED



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

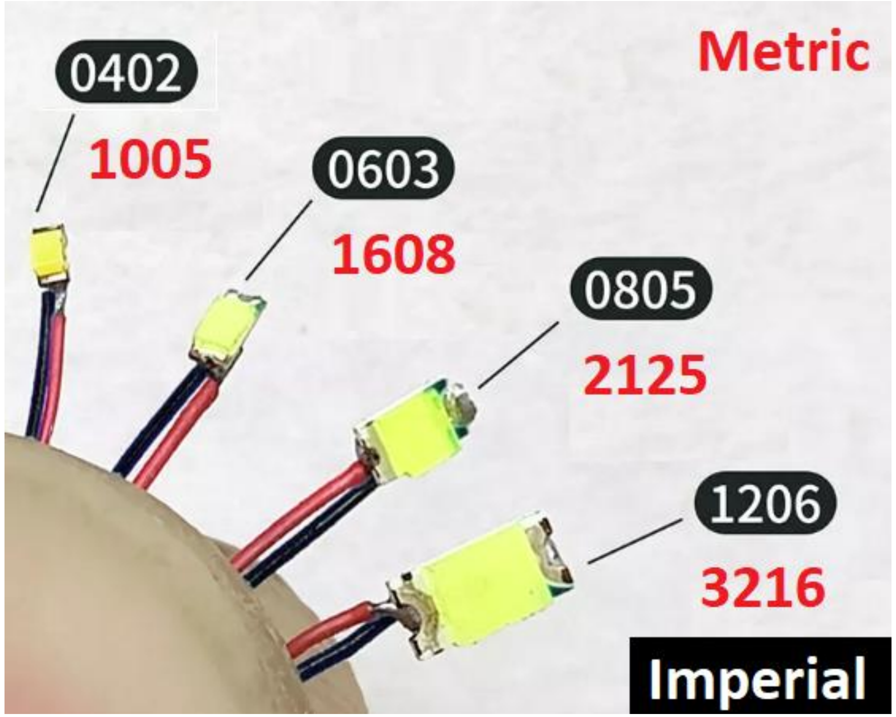
Tri-Colour LED…

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.

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.

The Internet has

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.

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 x 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.

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Non-Latching Relays…

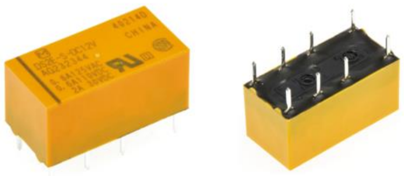
These types of relays have one coil. For operation the non-latching relay requires current flow through the relay coil to hold its state. Therefore, connection to a single HFO is straightforward without any special programming of the decoder HFOs etc. i.e. the HFO switch is turned on and off activating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

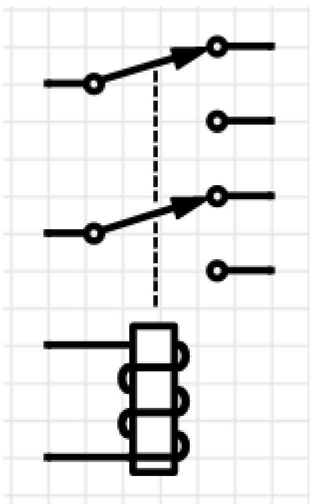
Example of typical DPDT relay…

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

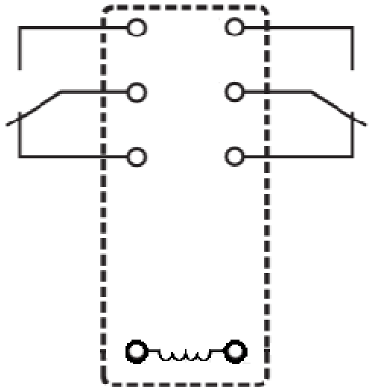


This type of relay consists of two change over switches that make up the DPDT element. The two switches are “ganged” together so they both operate when the relay is activated.

