ZTC Steam & Diesel

Installation and Programming

Manual

WARNING:
If you fail to read the installation instructions properly it is possible that you could accidentally damage your ZTC unit. Such damage is **NOT** covered by our guarantee. So to prevent avoidable and potentially expensive mistakes, please take the time to read these instructions before attempting to install your equipment

The ZTC System is only intended for controlling model railways by experienced modellers over the age of 14 .
It should only ever be operated by young persons under competent adult supervision.

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PART I: OWNER'S MANUAL

Introduction.

Congratulations on the purchase of your ZTC RealFeel™ Digital Sound Decoder (RDSD). Properly installed, the RDSD will provide all the pleasures of high quality, digital onboard sound and the benefits of today's DCC (Digital Command Control) technology.

With the proper tools, basic modelling skills and common sense, equipping a locomotive with sound is not difficult. It may, however, be a new experience for you, and you will find that

successive installations will go more quickly than the first. The ZTC RealFeel™ Digital Sound Decoders have some unique features and capabilities that require some steps not found in regular decoder installations. We strongly encourage even the most skilled and experienced modeller to read this manual thoroughly as it contains instructions and information designed to provide optimum, trouble free performance from your RDSD.

We urge you to test the decoder first using the simple test procedure in Appendix B to verify that everything is working as it should. If you do not feel comfortable attempting the installation then don't! You may prefer to have ZTC or their authorised dealer to perform the installation in which case please contact us for details.

Please note that while each decoder is tested thoroughly before it is shipped, we cannot control the correctness or quality of the installation. It is imperative that you follow the directions and do not install the decoder before you have tested it. Never remove the protective heat shrink from the decoder; there are no adjustments or user serviceable parts and this will void your warranty. Do not shorten any of the decoder wires until you have verified that it is functioning properly using the decoder test circuit.

This manual is divided into two parts for your convenience. Part I is the Owner's Manual, which covers the features of the RealFeel™ Digital Sound Decoder, it's installation and operation. Part II is the Decoder Technical Reference. This is designed for the advanced user who wishes to have the technical data on the RealFeel™ Digital Sound Decoder as a reference during advanced programming sessions. If this is your first decoder installation, Part I will provide you with all the information you need to get started.

RealFeel™ Digital Sound Decoders Features.

The RealFeel™ Digital Sound Decoder is designed to be installed onboard a locomotive in conjunction with a miniature speaker to provide the ultimate in realism and control. The RDSD is available in two styles, the ZTC 45X range is a fully featured digital sound system the second the ZTC 47X range integrates a fully featured digital sound system with a lighting and a DCC motor drive decoder into a single miniature electronic module. All ZTC RealFeel™ Digital Sound Decoders are compatible with the latest NMRA DCC Standards and Recommended Practices.

The range of RDSD`s will be made available with specific sound and lighting effects for a British Outline, foreign and American locomotives. Depending on the effect, the sounds are generated continuously, automatically in response to some other action, or as controlled by the user. Additionally, certain sounds can be modified using specific Configuration Variables (CVs).

Decoder Features.

Compatible with the latest NMRA DCC Standards and Recommended Practices as defined by S-9.1, S-9.2, RP-9.1.1, RP-9.2.1, RP-9.2.2, RP-9.2.3 and RP-9.2.4.
Supports 7 bit address modes for compatibility with 'simple' systems.
Supports 14 bit address modes for addressing locomotives number up to 9,999.
Supports 7 bit consist addressing.
Supports Function Mapping.
Supports paged, register, and direct mode CV programming.
Supports 'Operation Mode Programming', allowing many CVs to be changed on the mainline without using a special programming track.

Steam Sound Features. ZTC 45X and ZTC 47X Range

The Steam RDSD provides high quality digital sounds specific to its prototype. Each Steam RDSD includes:

- Steam Exhaust Chuff
- Whistles
- Vacuum Pump
- Cylinder Blow-down (Hiss)
- Fireman Pete
- Adjustable Volume Control
- Auto-Exhaust™ allows chuff to be synchronised using an exhaust cam
- Firebox Blower
- Boiler Pressure Relief Valve
- Buffer and Coupling Clank
- 1 Watt Audio Amplifier
- Dynamic Digital Exhaust ™ Modifies exhaust volume, cut off and timbre sensor or track voltage as the locomotive load changes.

Diesel Sound Features. ZTC 45X Range

The Diesel RDSD provides high quality digital sounds specific to its prototype. Each Diesel RDSD includes:

- Exhaust
- Two tone horns
- Vacuum Pump
- Presure releife (Pop) valve
- Adjustable sound steps
- Adjustable Volume Control
- Independent Hi Tone Horn
- Independent Lo Tone Horn
- Buffer and Coupling Clank
- 1 Watt Audio Amplifier
- Wheel/Brake Squeal

Motor Control Features. (ZTC 47X Range Only).

- Supports 14, 28 and 128 speed step modes.
- Programmable acceleration, deceleration and starting voltage, for prototypical starting and stopping.
- Use of standard and alternate speed tables; 14 built-in speed tables and 1 user programmable speed table.
- Thermal and overload protection.
- ZTC 47X RDSD range is suitable for engines whose current draw (stalled) does not exceed 1.5 amps.

Lighting Features. (ZTC 47X Range Only).

Each RDSD comes equipped with four auxiliary function outputs that can be programmed to accommodate a number of auxiliary features.

- Simple On/Off Lamp controls
- Intelligent Firebox Flicker, which is Synchronised with sound of the firebox door being opened.
- Firebox Flicker.
- Coupling operation.
- Supports automatic direction control of lights.
- Function output rated at 100mA current sink capability.

IMPORTANT STEPS FOR A SUCCESSFUL INSTALLATION.

It will be a great temptation to begin connecting wires immediately. Before you install your RDSD, there are some simple precautions you should take.

First, finish reading this Sound Decoder Manual!

The RDSD`s should be handled carefully in a static-free environment. To discharge static electricity, you should touch a grounded water pipe or bare sheet bonded metal surface before handling the RDSD.

Work in a clean, well lit area on a non-conductive surface. Metal fillings and dirt etc. can get into the RDSD's circuitry and it will cause shorts which could damage your decoder permanently.

Never, ever remove the decoder’s protective heat shrink sleeves. First, it will void your warranty and secondly, you will compromise part of the decoder’s built-in thermal management system.

Never, ever make connections to the decoder while it is powered. Doing so WILL damage your decoder.

Make sure all the electrical connections are properly insulated. Avoid using PVC electrical tape as it tends to unravel over time. We recommend using heat shrink tubing from our ZTC 399 Zippy pack.

Never, ever allow the decoder leads to come in contact with any DCC track wiring except those specifically designed for that purpose.

Never allow speaker outputs to become shorted together this will cause permanent damage will be the result.

Never allow the motor outputs of the ZTC 47X decoder to become shorted together or again permanent damage will be the result.

Do not exceed the output ratings for which the decoder is designed.

Take your time, double check everything and have fun!

RDSD Functional Testing
Although each RDSD has been fully tested prior to shipment and is ready for installation, we urge you to test your decoder before installing in your locomotive!

We have developed a simple procedure (see Appendix B) that assures you that the RDSD is functioning properly before you do the proper installation. If this is your first sound or decoder installation, it will give you an added boost of confidence, knowing that as long as you follow the installation instructions...it *will* work!

In the event you do have a problem, please contact ZTC Controls Ltd or your authorised dealer for technical assistance. We will gladly refund payment or replace any decoder that does not pass the functional test free of charge provided that none of the decoder wires have been cut short.

Before you get started, we must reiterate - **Do not shorten any decoder leads** until you have verified that the decoder is functioning properly. **Do not install any decoder that does not pass the Functional Test.**

INSTALLATION.

The following are ten easy steps to install a ZTC Sound Decoder.

Installing the RDSD generally requires the following steps:

1. **Select the Locomotive**
   Choose a Decoder appropriate to the Locomotive and select a suitable Loudspeaker from the ZTC 17X range.

2. **Plan the Installation**
   Determine the location of the RDSD, speaker, cam if required, lamps and connectors.

3. **Isolate the Motor**
   Take the locomotive apart and disconnect all wires to the motor and lights.

4. **Modify the Tender Body and Floor**
   Modify the tender to accept the speaker and decoder.

5. **Fit the Speaker**
   If necessary trim the speaker frame and/or add baffles to get a sound-tight fit.

6. **Install the Lamps**
   Modify lamp castings to accept miniature LED's or bulbs.

7. **Install the Exhaust Cam**
   If required, Install synchroniser disk and mount cam switch.

8. **Install and Wire the Decoder**
   Mount the decoder using a double sided self adhesive pad (See ZTC 399 Zippy pack) and connect the LED's, lamps, motor, speaker, etc.

9. **Test the Installation**

10. **Program the CVs**
    Program CVs to tune performance and sound effects.

Tools Required to fit decoders.

In addition to normal hand tools found on most modeller's workbenches, you will require the following items:-

A Low wattage (under 25 watts!) soldering iron.
A length of 0.7 mm multicore tin/lead solder.
A scalpel or X-acto knife.
A watchmakers miniature screwdriver set.
A pair of side cutters and wire stripers.
A high speed electric drill such as a Minicraft or Dremel.
A Digital or analogue multimeter.
A tube of silicone RTV or similar product.
A length of double sided self adhesive tape, or better still, a few double sided self adhesive, sticky pads as supplied in our ZTC 399 Zippy Pack.

We also recommend the following items to ease your installation:

ZTC 399	Zippy Pack
ZTC 160	Acoustic Wool to reduce resonance and deaden vibration.
ZTC 161	Black Acoustic screen material to protect the speaker.
ZTC 162/3	Micro-bulbs 1.5v.
ZTC 164/5	Micro-connectors to enable for easy separation of items such as cam switches, micro-bulbs and loudspeakers etc. from locomotives pickups and tenders etc.

It is strongly suggested that small lengths of Heat Shrink Tubing (HST) are used to insulate your wiring connections, such as found in the ZTC 399 Zippy Pack, which contains an assortment of heat shrink tubing suitable for this purpose. Please note that we have found that **ALL** self adhesive electrical tapes will unravel with time and are strongly **not recommended**!

If you intend to take advantage of the special lighting effects of the ZTC 47X RDSD`s and wish to use 1.5 Volt micro-bulbs for this purpose, ZTC Controls Ltd can offer two sizes. The ZTC 162 which has a diameter of 1.3mm for smaller gauge models and the ZTC 163 which has a diameter of 2.5mm for use in larger scales.

Examples of some of our Range		SUITABLE SCALES				
P.N.	SPEAKER SIZE	N-Scale	HO-Scale	S-Scale	O-Scale	G-Scale
ZTC 175	3/4" Speaker	●	●			
ZTC 177	1" Speaker		●	●		
ZTC 196	1-1/2" Speaker		●	●	●	
ZTC 183	2" Speaker			●	●	
ZTC 188	3" Speaker				●	●

ZTC Controls Ltd also offers a carefully selected high quality range of 8 ohm Loudspeakers which are most suitable for use with our RDSD`s. Starting with the ZTC170 through to the ZTC 199. We recommend that you choose the largest and best quality speaker that can be fit in your locomotive. The larger the size, the better the sound quality and volume. Oblong speakers have a much greater power rating and frequency response than similar sized round ones and are therefore to be preferred. See Appendix D for the full range.

ZTC Controls Ltd also offer suitable micro-connectors for locomotives and tenders. They are the multipin ZTC 164 and single micro pin ZTC 165. The particular connector you will use will depend upon the number of functions you are using. The advantage of the individual connector pins such as the ZTC 165, is that they will allow you to disguise the connecting wires as vacuum, air or water lines, but they do require great care when reconnecting them so as not to incorrectly wire the decoder.

Step 1. Select your Locomotive

If this is the first time you have installed sound in a locomotive, then we suggest you choose your locomotive carefully. A few simple precautions will ensure that your first effort produces a great sounding locomotive instead of an intimidating rats nest of wires:

Select a locomotive that is well run-in and runs smoothly, it must run well on ordinary smooth DC power. A smooth running mechanism is vital for good regulator control and enhances the realism of the sound. Dirty, worn out or binding mechanisms not only overload decoders, but they will have trouble starting smoothly and will destroy the illusion created by the Auto-Exhaust feature if they barely lurch along at half regulator setting.

Try to pick a locomotive with a reasonably large, empty and rectangular tender. The larger the tender, the more room you will have for installing the decoder and speaker. It will also allow you to use a larger speaker, giving both better volume and sound fidelity. Reserve that favourite little 0-4-0 for a future installation when you have some experience behind you.

Ideally you should start with an engine that is ‘Sound-Ready’, such as an engine with predrilled speaker holes, for example. The simpler you can make your first installation, the better. Unfortunately we do not know of any British outline sound ready locomotives at present, but they will come, just as DCC ready locomotives are starting to appear on the UK model scene.

DO NOT pick a noisy engine, or one which experiences some brush arcing or sparking when in operation. The best sound will come from locomotives powered with can motors. Older, open-frame motors may produce an offensive sound due to RF interference.

DO NOT pick a locomotive whose stall current exceeds the rating of the ZTC 47X decoder.

The following procedure can be used to determine a locomotive’s stall current:-

1. Place the locomotive on a section of track powered with a conventional DC power pack set to 12 volts for N, HO, S, and O scales or 16 volts for G scale.

2. Connect a DC Ammeter in series with one of the track feeders as shown in Figure 1. If your controller has built-in meters, they may be used for this purpose.

3. While holding the locomotive to prevent it from running, turn the controller to maximum speed.

4. Stop the motor from turning by firmly holding the locomotive down onto the track or holding the flywheel or driveshaft. **DO NOT** hold the Rotor of the motor as this may result in damage to the windings.

5. To ensure the most accurate current measurement, be sure that the power pack voltage remains at 12 volts or more (16 volts for G scale) during this test.

6. Measure the current the locomotive is drawing while the motor is stalled. This is the stall current and must be less than 80% of the decoder's rated capacity.

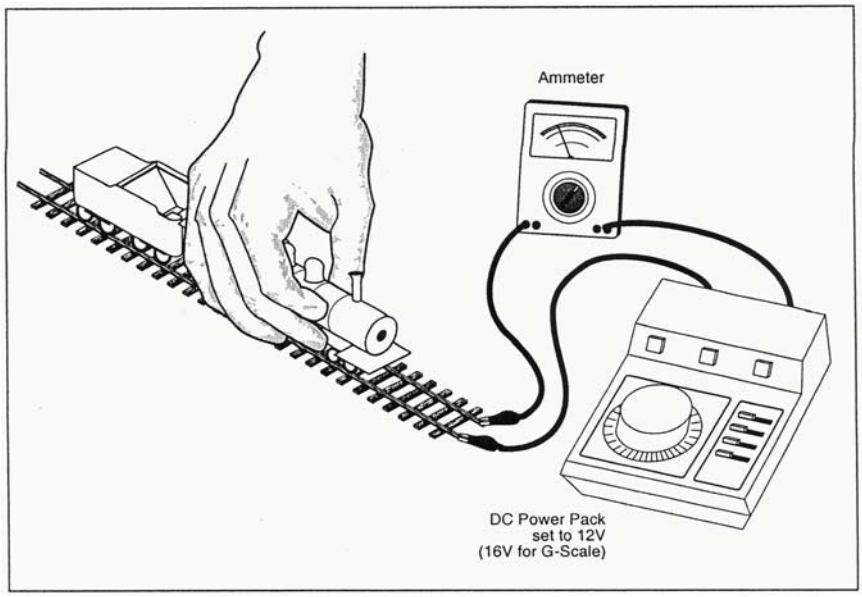


Figure 1 - Stall Current Test Setup

Step 2. Plan the Installation

You should give some thought to where the installation of the various RDSD components will be located within the locomotive before you start cutting parts of the model away. Figure 2 shows a typical installation.

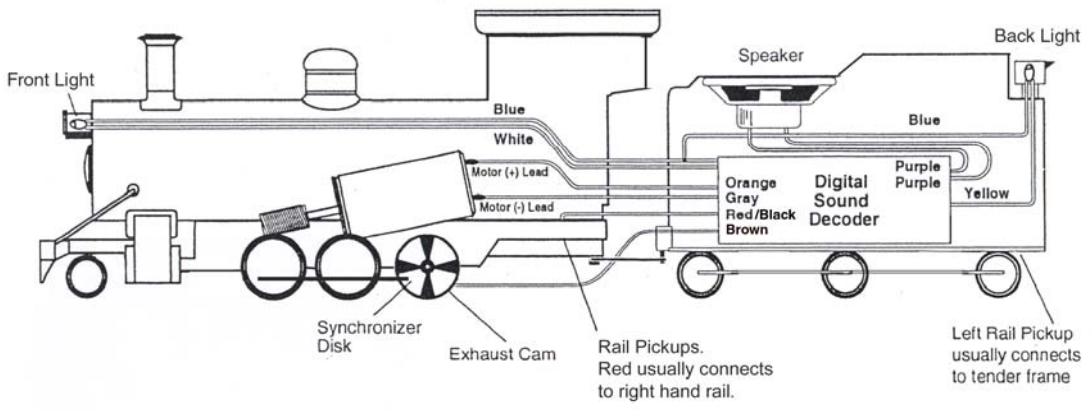


Figure 2 - Typical Sound Installation

The decision most critical to the success of your installation will be where to put the Loudspeaker. Obviously, the ‘where’ of speaker installation will depend on the size and type of the locomotive.

But when considering the speaker’s location, remember that the volume of the speaker will be greatly enhanced when the speaker is fitted into a small airtight enclosure with the front of the speaker open to surrounding air.

The reason for this is simple: in order to generate any appreciable sound, the speaker must develop air pressure. Without an enclosure, any pressure developed by the front of the speaker is cancelled by an opposite pressure behind the speaker. The enclosure isolates the front and back surfaces of the speaker, thereby increasing the sound pressure and hence, the volume.

Additionally, the enclosure must be sized proportionally to the speaker such that the volume of air enclosed is several times larger than the speaker diameter. If an enclosure is too small, it will interfere with the speaker operation and although it cannot be made too large, there is a point of diminishing return. As a rule of thumb, for small speakers, the minimum dimension for the length, width and height should be equal to the speaker diameter. Thus the smallest enclosure for a 1" speaker would be 1" X 1" X 1", while 2" X 2" X 2" would be the smallest size enclosure for a 2" speaker. This is only a general guideline, exceptions can and must be made in many circumstances, especially in 00/HO locomotives..

The use of acoustic wool to fill the enclosed space behind the speaker is strongly recommended. This reduces the resonance of the small enclosure and produces a better frequency response and much clearer chuff note

The use of a proper speaker enclosure cannot be over emphasised and failure to use one is almost always the cause for poor sound quality.

Fortunately, most steam engines have a tender and with a little work, the tender itself becomes an ideal Loudspeaker enclosure. The Loudspeaker can face up through the coal bunker or down through the floor. Either way will produce equally good sound. Using our Black Acoustic Matting, ZTC 161 allows a coal base to be made, through which sound will satisfactorily penetrate with no loss of quality. This then provides a suitable base on which a sprinkling of small coal particles can be glued using a dilute solution of latex glue such as Resin W, to form a protective Loudspeaker grill.

An alternative and sometimes better approach in 0 Gage (7mm/ft) models is to mount the Loudspeaker in the smoke box and allow the sound to come out through the open chimney.

You must use the largest speaker possible to get the best bass response. Some larger diameter speakers can, with great care, be trimmed down in width so they will fit within the tender shell. By building an internal baffle, they can also be mounted at an angle although this will reduce the available space for the RDSD module in some 00gauge tenders.

In small tenders, the speaker should be mounted rearward in the coal bunker area, where higher walls are available to cover the speaker magnet. In small tank engines where the coal bunker is part of the cab, a small Plastikard box can be manufactured with the loudspeaker mounted vertical. This box should be mounted in the coal bunker under the coal, with the loudspeaker facing into the locomotive cab. The sound can now exit through the cab doors.

For other locomotives, the speaker enclosure need not be fancy and can be fabricated from Plastikard or sheet polystyrene, plywood and even cardboard at a pinch! A 35mm film canister usually produces excellent results, as does the cardboard tube centre from a roll of paper towels.

The Digital Sound Decoder is best suited for installation in the tender of 4mm/ft models. For 7mm/ft or larger models, they can be fitted into the boiler/smoke box. Boiler installation has the advantage of requiring considerably less wires all of which have to be routed between the engine and tender. It will usually come at the expense of some boiler weight and possible reduction in traction.

It is even possible to fit the RDSD into an N gauge bogie wagon or coach and permanently couple the vehicle to the locomotive in question. It is however more common to fit the RDSD and a larger 4” or 6” speaker permanently across the track power BUS with the loudspeaker mounted beneath the base board. This approach provides an extremely realistic and effective solution to sound in the smaller scales.

It is normal for the RDSD to get warm after periods of extended operation and its built-in thermal overload protection will automatically shut down the throttle and audio amplifier if it gets too warm. Therefore, it is important to install the RDSD in a location where it can dissipate the heat. Avoid placing the RDSD near any heat sources such as the motor or lights.

You will also need to decide how you want to synchronise the exhaust chuff. The range of ZTC RDSD`s provides for two methods for synchronisation. The first method is to use the mechanical cam which works by opening and closing a switch contact mounted on the locomotive wheels or axle.

The exhaust cam switch is best mounted so it contacts the inside face of one driving wheel. This will give the most precise synchronisation and even produce a wheel slip effect if the locomotive is accelerated too quickly! In a pinch, the exhaust cam can be used with a tender axle, although the synchronisation effect will not be exact unless the tender wheel diameter is an exact multiple of the locomotive driver diameter. Alternatively a cam can be fitted to one of the driving axle’s, which operates a micro switch or similar set of contacts.

The other method of exhaust synchronisation is to use the very popular RDSD’s Auto-Exhaust feature which produces chuffs in proportion to the throttle setting. This method is recommended for those locomotives where a mechanical cam would be difficult to install such as N scale and smaller 00/HO locomotives. When used in conjunction with the programmable speed curves, it is difficult to tell the difference between the Auto Exhaust and the exhaust cam approach at all but the slowest speeds.

Next, you will need to consider which lighting effects you will use. The ZTC 47X RDSD`s provides four auxiliary function outputs which can be used for controlling miniature lamps, LED’s or even un-couplers Two of the outputs will usually be used for a front light and back light. These outputs may even be configured for automatic direction control such that the front lights are on when the locomotive is travelling in the forward direction and the back light is on when the locomotive is reversed, which is particularly useful on diesel decoders. The lights may also be setup for operation where the driver must manually turn each light on or off as appropriate on American locomotives this is referred to as “Rule 17” operation, for simplicity in this manual this notation is used to describe this style of operation.

The other two outputs provide programmable effects and may be used in a variety of ways:

- As a conventional on/off output. In this case they may drive additional bulbs for the cab light, running lights, number boards, small relays and un-couplers or other electronic circuits.

- As a Beacon light. In this mode it may be used to simulate the warning beacon found in front of some industrial diesel and steam engines.

- The outputs can also be set up to simulate the flickering glow from the firebox. This is best done by mounting an orange or red lamp underneath the locomotive's firebox area.

- A second version of the firebox flicker effect is available that turns on only when the sound of the firebox door opening has been activated and turns off when the doors "close". The lamp for this effect is best mounted in the cab behind a partially open firebox door detail.

Each light effects output can be independently set so it is possible to use one bulb as a Beacon light and the other bulb for the firebox.

The function outputs may also be used to control other electrical devices such as a smoke generator although you must be careful that such devices do not exceed the output's current rating (100 ma) in which case you will need to add a relay or other low current switching device. A clamping diode will also be required for inductive loads, such as a relay coils etc to avoid damage to the output transistor..

You must also be careful that the combined current drawn by each lamp and the locomotive's stall current does not exceed the decoder's total current rating.

Finally, you will need to decide whether or not to hardwire the electrical connections between the tender and the locomotive or use small micro connectors. Using a connector will allow you to separate the engine and tender for storage as well as make painting and servicing a lot easier. But can be unsightly on smaller models and also makes it possible too accidentally damaging the decoder by reversing the connector during assembly. Hardwiring the decoder will prevent this possibility but at the expense of making tender separation difficult.

ZTC Controls Ltd offers suitable micro-connectors for locomotive use, they are the ZTC 164 and ZTC 165. The particular connector you will use will depend upon the number of lighting functions you are using. The advantage of the individual connector pins such as the ZTC 165, is that they will allow you to disguise the connecting wires as vacuum, air or water lines, but they do require great care when reconnecting them so as not to incorrectly wire the decoder.

After you have fully read the installation manual, we suggest reviewing Step 8 on wiring the decoder and draw yourself a schematic similar to Figure 2 showing all connections between the RDSD and various sub-components. This will also help you determine which connector is best suited for your needs.

Step 3. Isolate the Motor

Pay careful attention to this step as it is the most important step in successfully converting any locomotive over to DCC operation.

The two motor brush connections must be electrically isolated so they are driven **exclusively** by the RDSD motor outputs of the ZTC 47X. If this is not done you will damage your decoder, and this type of failure is not covered by the product warrantee.

Failure to properly isolate the motor <u>will</u> always damage your decoder and turn it into an effective, but short lived smoke generator!

Please note that our RDSD warranty specifically excludes damage caused by improperly isolating the motor; however, in the event you do damage your decoder, do not despair. Simply return it to ZTC Controls Ltd and if we can we will for a small charge, repair and then return it to you.

Begin motor isolation by removing the boiler and tender shell from the locomotive and tender frame. Before you proceed further, it is important to carefully examine the locomotive wiring and determine where each wire goes and what it does. The manufacturer's assembly drawings may be useful here or you may decide to create your own wiring diagram. In particular, you will need to identify the connections to the left and right power pickups as well as the (+) and (-) motor connections. Note: Manufactures who follow the NMRA Recommendations and practices will make N, 00/HO, S and O scale locomotives with the positive motor connection the one connected to the right rail power pickup. On G scale locomotives, the positive motor lead is connected to the left rail pickup.

Disconnect all wires leading to both motor terminals. Note that some motor brush connections are made using a spring contact to the chassis. In such cases, it will be necessary to remove or modify the spring contact as well.

Be aware that some locomotives may make contact between the motor, frame and track work only when the body is reinstalled or the tender connected to the locomotive.

Next, verify that each motor terminal is electrically isolated from the left and right rail pickups using a multi-meter or continuity tester. With your meter set to the ohms scale, touch both meter probes together and note that the meter indicates 0 ohms (short circuit). You don't want to see this indication again! Touch one of the probes to one of the motor brush terminals. Touch the other probe to the locomotive frame, then the left rail power pickup wire, and finally to the right rail power pickup wire. Move the first probe to the other motor brush terminal and repeat the tests. If all tests indicate an open circuit, the motor is properly isolated. Do not proceed further until this is done.

You will also need to disconnect the wires leading to any lights you wish to use. If you plan to use the Full-Wave method of lamp wiring (see page 20), you must disconnect and isolate both lamp wires. Using an multimeter, check that each lamp lead is electrically isolated from the frame as well as the left and right rail pickups.

If you choose to use the Half-Wave method of lamp wiring (see page 20), leave one lamp lead connected to the locomotive frame or tender chassis provided the frame or chassis is electrically connected to the proper power pickup. This will allow you to use existing lamp sockets if your engine is so equipped. See page 20 "Lighting Outputs" for specific details.

<u>Step 4. Fit the Speaker.</u>

In most 00/HO Locomotives it is only realistic to consider fitting the loudspeaker in the tender, however in 0 gauge or larger then it becomes very practical and desirable to fit the loudspeaker in the body of the locomotive. In particular the smoke box is an ideal location,

In this case it is often simpler to mount an oblong miniature speaker in a small sealed plastikard box and slide it in to the smoke box, allowing the sound to exit through the open chimney.

In the 00/H0 locomotive, if the loudspeaker is wider than the tender, it will be necessary to reduce the loudspeaker width to get a proper fit. Determine how much the loudspeaker must be cut down and remove half of that amount from each side of the unit.

Loudspeakers with plastic frames may be trimmed down using a sharp flat file. File down each side – working slowly and alternate from side to side until the loudspeaker just fits within the tender shell. Be careful to remove only the frame and not the outer edge of the diaphragm. Avoid cutting into the diaphragm itself.

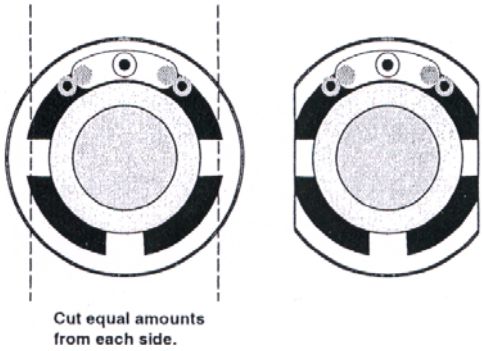


Figure 3 Modifications to a Loudspeaker.

Loudspeakers with metal frames can generally have a larger amount of frame removed and still maintain a satisfactory sound. On the back of the speaker frame, draw a line where the first cut will be made. Draw a second, parallel line marking the other cut. Make sure that neither of the lines cut into the loudspeaker coil wires.

A small modellers electric power drill with an abrasive cutting wheel will make the job of cutting a metal speaker much simpler. **Be sure to wear safety glasses!** Hold the speaker face down and make shallow cuts along each line until the frame has been cut through take great care that steal dust does not get into the speaker cone as this will degrade the sound quality. Iron filings that adhere to the loudspeaker magnet may be carefully removed with Bluetack or low tack Magic tape. Trim all plastic speakers frames with a sharp scalpel or razor saw.