Schematic Symbol of DPDT Relay



Pin Layout of example DPDT relay



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

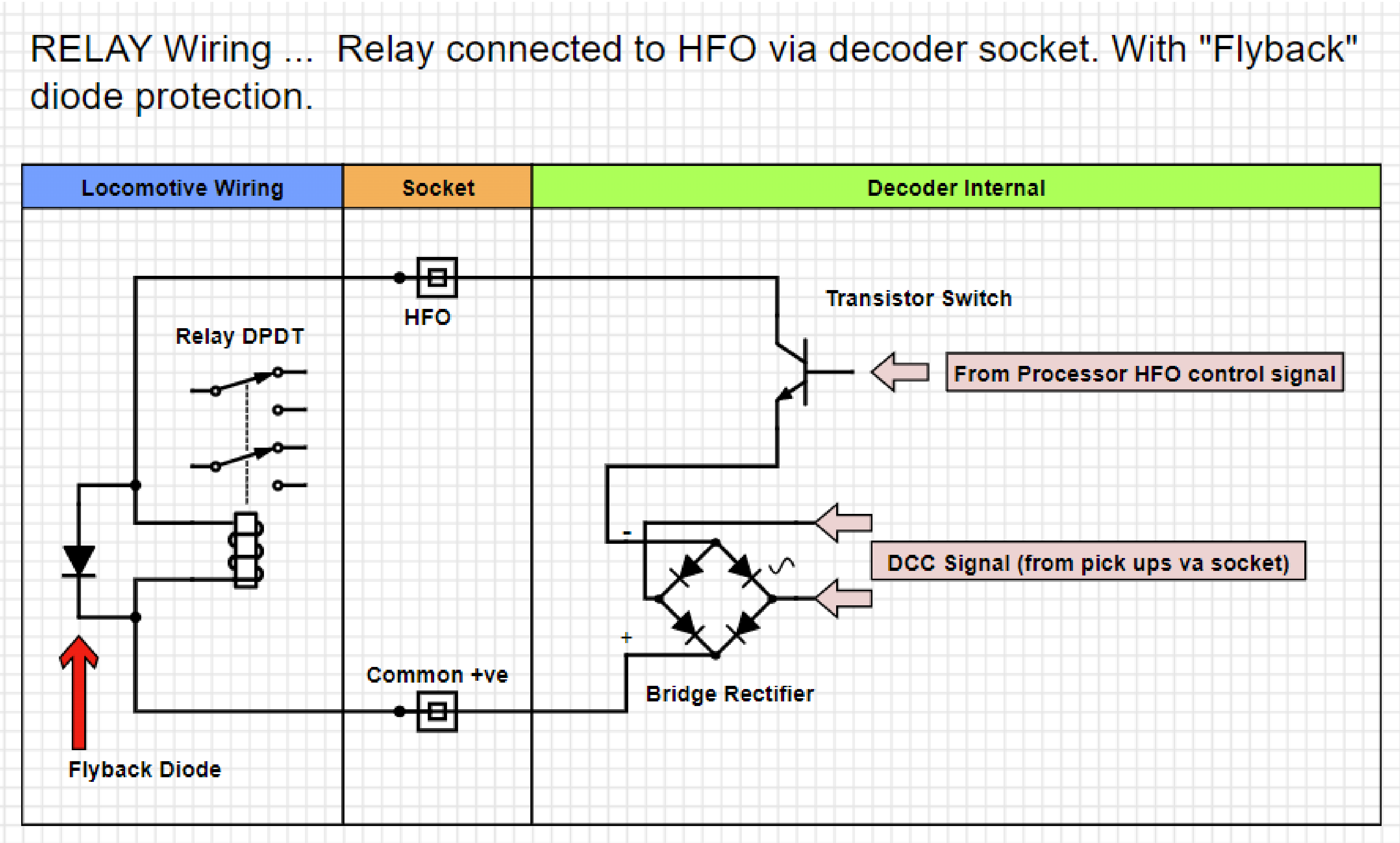
The current draw of a relay can be calculated simply using Ohms law. i.e., The current draw is equal to the voltage of the relay divided by its coil resistance. Generally, in model rail applications, 12V coils are usually used. I.e., this matches the typical output of a decoder HFO and is also a common 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 coli 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.



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

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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!

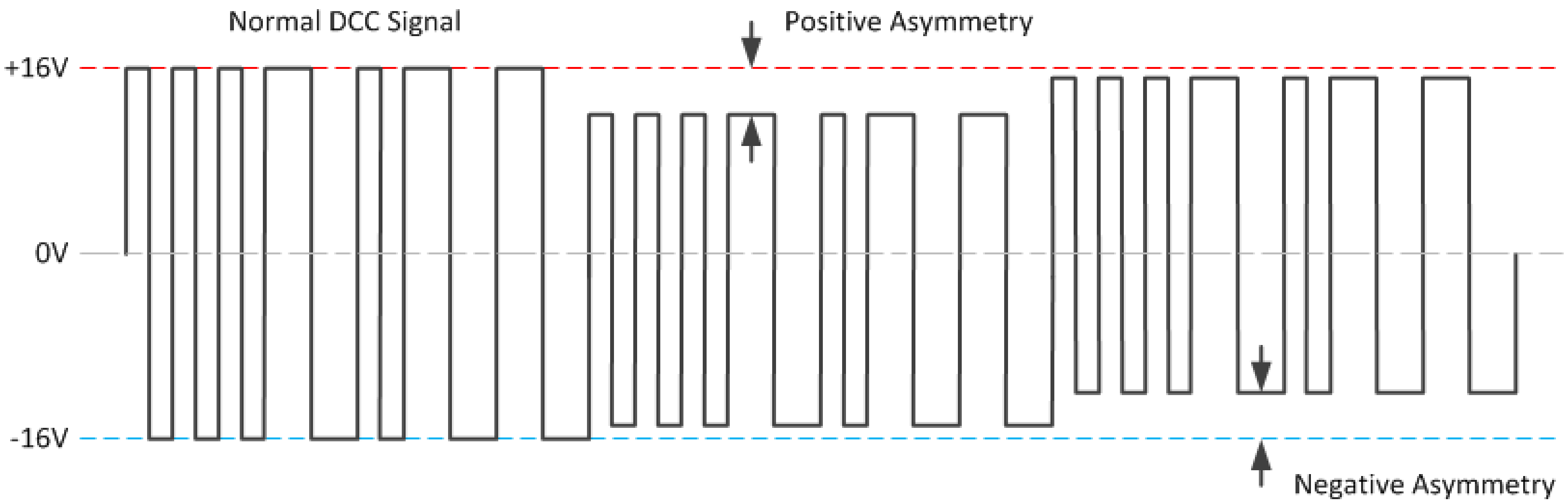
Appendix 4: Setting up Asymmetrical DCC Control… (ADCC)