Check the fit of the Loudspeaker into the installation site and trim the speaker frame and cone as needed until the desired fit is achieved. For best performance, the speaker should fit snugly within the tender or enclosure so that the edges of the speaker cone are as close to the sides as possible without actually touching. **Do not** allow the speaker cone to rub the tender walls as this will produce a “scratchy” sound. Likewise, an air gap will reduce the speaker’s bass response but can be filled in with Plastikard or thin cardboard packing if required.

Step 5. Modify the Tender Body and Floor.

Depending upon your choice of tender, you will possibly be mounting the speaker facing down on the tender floor or facing up in the coal bunker. In either case, a certain amount of “body work” is usually necessary to accommodate the speaker and decoder. This may include removing weights, mounting brackets, internal bracing and other structural features.

You will probably need to cut an opening in the tender shell or floor for the speaker. A series of small holes can be easily drilled and will work as well as one large hole provided the open area is at least one half the area of the speaker cone. In either case, there should be no openings outside or larger than the speaker cone itself.

Tender Body Modifications

On tenders with low side walls, the speaker is often best mounted facing up in the coal bunker so as to provide adequate clearance for the RDSD which will be mounted against the tender floor.

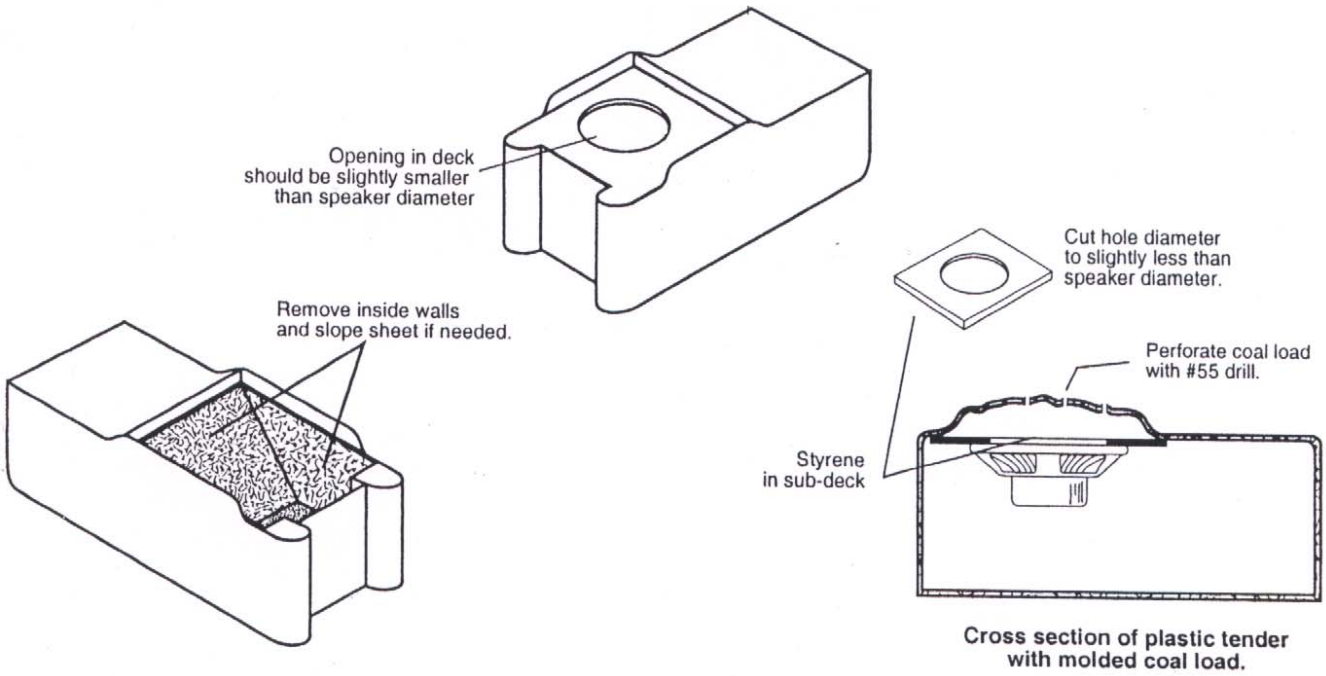


Figure 4 - Tender Shell Modifications

The simplest tenders have a flat deck across the coal bunker and are the easiest to deal with. Simply mark or scribe the speaker outline onto the tender deck and using a Piercing saw with a fine blade (Number 2/0), cut out a circular opening about 1/16" inside the outline marks. Remove all sharp edges and burrs.

The Loudspeaker is then disguised by covering the opening with an acoustically transparent coal load. The coal load can be fabricated by contouring a piece of black Acoustic Mating such as ZTC 161, to represent a coal load. Then cover it with a very thin layer or sprinkling of scale coal cemented in place with a thin wash of diluted white PVA glue such as a 50-50 water and Resin W mix.

Plastic tenders often have a moulded coal load already in place. Unfortunately, many of the inside surfaces of such tenders are also contoured to match the coal load and do not provide a flat mounting surface for the loudspeaker. In such cases, the modeller has two options. The first is to cut out and remove the coal load entirely and replace it with a flat sheet of 0.060" or thicker plastikard or styrene and then proceed as described above for the flat decked tenders.

Alternatively, a sub-deck can be fabricated also from 0.060" sheet Plastikard or styrene such that it fits below the coal load tightly against the tender sides. Cut a large circular opening suitable for the speaker diameter in the styrene sheet and then glue the sub-deck to the inside of the tender shell. Perforate the coal load by drilling a series of small holes (use a 1.5 to 2 mm or Number 50 to 60 size drill) at random angles between the coal “nuggets”. This way, the sound will be allowed to escape yet the speaker remains relatively invisible regardless of viewing angle.

The more realistic tenders will have fuel bunkers that prototypically extend to the tender floor. For larger tenders with such a feature, the speaker is best mounted on the tender floor. For smaller tenders, the slope sheet and interior walls will not only interfere with the speaker, but the decoder as well and it will usually be necessary to remove and replace them with a sheet of wood, brass, plastikard or styrene to create a flat topped tender.

Tender Floor Modifications.

If you are mounting the loudspeaker to the tender floor, first determine the exact speaker location within the tender and verify that there is adequate clearance between the wheels, tender body and loudspeaker magnet. Use a marker or scribe to note the location of the speaker on the tender floor and then drill three rows of holes (see Figure 5) in the pattern shown to provide an opening for the sound to escape. A drill bit of approximately 4 mm in diameter (150") is a good size. Use an 8 mm (0.30”) drill bit to de-burr all holes on both sides of the material. Space the holes as best you can, taking into consideration the tender underbody detail. Although the spacing is not critical, you should attempt to provide at least this much of an opening. If necessary, use more holes of a smaller diameter. It is important to keep all the holes within the expected cone area of the speaker. Take care not to place holes at the outer edge of the Loudspeaker assembly itself.

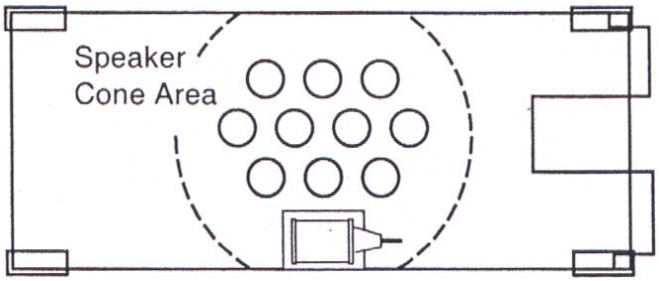


Figure 5 - Tender Floor Modifications

Once you have drilled your holes, remove all the burrs and uneven edges from both sides of the material with a de-burring tool, or at a pinch an 8 mm (0.3” drill bit). Makes sure there are no material burrs or sharp edges projecting up to damage the loudspeaker cone. The speaker floor should be smooth, with nothing to physically interfere with the speaker’s ability to lay completely flat on the tender floor, such as solder joints, screw bosses, and mounting studs.

Secure the Speaker in Place

Once body work is complete and the speaker has been fitted in place, it must be secured tightly to the enclosure. **If it is not secured then it will vibrate and sound scratchy**. For the best sound, an airtight seal is needed around the speaker edge this is achieved when the loudspeaker is mounted in a separate enclosure (Box) such as in the smokebox of a gauge 0 locomotive. However in 00/H0 locomotives with the loudspeaker in the tender, we have found the best way to hold the speaker in place is to use silicone RTV. This provides a secure fixing and the airtight seal needed. Unlike epoxy or other hard glues this approach allows the speaker to be readily removed in the future. **Do not get any RTV onto the speaker cone itself as this will severely distort the sound quality!**

Step 6. Install the Lamps

Front lights or Front lights, Back Lights and Beacon Lights.

Drill out the front/front light castings to accept any lamp bulbs or LED's you intend to use, including the tender back light. If you are using ZTC 162 1.5V, 1.3mm micro bulbs, a No 53 (1.6mm) twist drill makes a perfect hole. If you are using the larger, 2.5mm micro bulbs, ZTC 163, a number 41 (2.1mm) twist drill works well.

Test fit the microbulb in the hole to check for adequate clearance and enlarge the hole if necessary. Next, paint the lamp reflector surface with white or silver paint and allow to dry.

Install the light bulbs and secure in place using a flexible glue that does not bond well to glass such as PVA white glue, rubber cement or RTV. Epoxy or Cyanoacrylate glues will make bulb replacement very difficult and occasionally actually break the bulb during the curing process and are therefore not recommended.

As a final touch, install a lens using white glue to hold it in place. You may wish to use a commercially available lens such as those offered by MV Lenses or make your own. A lens can be easily fabricated from a sheet of clear polystyrene or alternatively, moulded from a drop of clear epoxy that is allowed to flatten and harden on a non-stick surface.

Firebox Lights

The firebox lights should first be coloured with a thin coat of orange paint followed with a few streaks of red and yellow. Humbrol make a variety of transparent glass enamels for modellers that work well for this purpose. Alternatively, you can use red or orange LED's in which case painting is unnecessary.

The firebox light should be mounted between the locomotive frames in the general vicinity of the ash pan. The idea is that the bulb is never directly visible but rather casts a gentle glow onto the ground below. The bulb may be held in place with silicone RTV or a Hot-melt Adhesive.

If you are using the RealFeel™ Intelligent Firebox Flicker effect, you may wish to modify the locomotive's firebox door so it is slightly open and then mount the bulb directly behind it. In this manner, when "Fireman Pete" puts a few scoops of coal into the fire, the cab will fill with a soft orange glow.

Step 7. Install the Exhaust Cam (Optional).

If you are intending to synchronise the steam exhaust chuff using a mechanical cam switch, you have a little more work to do! Otherwise, if you are planning to use the RDSD's Auto-Exhaust feature, you may skip this step.

ZTC Controls Ltd offers its ZTC 166 Exhaust Cam Kit as an easy to install alternative to traditional axle mounted sound cams. The Exhaust Cam set provides nine different synchronising disks of varying diameters and configurations. Installation is straightforward and unlike the traditional axial cam, has the advantage that the drive wheel does not need to be removed from the axle.

Begin by selecting the synchroniser disk pattern appropriate for your engine:

2-Cylinder Steam Locomotives.

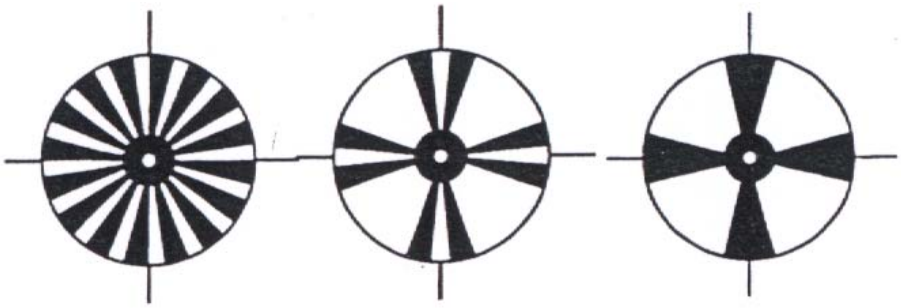
In all conventional 2-cylinder steam engines, use a synchroniser disk with 4 foil segments. You can achieve the proper prototypical exhaust chuff timing by aligning the foil strips of the synchronising disks to the crank pin on the driver wheel.

Compound Steam Locomotives.

On compound engines, one set of cylinders is considerably larger than the second set, but 4 chuffs per driving wheel revolution is correct. Install the same as for regular locomotives.

Geared Locomotives

Geared engines require a larger number of chuffs due to multiple cylinders and gearing of the drive wheels. Due to the large number of contacts required for each wheel revolution, it is usually impractical to achieve the prototypically correct number of exhaust chuffs per revolution. The Shay disk (supplied with the Exhaust Cam set) will provide a reasonable compromise. Optionally, you may elect to use the Auto-Exhaust feature.



Install the Synchroniser Disk

Carefully measure the diameter of your locomotive's driver axle. Drill a hole of the same diameter in the centre of the synchroniser disk you plan to use. Note: the thin disk material will be easier to drill if you temporarily adhere it to a smooth wood block with a water soluble glue (or low tack double sided tape). The disk can then be separated from the block by soaking in water after the drilling operation is complete. Be sure to use a sharp drill to get a clean burr-free hole.

Once the hole is drilled, check that there is still enough foil at the 'hub' to connect all the spokes together. If not, you will need to use a synchroniser disk with a larger hub.

Cut the disk out with a sharp pair of scissors or metal sheet cutters and trim the diameter to slightly less (approximately 2.5 mm) than the diameter of locomotives drive wheel. **This is important** as clearance will be needed to clear point frogs, check rails, and other track work features.

Using the pair of scissors, make a single radial cut in the disk between the foil spokes from the outer edge to the centre hole. Slip the disk over the drive axle with the insulated side facing against the drive wheel. Check for a correct fit and make any needed adjustments. The disk should fit centrally and flush against the drive wheel and there should be a close fit on the axle. Once you are satisfied with the fit, glue the disk against the drive wheel with epoxy or contact cement.

You will need to electrically connect the synchronising disk to the rim of the driving wheel. This is best done by soldering a wire from the driving wheel rim to the foil. However it is simpler to use ZTC 167 which is an epoxy based conductive adhesive/paint supplied in small bottles.

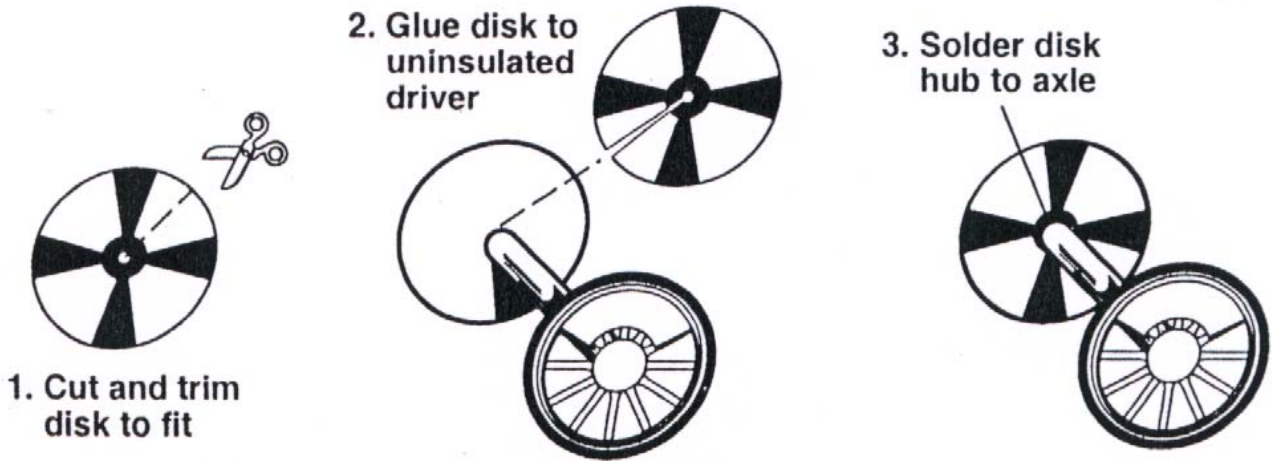


Figure 6 - Synchroniser Disk Installation.

Install the Cam Wiper

Using the spring wire supplied with the Exhaust Cam set, fabricate a contact wiper. Bend the wire to match the pattern of Figure 7 using a pair of round nose pliers.

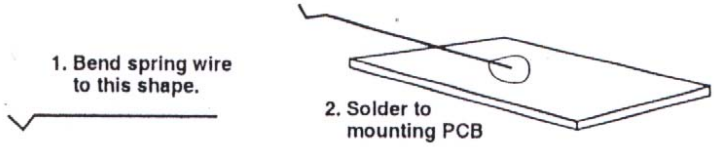


Figure 7 - Cam Wiper Fabrication.

Solder the wiper to the small printed circuit board base as shown in Figure 7. Keep the spring wire as long as possible to provide flexibility. If the wire is too short, it will rub against the synchroniser disk with excess force causing premature wear and possible binding.

Temporarily mount the insulated side of the wiper base to the locomotive frame such that the wiper end barely rubs against the synchroniser disk and does not touch any other part of the locomotive. Referring to Figure 8, adjust the spring wire so that the contact point is centered directly below the axle and its plane is parallel with the top of the rail. Once the wiper has been properly adjusted, move the wiper base until the spring wire is deflected by about 0.75 to 1.5 mm (1/32" to 1/16") and secure the base in place with epoxy or Cyanoacrylate.

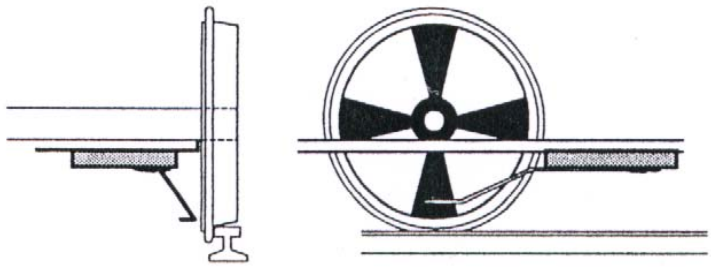


Figure 8 - Contact Wiper Alignment

Step 8. Install and Wire the Decoder

Begin by securing the decoder in place using a self adhesive double sided foam pad. Temporarily refit the body shell to ensure that adequate clearance still exists.

When wiring the decoder, trim all wires to reduce unnecessary lead length. This will not only give your installation a neater appearance but also prevent wires from interfering with the drive mechanism and getting pinched between the frame and body shell.

Remember that you should have tested your decoder prior to cutting the leads short.

To ensure long-term reliability, solder all connections and insulate with heat shrink tubing. ZTC Controls Ltd has heat shrink tubing available for this purpose in our Zippi Pack's, part no. ZTC 399.

A separate connector should be used for the cam switch (if used) and wired to a ZTC 165 connector.

It is also recommended that the female end of all connectors be wired to the decoder side of the harness. If the connector becomes unplugged, it is less likely for the female end to inadvertently come in contact with a potentially harmful electrical signal.

Motor and Power Connections for ZTC 47X.

The RDSD uses two wire harnesses both colour-coded to the NMRA Standard:

POWER, MOTOR AND LIGHTS (9-Pin Connector Pin-outs)

1	GREEN	F1 Power Sink
2	RED	Right Hand Rail Power Pickup
3	ORANGE	Motor (+) Terminal
4	BLUE	Function Common (+Raw)
5	WHITE	Front Light Power Sink
6	YELLOW	Back Light Power Sink
7	GREY Motor	(-) Terminal
8	BLACK	Left Hand Rail Power Pickup
9	BROWN	F5 Power Sink

SPEAKER AND CAM harness (3-Pin Connector Pin-outs)

10	PURPLE	Speaker (-)
11	BROWN	Cam Input
12	PURPLE	Speaker (+)

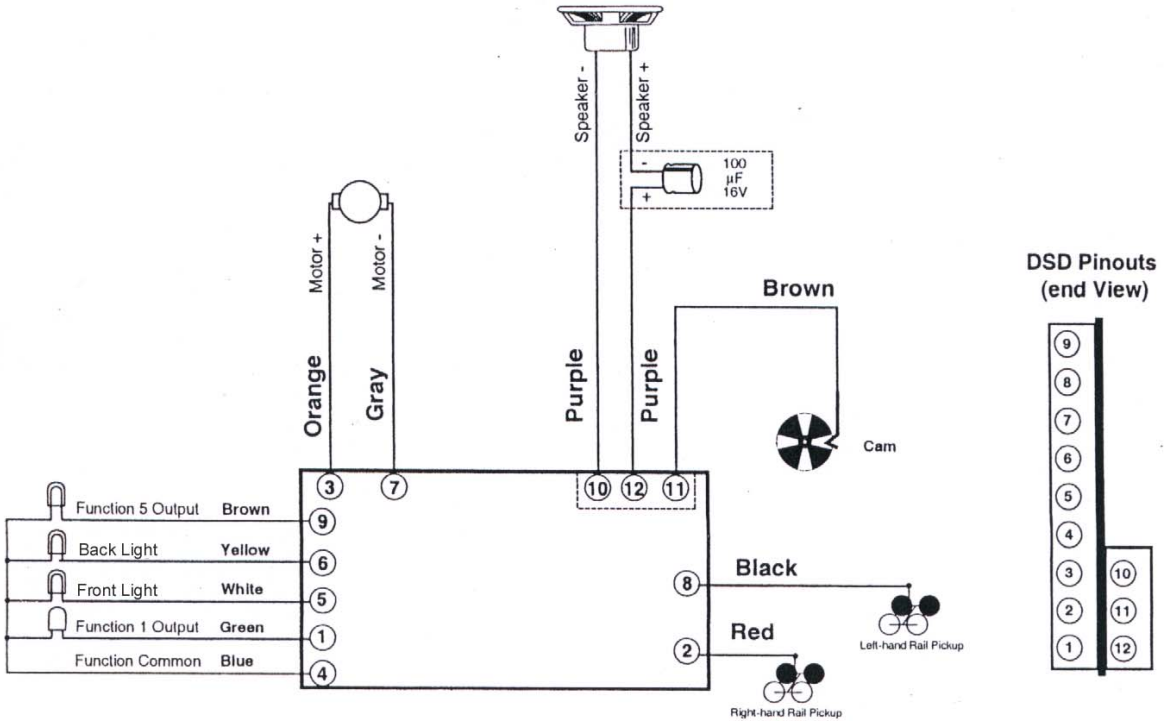


Figure 9 - Master Wiring Diagram

Referring to the master wiring diagram (Figure 9), begin with the power connection.

1. Connect the decoder's RED wire to the right hand rail power pickup.
2. Connect the decoder's BLACK wire to the left hand rail power pickup.
3. Connect the decoder's orange wire to the motor's (+) brush terminal.
4. Connect the decoder's grey wire to the motor's (-) brush terminal.

BE ABSOLUTELY SURE THAT THE CONNECTIONS TO THE MOTOR ARE ISOLATED FROM EVERYTHING OTHER THAN THE DECODER CONNECTIONS DESCRIBED ABOVE, AND MAKE SURE THERE ARE NO SHORT CIRCUITS.

Motor and Power Connections for ZTC 45X.

INSTALLATION The ZTC 45X wires are colour coded as follows:

1. BLACK Left Hand Rail Power Pickup
2. PURPLE Speaker (+)
3. BROWN Cam Input (Steam Only)
4. PURPLE Speaker (-)
5. RED Right Hand Rail Power Pickup

Referring to the master wiring diagram (Figure 1), begin with the power connections.

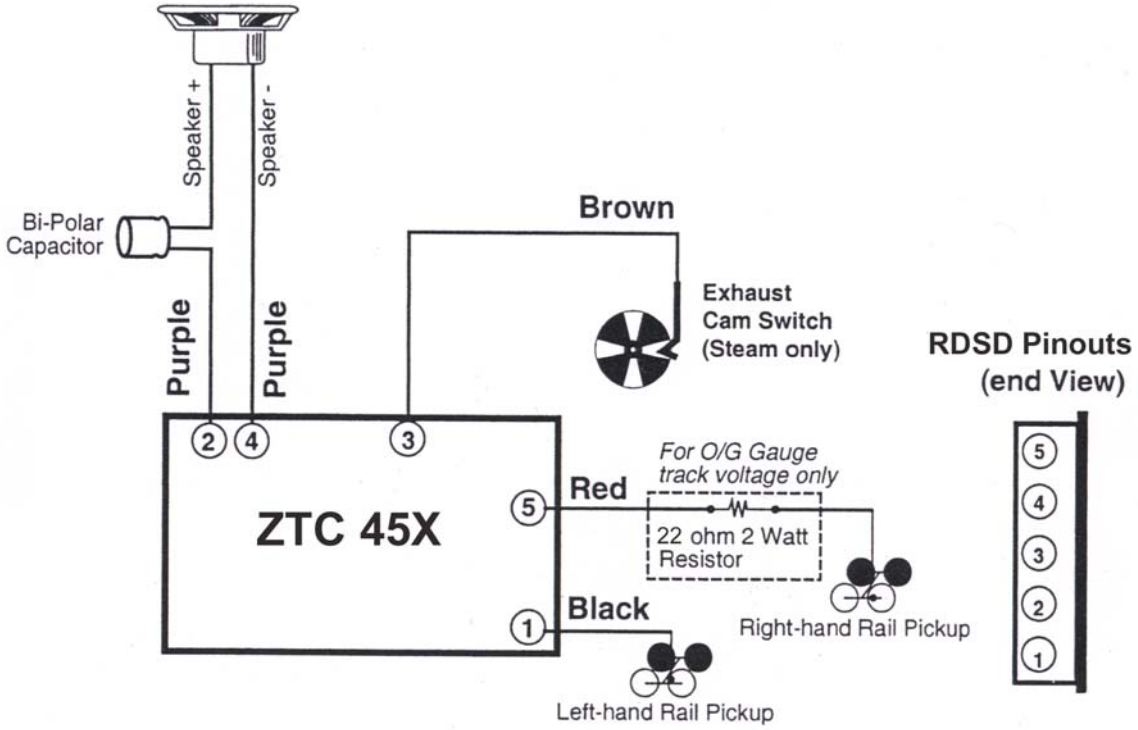


Figure 1 - Master Wiring Diagram

IMPORTANT!

Many command stations have adjustable track output voltages. The DSX is designed to operate with track voltages between 7 and 18 volts, typical of N and HO scale settings. To use the ZTC 45X with larger scales at higher track voltages, a 22 ohm, 2 watt resistor (ZTC 152) **must** be wired in series with the RED power lead to prevent overheating and damage to the audio amplifiers.

1. For Track Voltages:-

a. Less than 18 volts:
Connect the decoder's RED wire (pin 5) to the right hand rail power pickup. Proceed to Step 2,

b. Greater than 18 volts:
Connect the decoder's RED wire (pin 5) to one lead of the 22 ohm power resistor. Connect the other resistor lead to the right hand rail power pickup. Note: when programming the ZTC 45X on a programming track, this resistor may interfere with proper operation and will have to be temporarily bypassed until programming is completed. You may wish to install and wire a small switch (not included) across the resistor to allow it to be easily bypassed without disassembling the locomotive.

2. Connect the decoder's BLACK wire (pin 1) to the left hand rail power pickup.

3. Speaker Connections
Connect the PURPLE speaker(+) wire (pin 2) to one lead of the bipolar capacitor included with the ZTC 45X **(Do not use polarised capacitors)**. Connect the other capacitor lead to one of the speaker terminals. Connect the other speaker terminal to the PURPLE speaker-) wire (pin 4).

4. Cam Connections (Optional, Steam DSX only)
Connect the BROWN wire (pin 3) to the cam wiper switch. If you are using the ZTC 45X auto-exhaust feature, leave this wire disconnected.

Speaker Connections.

5. Connect the decoder's PURPLE wires to the plus and minus terminals on the speaker. If you have installed multiple speakers, make sure they are phased properly, i.e., connect them in parallel; positive lead to positive lead and minus lead to minus lead of each speaker.

   A 33µf, 16V bipolar capacitor must be wired in series with the speaker (+) wire (pin 12). The positive (+) lead of the capacitor should connect to the RDSD wire. The negative (-) capacitor lead should connect to the speaker as shown in Figure 9.

Lighting Outputs

Each ZTC 47X series of RDSD is equipped with four function outputs that are intended to drive front and rear lights, and special effect lights. Each output is rated for 100mA.

Do not exceed this rating! Be sure that the combined current of all lights as well as the motor stall current measured in Step 1 does not exceed the decoder rating.

The lamps may be wired for one of two modes of operation: full-wave and half-wave. Full-wave operation is the preferred wiring method and supplies power to each lamp via the common BLUE wire. The advantage of the full-wave wiring scheme is that the lamp brightness will be unaffected when the layout is operating another locomotive as LOCO 0 in analogue mode.

The half-wave wiring method has the advantage that the BLUE common wire is not used meaning there is one less wire connection to the decoder which may be an issue when installing the RDSD into smaller locomotives. The primary drawback is that lamp brightness will change when operating another locomotive as LOCO 0, in the analogue mode.

The RDSD lighting outputs may be used with 12-16 volt incandescent lamps, 1.5 volt micro bulbs or LED's. If you are using the RDSD to drive 12-16V lamps, each bulb can be directly wired to the function outputs as shown in Figure 10. If the lamps draw more than 50mA, wire a 22 ohm, 1/4W resistor ZTC 152 in series with each lamp to prevent the lamp start-up currents from overloading the decoder outputs.

If you are using the RDSD to drive 1.5V micro bulbs, it will be necessary to wire a small current-limiting resistor in series with each of the lamps to prevent them from burning out. A 560 ohm, 1/4W resistor ZTC 153 is recommended for use with ZTC Controls Ltd micro bulbs, however, you may need to adjust this value to get the desired brightness depending on the output voltage of the command station. Lower resistances will increase the brightness of the lamp, higher resistances will reduce the lamp brightness.