Asymmetrical DCC Control is a Lenz invention and found on many higher specification DCC decoders… Lenz refer to ADCC triggered operation as ABC Braking, naturally, the HM700 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 function can be programmed to carry out a range of automatic actions.

In order to implement ADCC operations the track has to modified with simple diode circuits.. see next.

ADCC Explanation

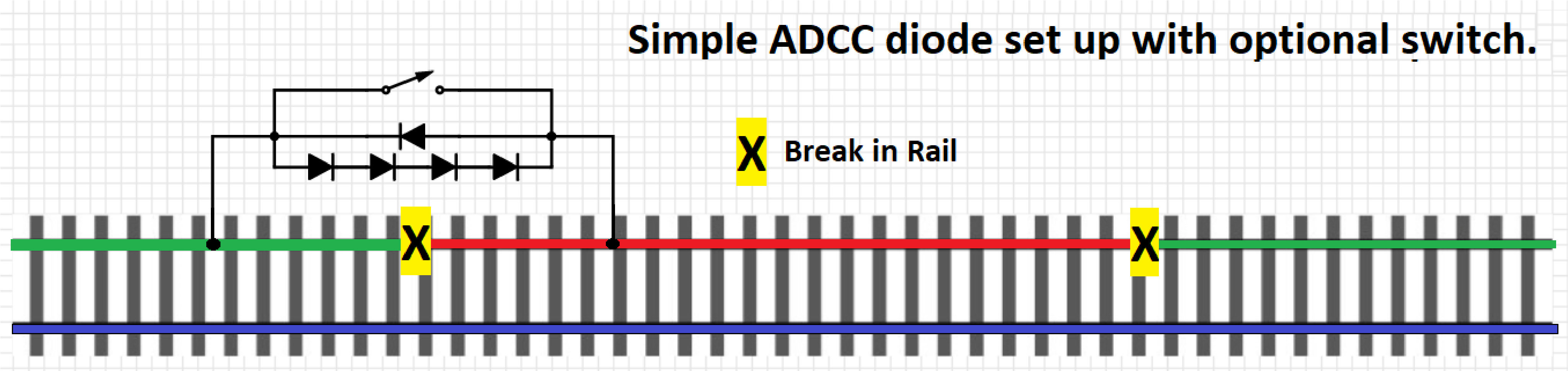
A normal DCC signal is made up of a "square wave" voltage wave form. If you look at the diagram below you can see that the square wave alternates around a zero point i.e., the voltage goes up to +15V and down to -15V… this is a symmetrical DCC wave shape… i.e. it is "balanced" … normal. The Asymmetrical wave form is where one of the voltages has a different level.. e.g., +15V to -12.5V i.e. they are not "balanced" … ADCC.



The decoder can detect a normal DCC signal and can detect when it changes to an ADCC wave form i.e. goes out of "balance." The decoder can then be programmed to automatically carry out an action on detection of the ADCC signal.

The conversion of a DCC waveform into an ADCC waveform is usually achieved by inserting a small diode network in-line with one rail to "unbalance" the DCC waveform within a region/length of track… the diode network 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 now "dead" rail is fed from the diode network. Thus, the waveform present in this region of the track is going to be ADCC or "not balanced." See below.



In the diagram above the normal DCC signal is connected to the Blue and Green Rail sections.

The Red Rail is the isolated ADCC section. As the locomotive crosses into this section the decoder will detect the change in the DCC signal level on the Red Rail and proceed to carry out any commands set up in the decoders ADCC configuration.

The X symbols indicate where the rail must be broken.

Notes...

The diodes used can be 1N4148/1N4001 or similar... it is not critical.

The switch in the diagram is optional. It allows the ADCC rail section to be disabled i.e., return to normal Non-ADCC operation. If the switch is replaced with 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.

in the image on the left we rigged an ADCC unit with a switch mounted in a 20mm x 40mm speaker enclosure.

Once the track section has been modified for ADCC operations the decoder must be programmed to enable the automatic brake actions etc.

Programming for ADCC involves CV27 and CV125-CV127... Start with CV27 to enable ADCC detection, then set up what actions you wish the locomotive to follow CVs 125-127... see below for the full explanation.

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

This CV is used to define which rail is detected for the ADCC imbalance. Detection of the presence of an imbalance or return to normal of rail voltage will enable/disable the triggered action.

Default Value	Range
0	0 - 2

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. See section.. [Appendix 1: CVs... what are they?? What do they do? And dealing with binary, if you really want too…]

*** At the time of writing the CV range is 0 – 2 i.e. value =1 means the right rail is used for detection, value =2 means the left rail isused. A value =0 means no ADCC condition will be detected i.e. ABC is Disabled.

Bit #	Purpose	Default State	ADD
0	Enable Auto Stop in the presence of an asymmetrical DCC signal which is more positive on the right rail.	Disable	1
1	Enable Auto Stop in the presence of an asymmetrical DCC signal which is more positive on the left rail.	Disable	2

Now go to the next stage to configure what type of automatic action you wish the decoder to carry out…

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.

CV125 ABC Action… Explanation	Bit0	Bit1	Decimal
ABC Stop with Deceleration set by CV4. Stop Duration is set by CV126. Without Shuttle Operation.	0	0	0
ABC Stop with Deceleration set by CV4. Stop Duration is set by CV126. With Shuttle Operation.	0	1	1
ABC Stop with Constant Braking Distance is set by CV127. Without Shuttle Operation.	1	0	2
ABC Stop with Constant Braking Distance is set by CV127. With Shuttle Operation.	1	1	3

CV#	CV Name	Default Value	Range	Comments
126	ABC Stop Hold time	1	0-255	Time in seconds
127	ABC Constant Braking Distance	25	0-255	

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 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 locomotives 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?!?.

The rate of motor voltage increase is controlled by the "shape" of the "Speed Curve."

The decoder holds two Speed Curves. Which Speed Curve is in use is set by CV29. Bit4

The two Speed Curve types are discussed next...

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…

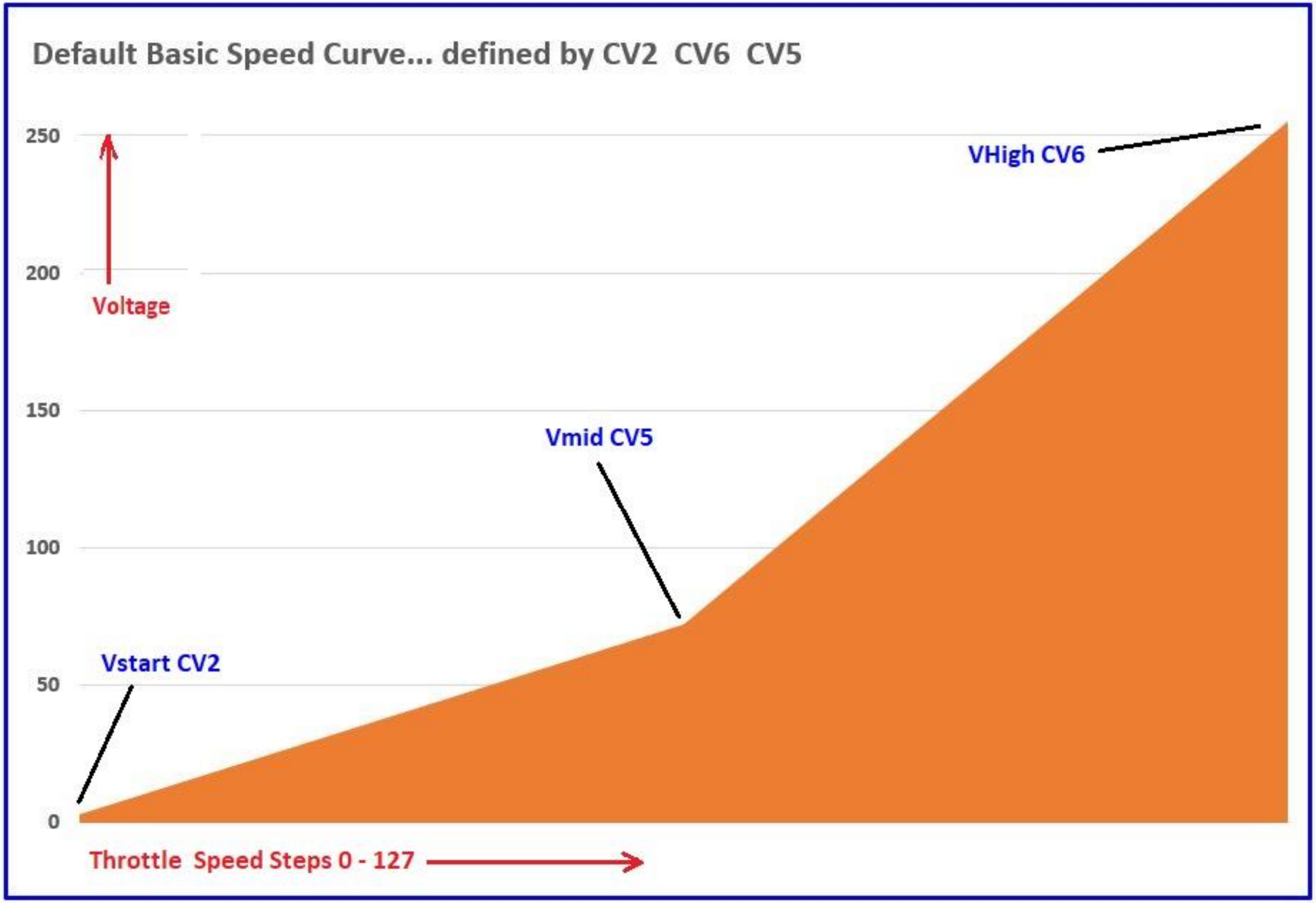
The BASIC 3-point Speed Curve is a left over from the very early days of DCC technology. Going back to when there were on 8 settable variables i.e., Registers. The advent of Paged mode and Direct mode programming increased the number of stored variables to 255 +… When this advance happened a new Speed Step Curve was introduced i.e. "The COMPLEX User define Speed Curve."