The RDSD may also be used with LED's, which also require a resistor, typically about 680 ohms, 1/4W such as the ZTC 154. Note that LED's are sensitive to polarity. The negative (minus or cathode) end of the LED must be connected to function output and the positive (plus or anode) end should be wired to the decoder's BLUE or common wire.

Note: LED's are not suitable for use with the Beacon Light effect.

1. To wire the Front light, connect one end of the bulb (or cathode of a LED) to the decoder's WHITE wire. Wire the other bulb or LED lead to the decoder's BLUE wire for full-wave operation. For half-wave operation, the other bulb lead may be connected to either the left or right hand rail power pickup as convenient.

2. To wire the Back light, connect one end of the bulb (or the cathode of a LED) to the decoder's YELLOW wire. Wire the other bulb or LED lead to the decoder's BLUE wire for full-wave operation. For half-wave operation, the other bulb or LED lead should be connected to either the left or right hand rail power pickup as convenient

3. To wire the Function 1 output, connect one end of the bulb (or cathode of a LED) to the decoder's GREEN wire. Wire the other bulb or LED lead to the decoder's BLUE wire for full wave-operation. For half-wave operation, the other bulb or LED lead may be connected to either the left or right hand rail power pickup as convenient.

4. To wire the Function 5 output, connect one end of the bulb (or cathode of an LED) to the decoder's BROWN wire. Wire the other bulb or LED lead to the decoder's BLUE wire for full wave-operation. For half-wave operation, the other bulb lead may be connected to either the left or right hand rail power pickup as convenient.

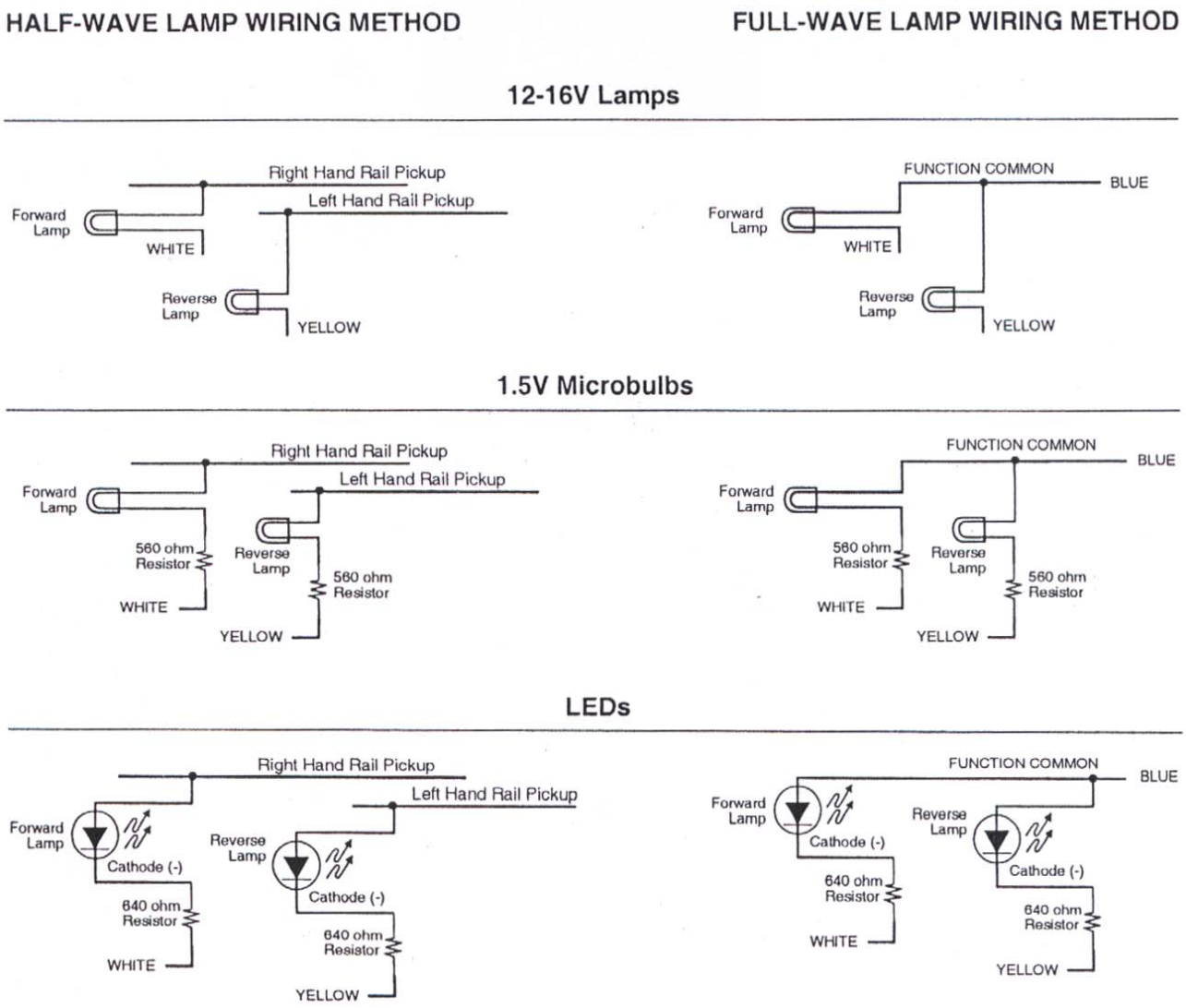


Figure 10 - Lamp Wiring Diagram

Any outputs not used can be left disconnected, but you must cut off and insulate the ends of the wires with heat shrink tubing so they do not come in contact with any part of the locomotive or the locomotive wiring.

Cam Connections

Connect the decoder's BROWN wire from the 3-pin Speaker/Cam Connector (pin 11) to the cam wiper switch.

This completes the wiring.

Double check all of the wiring and verify that all the joints are insulated and there are no short circuits. Be sure that **BOTH** motor brush connections are completely isolated from all of the other connections, other than to the decoder's Orange and Grey wires.

Reassemble the locomotive. Be sure that no wires are pinched between the various assemblies and that there is no interference with moving parts that could causing chafing and short circuits in the future.

Step 9. Test the Installation.

Now you are ready for the test track!

If you are using any other system other than a ZTC 511 OR 505 controller then we strongly recommend your test track be fused with a fast-blow fuse appropriately rated for your decoder (i.e. 1 amp decoder therefore fit a 1 amp fuse).

If you are using a ZTC 511 OR 505 then use the programming track which is limited to a maximum output of 100 ma.

Place the locomotive on the test or programming track, and turn on power to the system. Once the controller has Booted up then turn the power on to the set up track. Set your controller so commands are sent to locomotive address 03.

After a second or two you should hear the locomotive gently simmering and fireman Pete shovelling coal into the firebox. Occasionally the blower may turn on and off and you should be able to run the engine in both directions as well as turning the lights if fitted on and off with the function keys.

If the locomotive does not travel in the appropriate direction, you have reversed the polarity of the motor brush connections. Turn the power off, change the ORANGE and GREY motor leads over and try again. It is possible to do this by setting CV 29 = to 3, but it may upset the lighting configuration. If everything seems OK at this point, it is time to program the decoder's Configuration Variables (CV`s) to get the desired sound and lighting effects.

Step 10. Program the CV`s.

The final installation step is setting the RDSD's (Configuration Variables) or CVs, this is often refereed to as programming the decoder, but this is a grand title for a simple process, which should approached in a relaxed manner.

But before we proceed it may be worth reviewing what we are about to do, as understanding this is straight forward, but important.

First, What is a CV?
CV stands for Configuration Variable which is the industry adopted term for a decoder's user-programmable memory locations. Simply put it's the name given to the pigeon hole that the required value between 0 and 255 are place in. CVs allow you to customise individual decoder properties such as the address, momentum, throttle response, sound volume and much, more. Once a CV has been set (or programmed), it will be permanently remembered even after the power has been turned off. A CV can be modified as often as you want by simply resetting (reprogramming) it with a new value.

The NMRA has defined over 70 standard CVs and their usage in a document called RP-9.2.2. Most of these CVs have been uniformly implemented by the various DCC component manufacturers including ZTC Controls Ltd, resulting in a high degree of standardisation, particularly with products designed after July, 1995 when the standards and recommendations were formally agreed upon.

For example, the Locomotives and therefore the decoder's identity number, (also known as the primary address), is always stored in CV 1. Be aware that there are also a number of CV`s which have been designated as "Reserved for Manufacturer Use". This allows a specific manufacturer to add a feature that is unique to their range of products. The ZTC Controls Ltd RDSD has several such CVs used primarily for customising the sound and lighting effects, but in the interests of commonality we have, where ever possible, used the same CV`s as our partners Soundtraxx.

With the large number of CVs available, first inspection of the available options may cause confusion and perhaps even cause the brain to boggle but relax, we have broken the process down into easily manageable steps that are easy to understand.

To assist in this matter the RDSD has been shipped with all CVs pre-programmed so you can begin using your locomotive immediately without having to worry about what adjustments to make or even fitting the mechanical cam switches.

Table A summarises the RDSD's default operating characteristics as shipped. Simply set your controller to address 03 and away you go! Be sure to also set your controller for 28 speed step mode or the lights may not operate as expected.

After a short time you will probably want to make some changes such as selecting a new address or changing a sound effect. The following paragraphs break the RDSD's CVs into various subsystems so it is only necessary to change a few CV's at a time. As you become comfortable with the RDSD's operation, move onto a new section and begin exploring the options and capabilities found there. Detailed information on any CV can be found in the **RDSD Technical Reference** located in Part II of this manual.

Table A ZTC Controls Ltd RDSD Default Operating Characteristics

Address	= 03
V start	= 7
Acceleration	= 0
Braking	= 0
Consist Addressing	= Off
Speed Steps	= 28
Speed Tables	= Not used
Lighting Control	= Automatic Direction Control
F1 Effect	= On/Off
F5 Effect	= On/Off
Audio Volume	= 50%
Background Sound	= All on.
Exhaust Sync	= Regulator

Function Mapping:

F0 = Front Light (forward) and Back Light (reverse) On/Off
F1 = F1 Function Output
F2 = Whistle long
F3 = Whistle short
F4 = Hiss
F5 = F5 Function Output
F6 = Not used.
F7 = Coupling Sound Trigger
F8 = Audio Mute

Bits and Bytes

One of the most confusing aspects of setting a CV is figuring out what the all the different bits, bytes and x's found on the various decoder manuals (including this one) mean. The problem is compounded further by differences in each command station manufacturer's user interface. For those users unfamiliar with such terms, a short math lesson may be helpful before proceeding:

Each decoder CV stores a numeric value that can be represented in one of three forms:

Decimal - This is the form we are all familiar with and use in our day-to-day lives. Numbers are represented as a sequence of digits composed of the numerals 0,1,2,3,4,5,6,7,8, and 9.

Hexadecimal - Also referred to as simply "hex", this is a more specialised number representation that, in addition to 0 through 9, also uses the characters A-F. It has the advantage that a given decimal number can be more compactly represented. For example, the decimal number 127 is simply 7F in hex (this uses one less digit), which allows user interfaces with a limited number of digits to display a wider range of numbers.

Binary - Binary numbers get their name from the fact they use only two digits 0 and 1 these are called '*bits*' and is the fundamental number system used by all computers including the ones found inside a digital decoder. Because there are only two bit values, it takes more digits to represent a number using binary. The decimal number 127, for example, is written as 01111111 in binary notation. A '*byte*' is a binary number made up of eight bits. And a '*nibble*' is half a byte or four bits.

Coincidentally, each CV is made up from one byte or eight bits and can store any number between 0 and 255. Most of the CVs contain a single piece of data that can be easily represented in any of the three forms. i.e., CV 3, the acceleration rate, can be loaded with any value from 0 to 255 and it always affects the same thing - the acceleration rate.

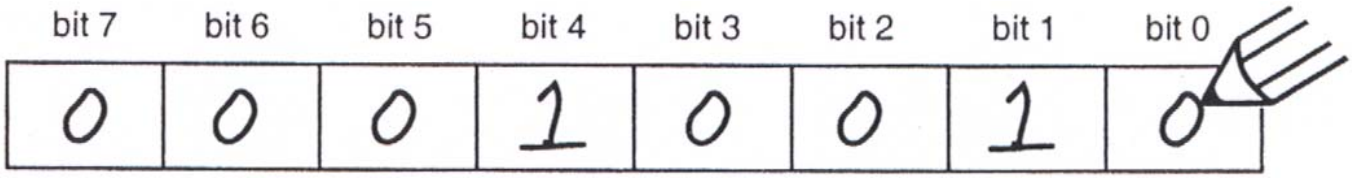
On the other hand, some CVs use individual bits to represent different variables. This allows a CV to hold up to eight individual variables within a single byte and is done in order to conserve the numbers of CVs. As the bit variables can take on only one of two values 0 and 1 they are usually used for simple variables that are either On or Off, enabled or disabled or something similar. Unfortunately, bit variables are difficult to represent in any form other than binary and still preserve any meaning. Because most DCC system user interfaces don't use binary representation, these numbers are the most difficult to work with and require a tedious series of additions to convert to the decimal or hex form used by most systems.

The ZTC 511 OR 505 Master controller greatly simplifies this process and enters all CV values in decimal and then displays both notations in its display panel as a check.

Also whenever possible, we have tried to use the decimal number system in this manual when describing the proper values to program into a given CV. For users of the systems that only use hexadecimal numbers, we have also shown the hex equivalent in parenthesis. Throughout this manual, a hex number can be distinguished from a decimal number by noting a **0x** prefix. Thus 0x10 is the hex version of sixteen and not ten as one might guess. Binary numbers are represented using a **'b'** suffix. 100b is thus the number four and not one hundred.

To further assist the operator, we have provided a handy conversion table in Appendix C that allows you to quickly convert between decimal, hex and binary.

When working with bit variables such as CV 29, we suggest the following procedure for determining the correct value to program. Referring to the CV description, write down from left to right, the value of each individual bit. Consider for example, the case of CV 29. We would like to set this CV so the speed tables are enabled and the 28 speed step mode is in effect. Referring to page 21 in the **RDSD Technical Reference**, we see that bit 4 and bit 1 should be set to 1 and all other bits are set to 0. Starting with bit 7 and working to the right, we write down the individual bit values and get:



We then look up the value Binary value 00010010b in Appendix C and see that it corresponds to the decimal value 18 (0x12 in hex). This is the value to use when programming the CV.

Setting or Programming Procedure
There are six methods for programming the RDSD which fall into one of two classifications:

Service Mode Programming - These programming modes usually require the locomotive to be placed on a special programming track or connected to a dedicated programmer. There are four types of service mode instructions:

Address Mode - Can change CV 1 (Primary Address) only.

Register Mode - Can change CVs 1,2,3,4,7,8 and 29 only.

Paged Mode - Uses a page register to indirectly modify any CV.

Direct Mode - Can directly change any CV.

Operations Mode Programming - Sometimes called 'Ops Mode' or 'Programming on the Main', these programming modes allow the CVs to be changed while the locomotive is operating on the layout even when other locomotives are present. The clever thing about these modes is that the CVs can be changed in the middle of operation allowing the engineer for example, to change the increase the momentum rate of a locomotive after it couples to a train. There are two forms of this programming mode:

Operations Mode Short Form - Uses an abbreviated packet format and allows only CV 23 and 24 (consist acceleration and braking) to be modified.

Operations Mode Long Form - Allows any CV to be modified.

Note: The RDSD imposes the restriction that CV 1, CV 17 and CV 18 cannot be changed in this mode to prevent accidental modification of the locomotive's address during operation.

It is important to realise that not all programming modes will program all CVs. The **RDSD Technical Reference** lists the programming modes that may be used for each CV.

The specific programming mode you use will depend upon the type of DCC system you are using. Some DCC systems can automatically select the proper programming mode so all you need to do is specify the CV number and its new value. On the other hand, some systems support only a few of the programming modes and may restrict which CVs you can program. If in doubt, refer to your DCC system's manual or contact the manufacturer to determine which methods they support.

If you have trouble reading or verifying CVs, the problem may be due to the design of your command station and not the RDSD itself. The RDSD and all other decoders communicate back to the command station using what's called an acknowledgement pulse, which is defined in NMRA RP-9.2.3 as "an increased load on the programming track of at least 60mA for at least 50ms." Like most decoders, the RDSD generates the acknowledgement pulse by momentarily applying power to the motor. You can often visually verify that the RDSD is properly responding to your programmer by observing a slight twitch in the motor shaft when a read or write command is given.

If your RDSD appears to be working properly (i.e., responds properly on the mainline to speed and direction commands), but your command station is having troubles reading CV data from the RDSD. It may be due to incompatibilities between the electrical requirements of the RDSD (which are different from conventional decoders due to the added audio circuitry) and the electrical characteristics of your programming track. In such an event, we suggest you simply go ahead and program the data into the CVs anyway. Usually the RDSD will accept the data and function properly when it's placed back on the main track. You can also try a different programming mode.

The Best way to program your RDSD with the ZTC 511 OR 505 is to use paged mode, but if your particular system supports Operations Mode, then use this method as it allows you to immediately see or hear the results of your changes.

As each DCC system is different, the specific procedure for programming a CV will vary depending upon the system. We have summarised the basic programming steps for several of the most popular systems below. For more information, as well as programming procedures for all other systems, please consult your DCC system manual.

ZTC 511 OR 505 Master Controller.

1. Place the locomotive on the programming track.
2. Switch the power to the program track on.
3. Press CLEAR, POINT, LOCO, enter the CV number,
4. Press PRESET followed by the value required. Press ENTER R.
5. Confirm this action by pressing ENTER R a second time.
6. Display will probably read "Track Overload, Try again".

   This is due to the amplifier circuits drawing more than the maximum safe current. The amplifier circuitry has been designed to cleverly shut itself down and to now draw the minimum current.

7. Press ENTER R a second time. The decoder should "squawk" and then report the set value.

Digitrax Chief and Big Boy.

1. Place the locomotive on the programming track.
2. Press the RUN/STOP and FUNC buttons together until the PROG light glows green.
3. Turn the left throttle knob until the left hand numbers on the LCD display correspond to the CV number you wish to change.
4. Turn the right throttle knob until the right hand numbers on the LCD correspond to the value you wish to program into the CV selected in step 3.
5. Press the SEL/SET button to store the new value into the CV.
6. Repeat steps 3-5 until you are finished programming the CVs you wish to change.
7. To exit the programming mode, press the RUN/STOP and FUNC buttons together until the PROG light turns off.

Wangrow System One.

1. Place the locomotive on the programming track.
2. Press the PROG MODE key several times until the display shows USE PROGRAM TRK.
3. Press the Enter key. The display will show 1=STD 2=CV 3=REG.
4. Press the 2 key. The display will show ENTER CV NUM:
5. Enter the number of the CV you wish to change and press ENTER.
6. After a moment, the display will show the current value of the CV.
7. Enter the new value for the CV and press ENTER.
8. Repeat steps 5-7 until you are finished programming the CVs you wish to change.
9. Press the PROG MODE button to exit the programming mode and return to normal operation.

Lenz Digital Plus, Version 2.1

1. Place the locomotive on the programming track.
2. To activate the programming mode, press F, 8, and ENTER.
3. Press the ENTER key again and the display will show CV.
4. Press the ENTER key again and the display will show SEARCH and after several seconds should show the Manufacturer ID for SoundTraxx as MF 141.
5. Press any key seven times until the display shows C_.
6. Enter the number of the CV you wish to change and press ENTER twice.
7. After a moment, the display will show the current value of the selected CV.
8. Enter the new value for the CV and press ENTER.
9. Repeat steps 6-8 until you are finished programming the CVs you wish to change.
10. Press the ESC button to exit the programming mode and return to normal operation.

Note: When using the Lenz Digital Plus's binary display mode, remember that it shows binary numbers with bit 0 on the left and bit 7 on the right which is opposite to normal convention and as used in this manual.

Configuring the Address

The first group of CVs you will want to change are those that set the RDSD's address:

CV 1, Primary Address
CV 17:18, Extended Address
CV 29, Configuration Data

The RDSD may be set up to recognise either the primary address which provides a range of 1 to 127 or the extended address which has a range of 1 to 9999. Whether you use the primary or extended address will first depend on whether or not your DCC system uses long addresses (not all of them do- if in doubt, see your owner's manual.) Second, it will depend on your preferences and the numbering scheme you use for setting your decoder addresses. The extended address has the advantage that you can use all four digits of a locomotive's cab side number for the decoder address making it easy to remember.

Note: The primary and extended addresses can only be set in service mode.

Primary Address
To use the primary address, simply set CV 1 to the desired address between 1 and 127 (0x01-0x7F).

Extended Address
The extended address is actually made up of two CVs, 17 and 18. Unless you are an experienced user, you should not try to program these CVs individually as a specific protocol is required in order for the RDSD to accept the new data (See the **RDSD Technical Reference** for details). Since most command stations that support extended addressing will automatically generate the correct protocol, simply follow their instructions for setting the extended address.

Once the extended address is stored in CV 17 and 18, bit 5 of CV 29 must be set to 1 so the decoder will recognise the extended address format. Otherwise, the decoder will continue to respond only to its primary address. See the next section, Configuring the Decoder.

Configuring the Decoder
The next CV you will want to change is CV 29, Decoder Configuration Byte. CV 29 is one of those complicated bit variables mentioned earlier and is used to set a multitude of decoder characteristics including:

Speed Step Mode - Sets the decoder to use 14, 28 or 128 speed steps (see "Configuring the Throttle", page 22).

Speed Table - Sets the decoder to use speed tables selected by CV 25 (see "Configuring the Throttle", page 23).

Primary or Extended Address - Sets the decoder to recognise its primary address in CV 1 or extended address in CV 17:18 (see "Configuring the Address", above).

Locomotive Direction - Sets whether the decoder will invert direction commands so that the locomotive runs in reverse when it receives a command to move forward and vice-versa. This operating mode has little use for steam locomotives providing the correct wiring procedures have been followed, but is useful for setting up diesel engines.

To assist the user, we have created the table below that lists the correct value for CV 29 to get the desired operating modes. Simply find the row that has the modes you want and program CV 29 with the listed value. The advanced user should refer to the **RDSD Technical Reference** for more details.

Table B. Quick-Reference Table for CV29 Values

CV 29 Value	Speed Steps	Use Speed Tables?	Address Type	Locomotive Direction
00 (0x00)	14	No	Primary (CV1)	Normal
16 (0x10)	14	Yes	Primary (CV1)	Normal
32 (0x20)	14	No	Extended (CV17:18)	Normal
48 (0x30)	14	Yes	Extended (CV17:18)	Normal
02 (0x02)	28,128	No	Primary (CV1)	Normal
18 (0x12)	28,128	Yes	Primary (CV1)	Normal
34 (0x22)	28,128	No	Extended (CV17:18	Normal
50 (0x32)	28,128	Yes	Extended (CV17:18)	Normal
01 (0x01)	14	No	Primary (CV1)	Reversed
17 (0x11)	14	Yes	Primary (CV1)	Reversed
33 (0x21)	14	No	Extended (CV17:18)	Reversed
49 (0x31)	14	Yes	Extended (CV17:18)	Reversed
03 (0x03)	28,128	No	Primary (CV1)	Reversed
19 (0x13)	28,128	Yes	Primary (CV1)	Reversed
35 (0x23)	28,128	No	Extended (CV17:18)	Reversed
51 (0x33)	28,128	Yes	Extended (CV17:18)	Reversed

Configuring the Regulator

There are eight CVs that characterise the RDSD's Regulator response and 28 more are used to create a custom speed table:

CV 2,	V Start
CV 3,	Acceleration Rate
CV 4,	Braking Rate
CV 9,	Motor PWM period
CV 25,	Speed Table Select
CV 29,	Configuration Data
CV 66,	Forward Trim
CV 95,	Reverse Trim
CV 67-94,	Loadable Speed Table.

This may sound like a lot of CVs but don't worry; it's not necessary to change all of them if you don't want to.

Speed Step Mode Selection

As it is a digital system, the RDSD splits the regulator voltage over its minimum and maximum range into discrete speed steps. The RDSD can be configured so there are 14, 28 or 128 individual speed steps. The largest number of steps will give the smoothest throttle response. Beware that not all DCC systems have the ability to control 28 or 128 speed steps and your choice will depend upon the capabilities of your command station. The RDSD's speed step mode is selected by CV 29. Refer to the previous section **Configuring the Decoder** or the **RDSD Technical Reference** to determine the correct value for CV 29.

Setting the Start Voltage

The RDSD provides CV 2, V start, to set a starting voltage that is applied to the motor at speed step 1 and is used to compensate for inefficiencies in the various locomotive's motor and gear system. CV 2 may be programmed with any value between 0 and 255 (0xFF) with each step in value being about 0.4% of the maximum available motor voltage. To calculate the value for CV 2, you should use the formula:

$$CV\ 2 = 255 \times \frac{\text{Desired Starting Voltage}}{\text{Maximum Motor Voltage}}$$

If your DCC system supports Operations Mode Programming, then an alternative method for setting V start is to turn your regulator to the first speed step and then use the operations mode programming feature to increase the value in CV 2 until the locomotive just begins to move.

Setting the Acceleration and Braking Rates

The RDSD provides two CVs to simulate the momentum due to train weight. CV 3, Acceleration Rate, which controls how fast the locomotive responds to increases in regulator settings and CV 4, Braking Rate, controls how fast the locomotive will respond to decreases in the regulator setting.

Both CVs can be programmed with any value between 0 and 255 (0xFF) with 255 corresponding to the **slowest** acceleration or braking rate. Lower settings yield a more responsive locomotive which is useful for shunting. When both CVs are set to 0, the locomotive will respond nearly instantly to any control changes. A setting of 255, on the other hand, will require **3.8 minutes** for a locomotive to reach full speed from a standing stop!

The RDSD's Dynamic Digital Exhaust feature (see page 33) will be more dramatic with larger CV values and we suggest setting CV 3 and CV 4 to a minimum value of 16 (0x10) or higher.

If you are using 14 or 28 Speed Step mode, setting CV 3 and CV 4 to any value greater than 0 will also improve the RDSD's throttle response. While it is accelerating or braking, the RDSD interpolates between speed steps so in effect, your locomotive will respond as if it were being controlled with 128 speed steps. No more sudden lurching from one speed step to another!

Selecting the Speed Table.

The RDSD provides 14 Preset and one loadable speed table which can be used for several purposes:

1. Matching the Auto Exhaust chuffing rate to locomotive speed.
2. Speed matching one locomotive to another.
3. Changing the feel of the Regulator. For example, you could configure a shunting locomotive so that there are more speed steps available at lower speeds and fewer steps at high speeds where the locomotive is seldom operated.
4. Compensating for an improperly designed geartrain so the locomotive will operate within its prototypical speed range.

CV 25, Speed Table Select, is used to select which speed curve will be used by the RDSD. CV 25 may be programmed with any value between 2 and 15 (0x02-0x0F) to select one of the Preset speed curves shown in Table C, page 24. The exact throttle response for each curve is shown graphically in the **RDSD Technical Reference** under CV 25.

To select the user loadable speed table, set CV 25 to 16 (0x10).

In order for the speed table selection in CV 25 to take effect, CV 29 must also be programmed so the RDSD knows to use speed tables. Refer to the previous section "Configuring the Decoder" or the **RDSD Technical Reference** to determine the correct value for CV 29.

Table C. Speed Table Selection

CV 25	Speed Curve Type
2 (0x02)	Straight Line
3 (0x03)	Logarithmic Curve 1
4 (0x04)	Logarithmic Curve 2
5 (0x05)	Logarithmic Curve 3
6 (0x06)	Logarithmic Curve 4
7 (0x07)	Logarithmic Curve 5
8 (0x08)	Logarithmic Curve 6
9 (0x09)	Logarithmic Curve 7
10 (0x0A)	Exponential Curve 1
11 (0x0B)	Exponential Curve 2
12 (0x0C)	Exponential Curve 3
13 (0x0D)	Exponential Curve 4
14 (0x0E)	Exponential Curve 5
15 (0x0F)	Exponential Curve 6
16 (0x10)	User Loadable Speed Table

Setting the User Loadable Speed Curve

If you set CV 25 to select the User Loadable Speed Table, you will also need to design and program the Loadable Speed Table. The Loadable Speed Table consists of 28 data points contained in CVs 67 through 94, each defining the *percentage* of motor voltage applied at a give speed step. Each data point can contain a value of 0 to 255 (0xFF) corresponding to 0 to 100% of available motor voltage.

In 28 speed step mode, each data point directly corresponds to a speed step. In 128 speed step mode, each data point corresponds to every four and a half speed steps. The motor voltage, for intermediate steps are interpolated by the RDSD to produce a smooth curve. In 14 speed step mode, alternate (odd numbered) data points correspond to speed steps 1-14. Important: all 28 data points must be programmed **even for 14 speed step mode** or an unpredictable throttle response may occur while accelerating or braking.

To create a speed curve, begin by assuming the RDSD will be operated in 28 speed step mode. Don’t worry if you are using another mode - the RDSD will automatically take care of the translation between modes.

1. Start by making a table containing 28 entries - one entry for each speed step.
2. For each entry, record the desired regulator response as a percentage of full speed. i.e., 0 to 100%
3. Compute and record the CV value for each step using the following formula:

$$\text{CV Value} = 255 \times \frac{\text{Percentage of Full Speed (from Step 2)}}{100}$$

4. Program CV 67 with the value computed in step 3 for the first data entry (Speed Step 1)
5. Program CV 68 with the value computed in step 3 for the second data entry (Speed Step 2)
6. Repeat step 5 for each of the remaining 26 CVs from CV 69 to CV 94 until they have been programmed with their respective values.