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. These multiple voltage levels are defined in two tables. The tables are configured 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. The tables can be represented as points on a graph… defining the "Speed Curve" or Throttle response.

The two tables/Speed Curves are called "Basic" and "Complex" they are examined next…

The BASIC Speed Curve...



This is the default of the decoder (*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.

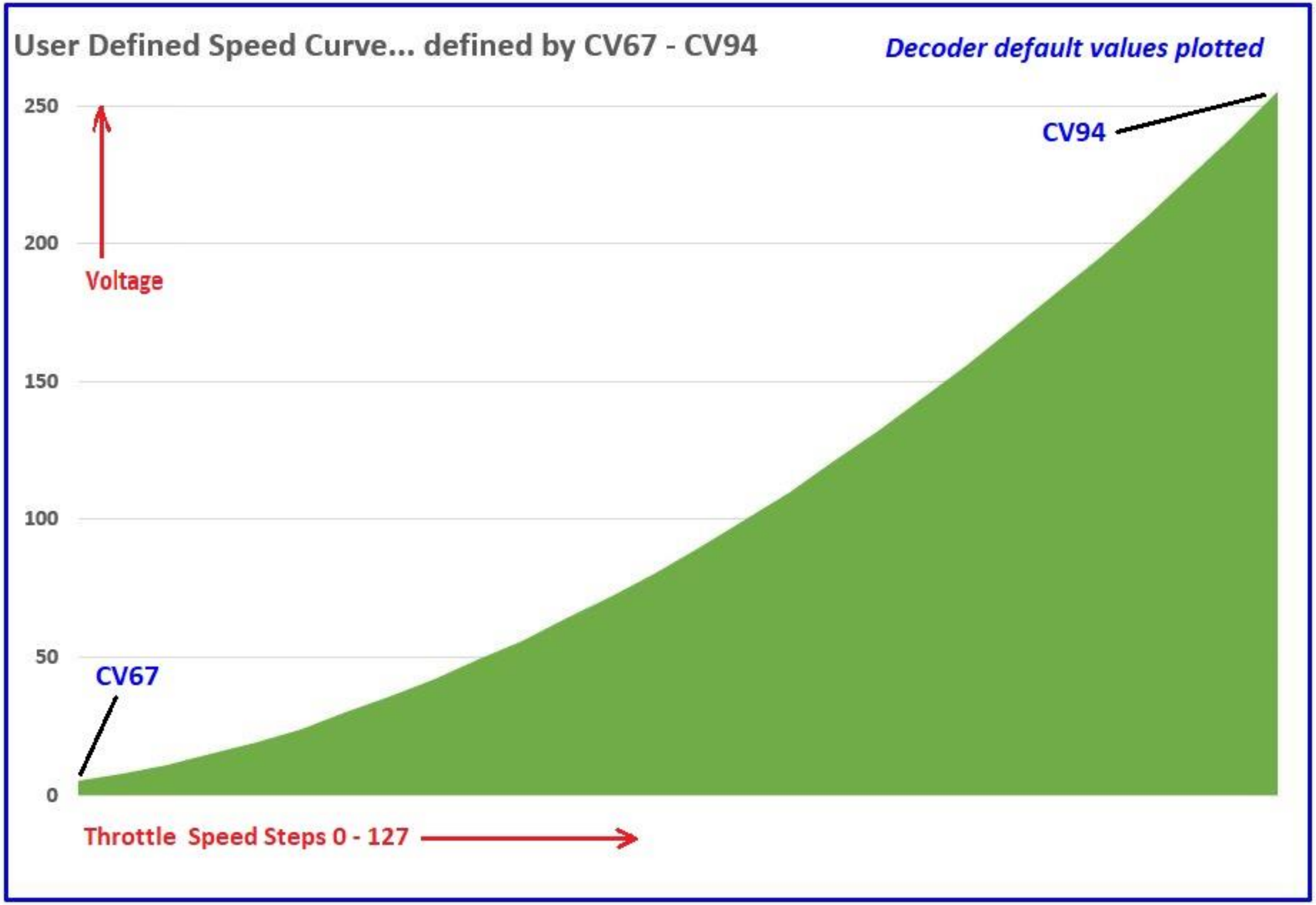
CV2 Vstart ... this is the motor voltage when the SS Step = 2

CV5 Vmid ... this is the motor voltage when the SS = 72

CV6 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.

The COMPLEX User define Speed Curve.



The Complex Speed 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.

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 need 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 decode 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 int 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.

Stages 1 and 2   **Stage 1 and Stage 2 adjustment (Auto-Calibration and PA Control Algorithm   CV149 = 2   (Default)**
Stage 1… Auto Calibration The PA control algorithm can be automatically written too using the Auto Calibration procedure. Affected are CV143, CV145, CV146 and CV147.
Stage 2… Further adjustment of the effectiveness of Auto Calibration parameters 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.

Stage 3   PID Control Algorithm   CV149 = 1
Stage 3… Manual PID Calibration. 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…

- Programme CV149 = 0 to arm the calibration process. The locomotive will now no longer respond to throttle input. Also, ensure that F0 is disabled (turn off the lights!) Return to locomotive control on your controller.

- Place the locomotive on the track and start the calibration sequence by pressing F0 on the control device.

- The locomotive will move off at a fast pace and stop within about 1.5 metres. CV143, CV145, CV146 and CV147 will now be populated by the AC process.

- 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.)

- 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 tun a locos running for heavier loads you can try running the AC procedure as required i.e., with a rake of carriages in tow.

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	Default = 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.

2, Stage Two … adding the PA Control factors… CV149 = 2

PA consists of two factors i.e., the **P**WM frequency of the motor drive and the **A**mplification 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…

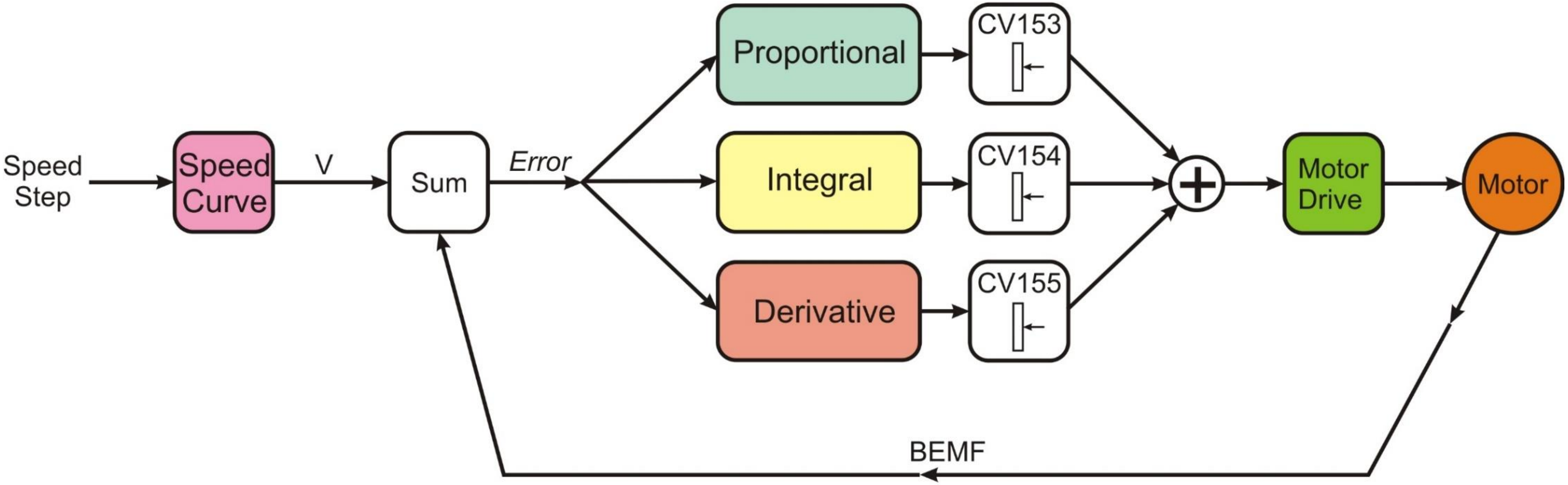
Integral… CV154 is the total of all the "error signal" values seen over a set period of time… the algorithm uses this information to create another "correction" value that once processed works with the Proportional value to further correct the motor speed. It is this value that you adjust via **CV154** 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 continuos loop.