Table D may be followed as an example and lists the default CV values already programmed into the RDSD.

Table D. Calculating the User Loadable Speed Table

CV #	Speed Step	% Full Speed	CV Value
CV 67	1	0	0 (0x00)
CV 68	2	4	9 (0x09)
CV 69	3	7	18 (0x12)
CV 70	4	11	28 (0x1C)
CV 71	5	15	37 (0x25)
CV 72	6	18	47 (0x2F)
CV 73	7	22	56 (0x38)
CV 74	8	26	66 (0x42)
CV 75	9	30	75 (0x4B)
CV 76	10	33	85 (0x55)
CV 77	11	37	94 (0x5E)
CV 78	12	40	103 (0x67)
CV 79	13	44	113 (0x71)
CV 80	14	48	122 (0x7A)
CV 81	15	51	132 (0x84)
CV 82	16	55	141 (0x8D)
CV 83	17	59	151 (0x97)
CV 84	18	62	160 (0xA0)
CV 85	19	67	170 (0xAA)
CV 86	20	70	179 (0xB3)
CV 87	21	74	188 (0xBC)
CV 88	22	77	198 (0xC6)
CV 89	23	81	207 (0xCF)
CV 90	24	85	217 (0xD9)
CV 91	25	87	226 (0xE2)
CV 92	26	92	236 (0xEC)
CV 93	27	96	245 (0xF5)
CV 94	28	100	255 (0xFF)

Adjusting the Forward and Reverse Trim

The RDSD provides two CVs for adjusting or 'trimming' the forward and reverse speeds.
CV 66, Forward Trim
CV 95, Reverse Trim

These CVs multiply all data points in the speed tables by a factor of n/128 (n is the CV value) allowing the overall speed curve to be adjusted up or down without reloading all 28 data points again.

These CVs may contain any value between 0 and 255 (0xFF). Trim values between 129 (0x81) and 255 (0xFF) will increase speed curve values between 100% and 200% in 1% steps. Trim values between 1 and 127 (0x7F) will decrease speed curve values between 1% and 99%. A value of 128 (0x80) yields a scaling factor of 1.0 and has no effect on the speed curve.

Using different values for the forward and reverse trim will yield different forward and reverse speeds.

Adjusting the Motor Drive Frequency

Virtually all DCC decoders, including the RDSD, drive the locomotive motor using a technique called Pulse-Width-Modulation or PWM. PWM works by alternately switching the motor from full off to full on. If the motor is switched fast enough, the speed can be controlled by varying the ratio between the time the motor is on and the time the motor is off. One drawback to PWM is that it can cause the locomotive to buzz, sometimes quite loudly, at low speeds.

To mitigate some of this noise, the RDSD provides CV 9, Motor PWM Period to control the frequency at which the motor is switched on and off. By adjusting this CV, one can usually find a drive frequency that is quieter than others.

CV 9 can be programmed with any value between 0 and 230 (0xE6). The RDSD Technical Reference (see CV 9) provides suggestions for selecting a proper value. A value between 170 and 190 works well for most locomotives.

Configuring the Lights and Function Outputs
The RDSD has four function outputs used for controlling the locomotive lights. Two of these functions, front light and backup light, are always used as on-off outputs.

Setting the various lighting Effects.

The other two functions, F1 and F5 can be also set-up for several special lighting effects using CV 49 as described under **Installation, Step 2**.

The table E lists the modes for each output and required CV setting:

Table E. Setting the lighting effects.

CV 49	F5 Output Type	F1 Output Type
0 (0x00)	On-off On-off	
1 (0x01)	On-off Beacon Light	
2 (0x02)	On-off Firebox Flicker	
3 (0x03)	On-off Sync. Firebox	
4 (0x04)	Beacon light On-off	
5 (0x05)	Beacon Light	Beacon Light
6 (0x06)	Beacon Light	Firebox Flicker
7 (0x07)	Beacon Light	Sync. Firebox
8 (0x08)	Firebox Flicker	On-off
9 (0x09)	Firebox Flicker	Beacon Light
10 (0x0A)	Firebox Flicker	Firebox Flicker
11 (0x0B)	Firebox Flicker	Sync. Firebox
12 (0x0C)	Sync. Firebox	On-off
13 (0x0D)	Sync. Firebox	Beacon Light
14 (0x0E)	Sync. Firebox	Firebox Flicker
15 (0x0F)	Sync. Firebox	Sync. Firebox

Configure Lighting Control.
The RDSD supports two modes of front light operation:

Automatic Direction Control.
Both the front light and back lights are turned on and off using the F0 function. The RDSD automatically switches the proper light on depending upon locomotive direction.

“Rule 17” Front light Operation.
This is the more prototypical form of operation and requires the engineer to manually switch each light ON or OFF individually. Thus, it is possible for both lights to be on at the same time.

The RDSD uses Function Mapping (see **Re-mapping the Functions**, below) to determine which mode is used.

For automatic direction control, the front light is mapped to F0(fwd) by setting CV 33 to 1 (0x01), and the backup light is mapped to F0(rev) setting CV 34 to 2 (0x02).

For Rule 17 Operation the front light is mapped to both F0(fwd and F0(rev) by setting both CV 33 and 34 to 1 (0x01). The backup light is remapped to a different function by setting the corresponding function map CV to 2 (0x02). For this example, let’s use F1. If CV 35 is programmed to 2, your controller’s F0 key would now control the front light (in both directions) and the F1 key controls the back light.

Configuring the Sound Effects.

The RDSD provides five CVs for customising the sound effects:

CV 50, Overall Volume Control
CV 51, Background Sound Configuration
CV 52, Foreground Sound Configuration
CV 54, Auto Exhaust Rate
CV 55, Exhaust Tone
CV 56, Exhaust Volume

Setting the Overall Volume.

CV 50 may be set with any value between 0 and 15 (0x0F) to control the overall volume of the locomotive's sound. A setting of 0 will turn the sound off and a setting of 15 will provide maximum volume (1.0 Watts of output).

Setting the Exhaust.
CV 54 is used to set the automatic synchronisation rate or cutoff rate if cam synchronisation is used.

For Auto-Exhaust synchronisation, the chuff rate will be generated in proportion to the Regulator setting. To select Auto-Exhaust mode, CV 54 is loaded with any value between 0 and 255 (0xFF). Higher values will yield higher chuff rates for a given regulator setting. The correct synchronisation rate may be computed as:

$$\text{CV Value} = 115.9 \times \frac{\text{SPD}}{\text{DIA}} \times \text{Gear Ratio (Normally 1)}$$

Where SPD is the locomotive's top speed in scale miles-per-hour with the regulator fully open and DIA is the locomotive's driver wheel diameter in scale inches. (The Gear Ratio is included to permit the gear ratio of the drive train for locomotives such as shays which re not usually found in the UK). For conventional steam engines, use gear ratio =1. The driver diameter can be easily measured with a scale ruler but remember to convert the measurement to scale inches.

If you don't know your locomotive's top speed, you can figure it out by using a stop watch to measure the time (in seconds) it takes for the engine to travel over a 1/4 scale mile of track and using the formula:

$$\text{MPH} = \frac{900}{\text{Time}}$$

Note: A 1/4 mile in N gauge (2mm=1 Ft) = 8' 8" (2.640 meters)
A 1/4 mile in 00/HO gauge (4mm = 1 Ft) = 17' 4" (5.28 meters)
A 1/4 mile in O gauge (7mm = 1 FT) = 30' 4" (9.24 meters)

For 00/HO, a 1/4 mile is 15 feet, 2". If an engine take 20 seconds to traverse this distance, its speed is 45 MPH. You can also estimate your locomotive's top speed and still get pretty good results. A good rule of thumb is to use 25 mph for a shunting engine, 45 mph for freight locomotives and 70 mph for passenger engines.

If you are using the exhaust cam, use the same formula as above for setting the cut-off rate.

CV 55 is used to set the exhaust tone and may be programmed with any value between 0 and 63 (0x3F). Higher values will produce a steamier exhaust chuff.

CV 56 is used to adjust exhaust volume when the DDE processor is disabled and may be programmed to any value between 0 and 255 (0xFF). Higher values will produce a louder exhaust.

Setting the Background Sound Effects

CV 51 is used to select which background sound effects are active as some may not be suitable for your particular model (an oil burning locomotive for example will not have a fireman shovelling coal).

CV 51 can be programmed with any value between 0 and 255 (0xFF). However, each bit in CV 51 controls a different effect and there are over 255 combinations! You will need to use the technique described under **Bits and Bytes** and refer to the **RDSD Technical Reference** to determine the proper value for CV 51. Alternatively, you can calculate the value for CV 51 with a series of additions as follows:

1. Start with CV 51 set to 0.

2. The intervals at which the background sounds occur are spaced randomly by a 'clock' inside the RDSD. This clock can work in scale time so that sounds occur every few minutes or in real time so sounds occur every few hours! To select real time intervals, add one to the value in CV 51. Otherwise, skip to step 3.

3. One of the RDSD background sound effect is the sound of Fireman Pete building up a good draft in the firebox with the blower. If you want to enable this sound, add 4 to the value in CV 51. Otherwise, skip to step 4.

4. Another RDSD background sound effect is the sound of Fireman Pete shovelling coal into the firebox. He'll do this whenever the loco is brought to a stop and again at random intervals. If you want to enable this sound, add 8 to the value in CV 51. Otherwise, skip to step 5.

5. Another RDSD background sound effect is the boiler pressure relief or safety valve blowing off. This is a loud effect that runs for about 10 seconds at random intervals. If you want to enable this sound, add 32 to the value in CV 51. Otherwise, skip to step 6.

6. The RDSD's Cylinder Drain cocks or Blow Down effect can be operated as function key or automatically whenever the locomotive comes to a stop. This frees up a function key to use for something else. If you want to use the Automatic feature, add 64 to the value in CV 51. If you want to use the function key instead, skip to step 7.

7. The RDSD background sounds selected in steps 2-6 will run whenever the locomotive is stopped. You can also silence them without changing individual settings for when the engine is the roundhouse for example. If you want the background sounds ON, add 128 to value in CV 51 otherwise skip to step 8.

8. Program CV 51 with the new value calculated in steps 2-9.

Setting the Foreground Sound Effects.

CV 52 is used to modify certain foreground sound effects. CV 52 can be programmed with any value between 0 and 255 (0xFF). However, each bit in CV 52 controls a different effect as with the Background Sound Effects, there are over 255 combinations! You will need to use the technique described under **Bits and Bytes,** and refer to the **RDSD Technical Reference** to determine the proper value for CV 52. Alternatively, you can calculate the value for CV 52 with a series of additions as follows:

1. Start with CV 52 set to 0.

2. If you are using the Auto-Exhaust feature on a locomotive with two cylinders the same size add one to the value in CV 52. This will produce a slightly uneven exhaust cadence effect. For all other types of engines, skip to step 3.

3. The RDSD features a Dynamic Digital Exhaust (DDE) processor that modifies the exhaust sound as the engine load changes. To activate the DDE processor, add 2 to the value in CV 52. Otherwise, skip to step 4.

4. If you are using the exhaust cam to trigger the exhaust chuffs, add 4 to the value in CV 52. Otherwise, skip to step 5.

5. Program CV 52 with the new value calculated in steps 2-4.

Configuring for Consist Operation.

The RDSD supports consist operations and has three related CVs:

CV 19, Consist Address
CV 21, Consist Function Active
CV 22, Consist F0 Function Active

The consist CVs allow the RDSD to recognise a new address assigned to the consist without changing the primary or extended addresses. Additionally, they allow each locomotive in the consist to be run as a single unit but with different function properties.

These CVs are useful when building up a multiple header for example. Each locomotive in the group is assigned the same consist address by programming CV 19 with the consist address between 0 and 127 (0x7F). If a locomotive is facing backwards in the consist (unlikely for steam operations but we mention it anyway), it should be programmed with the same consist address plus 128 (0x80). If the forward locomotives are set to address 60 for example, the backward engine must be set to 60+128 = 188. Failure to do this will cause problems as all locomotives will try to move forward from the perspective of their own cab.

With a number of engines in the consist, you'll probably want the front light function to activate only the lead engine's light. And you'll only want the back light on the trailing engine to work (assuming there are no wagons or coaches). But you probably want the firebox flicker on for all of the engines. CV 21 and 22 allow you to define how each engine responds to function commands sent to the consist address. CV 21 controls which of functions 1-8 are active when the consist address is enabled and CV 21 controls the F0 function for forward and reverse. As each bit in both CVs enable a different function, you'll need to refer to the section on **Bits and Bytes,** and the **RDSD Technical Reference** to determine the proper value for each CV.

Note that when the consist address is set, the locomotive will continue to respond to instructions sent to its primary or extended address except for speed and direction data.

To deactivate the consist address and restore normal operation, CV 19 must be reprogrammed to 0.

Re-mapping the Functions.

Function Mapping Explained

Function mapping allows the RDSD's sound effects and function outputs to be reconfigured to respond to a different function key input. This especially useful for users who have Controllers with less than eight function keys as now they can pick and choose what effects they can control instead of being restricted to an arbitrary assignment.

There are 10 function mapping CVs - eight CVs, 35-42 are used to assign output control to function keys 1 through 8 respectively.

The other two CVs, 33 and 34 are both for the F0 function. CV 33 controls which outputs are on when F0 is on and the locomotive is moving forward. CV 34 controls which outputs are on when F0 is on and the locomotive is moving in reverse. If the same output is selected in both CV 33 and CV 34, that function will turn on when the F0 function is on regardless of locomotive direction.

As the RDSD has more function outputs (for the purpose of discussion, we'll consider sound effects to be outputs) than there are function keys, not all keys can control all outputs. The table in the **RDSD Technical Reference** shows which functions can be mapped to which outputs. Note that a function key can be set up to control more than one output and also an output can be controlled by more than one function key. In the second case, the outputs are logically or'ed to the function keys so that if an output is mapped to two function keys, either key will turn that output on, however, the output will not turn off until both function keys have been turned off.

Function mapping is tricky and if the user is not careful, 'interesting' things can happen. As each bit in the function mapping CVs enables a different output, you'll need to refer to the section on **Bits and Bytes** and the **RDSD Technical Reference** to determine the proper value for each CV.

Function Mapping Example

There are a several controllers on the market that have only four or five function buttons. The following example describes one way to reconfigure the RDSD for such a controller with five function keys and still maintain access to most of the RDSD's functionality.

We'll use the F0 (FL on some units) key for turning on the front light and back light and use automatic direction control to select which light is on.

We'll use the F1 key to turn on both auxiliary function outputs F1 and F5. This makes particular sense if both outputs have been setup as a firebox flicker effect

The F2 and F3 keys will be used for the long whistle and short whistle respectively. The F4 key will control the buffer contact and coupling clank sound.

The two functions that had to be given up are the cylinder blow down effect and the audio mute function. The cylinder blow down effect can still be used by enabling the automatic blow down effect (see **Configuring Background Sounds**) which will produce the effect whenever the locomotive is brought to a stop. The audio mute function can be implemented by setting CV 50, volume control, to zero when sound is not desired. Not too bad a sacrifice!