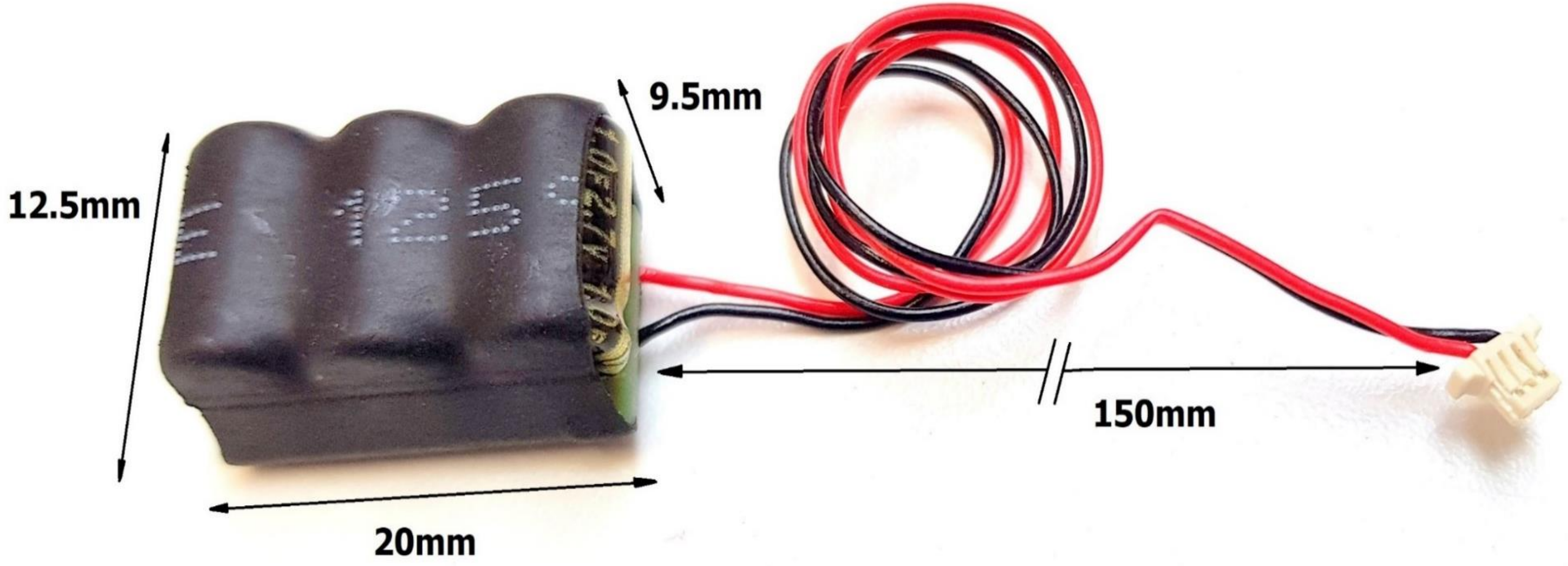
Appendix 7: Power Bank… Hornby *"Stay Alive"* Connection and Implementation

The HM7000 series decoders support "Stay Alive" functionality when fitted with the Hornby R7377 Power Bank.

Smart Charging…

The decoder supports "smart charging" this is a feature which controls the charge process of the Power Bank. The Power Bank will only charge while the locomotive is in motion. 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.*



The decoder pcb has all the support components fitted to support the external R7377 Power Bank. 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.

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…

CV #	CV Name	Default Value	Range	Comments
1	Primary Address	3	1-128	
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… CV7… Manufacturer Version number
8	Manufacturer ID	48	48	Assigned by NMRA… READ ONLY. However, Writable for reset functions… CV8… Manufacturers ID
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.	0	0 - 3	Enables Asymmetrical DCC Automatic Brake Control (ABC) and sets rail symmetry for detection. 0 = No ADCC 1 = ADCC Left Rail 2 = ADCC Right Rail 3 = ADCC Both rails See, Appendix 3: Setting up Asymmetrical DCC Control… (ADCC)
29	Configuration Data #1	2	1-255	CV29… Decoder Configuration

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

Special Decoder Functions				
120	Shunting Percentage	1	0 - 2	Percentage of current NMRA speed 0: 25% 1 : 50% 2 : 75%
121	Creep speed	1	1 - 127	
122	Creep pre-set duration (10mS increase)	2	0 - 255	
123	Brake deceleration rate	5	0 - 255	CV123 = 1 will result in an instant stop.

ABC Configuration Appendix 4: Setting up Asymmetrical DCC Control… (ADCC)				
125	ABC Control Function	3	0 - 3	Appendix 4: Setting up Asymmetrical DCC Control… (ADCC)
126	ABC Stop Hold time	5	0 - 255	
127	ABC Constant Braking Distance	2	0 - 255	

Motor Control Algorithm… CVs affected by the Auto-Calibration Procedure. CV149 = 0 to arm process. (CV149 returns to = 2 after process has completed.)				
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	0	0 - 2	0 : Arm Auto-Calibration process 1: Use PID Motor Control Algorithm 2: Use PA motor control algorithm

Motor Control Algorithm… CVs used for PA adjustment after Auto-Calibration. 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				
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…				
158	Global volume set	50	0-255	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)	50	0-255	This applies to non-locomotive decoder profiles only i.e., like the original Vent Van projects etc.
160	ELECTRIC Volume of Locomotive Motors	50	0-255	Applies to both acceleration/deceleration phases of operation. Applies when the locomotive is Stationary.
161	DIESEL and STEAM Volume of locomotive Engine	50	0-255	Applies to both acceleration/deceleration phases of operation. Applies when the locomotive is Stationary.
162-180	Volume of F2 - F20.	50	0-255	Volume of all Spot Sound Play

181-199	Reserve for future use			

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	

Horns and Whistle play… F2 and F3 Configuration…

205	Sound Selection for F2	255	0-255	F2 sound selection, maximum 8 sounds, default 0xff to play all 8 sounds.
206	F2 Play Mode	0	0-1	F2 sound play mode, 0=sequential, 1=random.
207	Sound Selection for F3	255	0-255	F3 sound selection, maximum 8 sounds, default 0xff to play all 8 sounds.
208	F2 Play Mode	0	0 - 1	F3 Sound play mode 0=sequential, 1=random

Sound Play Configuration DIESEL Engines… Idle + 3 Notches… Earlier TTS projects etc.				
	Idle			Applies to SS of < **DTT1**
210	Trigger Threshold 1	5	5-15	Applies when SS > **DTT1** but < **DTT2**… Plays Notch 1
211	Trigger Threshold 1 Window	5	5-9	**DTTW1**… Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
212	Trigger Threshold 2	30	25-45	Applies when SS > **DTT2** but < **DTT3**… Plays Notch 2
213	Trigger Threshold 2 Window	5	5-14	**DTTW2**… Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
214	Trigger Threshold 3	60	60-80	Applies when SS > **DTT3…** Plays Notch 3
215	Trigger Threshold 3 Window	5	5-15	**DTTW3**… Forces Notch to Decrease back to Notch 2

Sound Play Configuration DIESEL Engines… Idle + 4 Notches… Later TTS projects etc.				
	Idle			Applies to SS of < **DTT1**
210	Trigger Threshold 1	5	5 - 15	Applies when SS > **DTT1** but < **DTT2**… Plays Notch 1
211	Trigger Threshold 1 Window	5	5 - 9	**DTTW1**… Forces Notch to increase from Idle to Notch 1 and then Decrease back to Idle
212	Trigger Threshold 2	20	20 – 30	Applies when SS > **DTT2** but < **DTT3**… Plays Notch 2
213	Trigger Threshold 2 Window	5	5 - 14	**DTTW2**… Forces Notch to increase from Notch 1 to Notch 2 and then Decrease back to Notch 1
214	Trigger Threshold 3	45	40 - 50	Applies when SS > **DTT3** but < **DTT4**… Plays Notch 3
215	Trigger Threshold 3 Window	5	5 – 14	**DTTW3**… Forces Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3
216	Trigger Threshold 4	65	65 - 70	Applies when SS > **DTT4**… Plays Notch 4
217	Trigger Threshold 4 Window	5	5 – 14	**DTTW4**… Causes Notch to increase from Notch 3 to Notch 4 and then Decrease back to Notch 3

DIESEL Start Delay after Brake release…				
225	Delay Time	25	0 - 255	1 = 100mS Default = 2.5S

Sound Play Configuration ELECTRIC Locomotive…				
	Automatic Idle			Applies to SS of > 0 but less than **ETT1**
218	ELECTRIC Trigger Threshold 1 **(ETT 1)**	3	1-127	Applies when SS > **EET1** but < **EET2**

219	ELECTRIC Trigger Threshold 2 **(ETT 2)**	30	1-127	Applies when SS > **EET2** but < **EET3**
220	ELECTRIC Trigger Threshold 3 **(ETT 3)**	60	1-127	Applies when SS > **EET3** but < **EET4**
221	ELECTRIC Trigger Threshold 4 **(ETT 4)**	80	1-127	Applies when SS > **EET4** but < **EET5**
222	ELECTRIC Trigger Threshold 5 **(ETT 5)**	100	1-127	Applies when SS > **EET5**

The following CVs are unique to Steam locomotives. These CVs have different purposes depending whether the locomotive is a Steam Engine or a Diesel.

Steam Wheel Slip Simulation Configuration… Applies to all Steam Locomotives.				
213	Wheel Slip Automatic Mode Enable	0	0-1	0 = Manual 1= Auto
214	Wheel Slip Triggering Step Difference	7	5-15	Overshoot value... i.e., how many speed steps you can apply before wheel slip engages
215	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.
216	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.

Appendix 9: Decoder Operational, Electrical and Physical Specifications

Sound Decoders specification.

	HM7000-21TXS	HM7000-8TXS	HM7000-N18TXS
Operational Modes	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		
Electrical Limits			
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		
Physical			
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
Operational Modes		
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	
Electrical Limits		
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)	
Physical		
Dimensions	8mm x 21.5mm x4 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: Need Help?

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 11: 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.

Revision	Date	General Description Changes	Notes
R1.00	140223	Initial Release	Some areas of the manual omitted at the moment until features become available.