Using the **RDSD Technical Reference**, we look up the proper bits to set for each CV and after a bit of head scratching, come up with the following list of values:

CV 33 = 129 (0x81), F0 (fwd) = Front light
CV 34 = 130 (0x82), F0 (rev) = Back light
CV 35 = 68 (0x44), F1 = F1 and F5 outputs
CV 36 = 8 (0x08), F2 = Long Whistle
CV 37 = 2 (0x02), F3 = Short Whistle
CV 38 = 32 (0x20), F4 = Buffer contact clank and Coupling sound
CV 39-42 = 0, Functions not used.

Once these are programmed into the proper CVs, the RDSD will exhibit the functionality described above. To enable the Auto-blow down effect, set CV 51 to 255 (0xFF).

OPERATING THE ZTC Controls Ltd RDSD.

Now that we've installed the RDSD and have all the CVs set up, it's time to operate the train! This section is intended to give you a general feel for how the RDSD is used in operation. We had to make a few assumptions on how the RDSD is set up and for the most part, will assume you've left most CVs at their default settings, particularly the function key assignments. If you've made a lot of CV changes then your RDSD may respond somewhat differently.

In the locomotive Engine Shed and yard.

Press the F1 and F5 keys on your controller to turn on the firebox flicker. When the engine is first fired up, you'll hear the boiler gently simmering away.

Press the F0 key to turn the lights on.

The engine's has now been sitting around for quite awhile and there's bound to be some condensation build-up in the cylinders. Press the F4 key to open up the cylinder cocks and blow out the moisture. Press the F4 key again to close the cocks.

It is now necessary to couple the locomotive up to the train. Press the F3 key and blow the short whistle to let everyone know you're about to start moving, If you don't remember your whistle signals then you see Table F which lists a selection of whistle codes.

As the locomotive makes contact with the train the buffers clank and coupling links are thrown over the coupling hook. Press the F7 button to activate the coupling sound.

After a few minutes, we're ready to head out onto the mainline. Now it's time to try out the RDSD's Dynamic Digital Exhaust (DDE) processor. This is a good time to set in a little inertia. Set CV 3 and 4 a typical value for these decoders is between 20 and 30.

On the Mainline.

Press the F3 key and let off two short blasts on the whistle. Push the cut off lever a quarter forward and open the regulator up. As the locomotive grunts out a couple long exhaust chuffs, the train begins to move forward. Push the cut off lever further forward and open the regulator slowly, as the locomotive gathers momentum push the cut off lever fully forward and also open the regulator. You should notice that the train inertia keeps the engine from taking off but the exhaust chuff becomes louder and more drawn out as the engine struggles with the train weight. As the locomotive and train builds up speed, set the regulator down to the desired setting and you'll notice the exhaust chuff quiets down a bit as the train has stopped accelerating. Back the throttle down to

zero and the exhaust chuff will really get quiet now and the vacuum pump becomes more audible because the train is just coasting along .

This is the RDSD`s DDE processor in action! The DDE senses the difference between the actual locomotive speed and the throttle setting, using the information to adjust the volume, cutoff and timbre of the exhaust chuff. If you slowly accelerate or brake the train the exhaust chuff will remain relatively constant. If you turn the throttle substantially up or down, you will hear a dramatic change in the exhaust sound until the train speed has reached the new throttle setting. The DDE works best when there is a reasonable amount of inertia programmed into CVs 3 and 4. With substantial amounts of inertia, you can even use the throttle as an exhaust volume control.

Arriving at the Station

Having travelled some distance on the main line we are now approaching a station and the train slows to a stop.

After a moment, Fireman Pete will open the firebox doors and shovel a few scoops of coal onto the fire grate to keep the boiler ready for the next trip out. Clink! The doors close and it's time for Pete to take a rest. But he knows better than to rest for too long and if you hang around long enough, you'll hear him get up and turn the blower on to draw the fire in the firebox. If he lets the boiler get too hot, you'll even hear the steam pressure relief valves blow off.

When the phone rings or a detailed conversation is taking place around the layout you may want to silence the decoder by pressing F8 key to mute the sound until later, pressing F8 a second time turns the sound output back ON.

Table F. A Selection of Whistle Signals

Rule	Action.	Description.
41	1 short blast.	Acknowledges signalman.
55	1 short blast.	Locomotive stationary at danger signal
127	1 short blast	Danger warning to people on or near the line. Also when view of line ahead obstructed.
127	Multiple short blasts	Warning signal when above not acted upon.
133	Rear engines 2 short Front engine 2 short.	Freight Train assisted from rear. Banking. Front engine replies when ready to move.
142	1 short blast	Driver wanting to gain attention of guard.
155	1 long blast	Something wrong on opposite line.
180	1 long blast	Disabled train fouling opposite line.
185	Series of short blasts	Travelling in wrong direction on line.
204	Series of short blasts	Single line working.
206	Series of short blasts	Ballast train working.
235	I long blast	Train unloading on the move.

PART II: DECODER TECHNICAL REFERENCE.

This section of the manual is designed to provide the advanced user with additional insight into the operation and capabilities of the ZTC Controls Ltd RealFeel™ Digital Sound Decoder (RDSD). By necessity, it is somewhat technical in nature and assumes a working knowledge of the NMRA DCC Standards and appropriate RPs as well as a familiarity with binary and hexadecimal number systems.

The novice user should not be dissuaded from studying this section as it will help add to his knowledge of DCC technology and enable him to take greater advantage of its capabilities.

Copies of the NMRA DCC Standards and Recommended Practices may be obtained by contacting:

Technical Department
NMRA Headquarters
4121 Cromwell Road
Chattanooga, TN 37421 USA
Phone: (615) 892-2846

As always, our Technical Support staff will be happy to answer any specific questions you may have regarding the ZTC Controls Ltd RDSD.

Applicable Standards.

The ZTC Controls Ltd RDSD has been designed to meet the requirements of the following NMRA Standards and RPs as defined by September, 1996:

Standard S-9.1	DCC Electrical Standard
Standard S-9.2	DCC Communication Standard
RP-9.1.1	Electrical Interface and Wire Colour Code
RP-9.2.1	DCC Extended Packet Format
RP-9.2.2	DCC Configuration Variable
RP-9.2.3 (Tentative)	DCC Service Mode
RP-9.2.4	DCC fail-safe Operating Characteristics

Bit Timing
The RDSD uses a quartz crystal timing reference and will recognise DCC packet bits that fall within the following timing constraints: “1” Bit, 52µS to 64µS
“0” Bit, 90µS to 12000µS

Packets containing bits that fall outside of this range will be rejected.

Addressing Modes.

The RDSD recognises the following address modes and ranges as defined by RP-9.2.1:

Broadcast Address 00
Decoder Addresses 01-127
Consist Addresses 01-127
Extended Addresses 0xC000 - 0xE7FF

Packets that contain addresses outside of these ranges will be ignored.

Command Instructions.

The RDSD will process valid packets containing the following instruction codes as defined by RP-9.2.1:

000 Decoder and Consist Control.
All currently defined forms of this instruction are processed except 00000110b, Set Advanced Acknowledgement. This instruction is ignored.

001 Advanced Operation Instructions.
The RDSD will process only the 128 Speed Step Control form (00111111b) of this instruction. All other sub-instructions will be ignored.

010 Reverse Speed and Direction Instruction.
The RDSD will process all forms of this instruction.

011 Forward Speed and Direction Instruction.
The RDSD will process all forms of this instruction.

100 Function Group One.
The RDSD will process all forms of this instruction.

101 Function Group two.
The RDSD will process all forms of this instruction.

110 Reserved. Set to 0 Instruction.
The RDSD will process all forms of this instruction.

111 Configuration Variable Access.
The RDSD will parse both the short form and long form of this instruction.

Only short form instructions formatted as 11110010b (CV 23 access) or 11110011b (CV 24 access) will be processed. All other short form instruction will be ignored.

All long form instructions will be processed. However, attempts to write to the following CVs in operations mode will be ignored:

CV 1	Primary Address
CV 7	Mfg. Version ID
CV 8	Mfg. ID
CV 17	Extended Address MSB
CV 18	Extended Address LSB

Write operations to other CVs may be ignored if an attempt is made to write illegal values. See individual CV descriptions for details on illegal values.

The RDSD will send a basic acknowledgement upon successfully processing an operations mode CV access instruction provided the locomotive is stopped. Otherwise, no acknowledgement is sent.

Programming Modes.

The RDSD will supports all six programming modes defined in RP-9.2.1 and RP-9.2.3:

Address Mode
Register Mode
Service Mode
Direct Mode
Ops Mode Long Form
Ops Mode Short Form

Not all CVs can be programmed using all modes. Table A lists all CVs supported by the RDSD, their applicable programming mode address as well as the factory default values.

When entering service mode, the RDSD will turn off all auxiliary functions and sounds to reduce its current draw to as low a level as possible.

If the RDSD receives an instruction packet to read or write a CV not listed in Table A, the instruction packet will be ignored and no acknowledgement will be generated.
Upon completion of a paged mode operation, the RDSD will reset the page register to 01.

The address query instruction is not supported by the RDSD.

Miscellaneous Operating Notes.

Consist operation is enabled whenever the consist address (CV 19, bits 0:6) is loaded with a non-zero value. Per the NMRA standard, when the consist address is enabled, the RDSD will no longer parse speed/direction packets sent to its primary address. Additionally, the RDSD will ignore long form CV access instructions sent to its consist address. Because the RDSD instruction parser assigns a higher priority to the consist address, this can cause unexpected behaviour under certain conditions:

When the RDSD is set up for 14 speed step mode with the consist address active, the RDSD outputs will no longer respond to F0 (FL) function commands sent to the primary address. This may be remedied by using a different speed step mode or enabling F0 (FL) consist functions (see CV 22).

If the consist address is set to the same value as the primary address, the RDSD will no longer process long form operations mode CV access instructions sent to the primary address. As a result, the user will be required to use service mode CV access instructions to clear the consist address. If the extended address is enabled (see CV 29), this will not be a problem.

Analogue Mode Operation.

The RDSD **does not support** Analogue Mode operation and will remain inoperative when placed on a conventional DC track.

CV`s Support.

The following table lists all CVs used by the RDSD. Details regarding each CV can be found on subsequent pages.

Table A. CV`s Used by the RealFeel™ Digital Sound Decoder

CV#	Name	Default Value		Program Mode Address: Direct Mode	Register Mode	Paged Mode Page:Register (Note 1)
1	Primary Address	3		01 (0x01)	0	1:0
2	V start	7		02 (0x02)	1	1:1
3	Acceleration Rate	0		03 (0x03)	2	1:2
4	Braking Rate	0		04 (0x04)	3	1:3
7	Version ID	06		07 (0x07)	6	2:3
8	Manufacturer ID	141	(0x8D)	08 (0x08)	7	3:0
9	Motor PWM Period	180	(0xB4)	09 (0x09)		3:1
11	Time Out Period	0		11 (0x0B)		3:3
17	Extend Address MSB	192	(0xC0)	17 (0x11)		5:1
18	Extend Address LSB	03		18 (0x12)		5:2
19	Consist Address	0		19 (0x13)		5:3
21	Consist Func. Active	0		21 (0x15)		6:1
22	Consist F0 (FL) Active	0		22 (0x16)		6:2
23	Consist Acceleration	0		23 (0x17)		6:3
24	Consist Deceleration	0		24 (0x18)		7:0
25	Speed Table Select	0		25 (0x19)		7:1
29	Configuration Data #1	02		29 (0x1D)	4	8:1
30	Error Information	0		30 (0x1E)		8:2
33	F0 (f) Output Location	1		33 (0x21)		9:1
34	F0 (r) Output Location	2		34 (0x22)		9:2
35	F1 Output Location	4		35 (0x23)		9:3
36	F2 Output Location	8		36 (0x24)		10:0
37	F3 Output Location	2		37 (0x25)		10:1
38	F4 Output Location	4		38 (0x26)		10:2
39	F5 Output Location	8		39 (0x27)		10:3
40	F6 Output Location	16	(0x10)	40 (0x28)		11:0
41	F7 Output Location	4		41 (0x29)		11:1
42	F8 Output Location	128	(0x80)	42 (0x2A)		11:2
49	Lighting Config.	0		49 (0x31)		13:1
50	Sound Volume	8		50 (0x32)		13:2
51	Background Config	190	(0xBE)	51 (0x33)		13:3
52	Foreground Config	70	(0x46)	52 (0x34)		14:0
53	Sound Config. Byte #3	0		53 (0x35)		14:1
54	Auto Exhaust Rate	94	(0x5E)	54 (0x36)		14:2
55	Exhaust Tone	08		55 (0x37)		14:3
56	Exhaust Volume	255	(0xFF)	55 (0x38)		15:0
66	Forward Trim	128	(0x80)	66 (0x42)		17:1
67	Speed Step 1	0	(0x00)	67 (0x43)		17:2
68	Speed Step 2	9	(0x09)	68 (0x44)		17:3
69	Speed Step 3	18	(0x12)	69 (0x45)		18:0
70	Speed Step 4	28	(0x1C)	70 (0x46)		18:1
71	Speed Step 5	37	(0x25)	71 (0x47)		18:2
72	Speed Step 6	47	(0x2F)	72 (0x48)		18:3
73	Speed Step 7	56	(0x38)	73 (0x49)		19:0
74	Speed Step 8	66	(0x42)	74 (0x4A)		19:1

Table A. continued.
CV`s Used by the RealFeel™ Digital Sound Decoder

CV#	Name	Default Value	Program Mode Address			
				Direct Mode	Register Mode	Paged Mode Page: Register (Note 1)
75	Speed Step 9	75	(0x4B)	75 (0x4B)		19:2
76	Speed Step 10	85	(0x55)	76 (0x4C)		19:3
77	Speed Step 11	94	(0x5E)	77 (0x4D)		20:0
78	Speed Step 12	103	(0x67)	78 (0x4E)		20:1
79	Speed Step 13	113	(0x71)	79 (0x4F)		20:2
80	Speed Step 14	122	(0x7A)	80 (0x50)		20:3
81	Speed Step 15	132	(0x84)	81 (0x51)		21:0
82	Speed Step 16	141	(0x8D)	82 (0x52)		21:1
83	Speed Step 17	151	(0x97)	83 (0x53)		21:2
84	Speed Step 18	160	(0xA0)	84 (0x54)		21:3
85	Speed Step 19	170	(0xAA)	85 (0x55)		22:0
86	Speed Step 20	179	(0xB3)	86 (0x56)		22:1
87	Speed Step 21	188	(0xBC)	87 (0x57)		22:2
88	Speed Step 22	198	(0xC6)	88 (0x58)		22:3
89	Speed Step 23	207	(0xCF)	89 (0x59)		23:0
90	Speed Step 24	217	(0xD9)	90 (0x5A)		23:1
91	Speed Step 25	226	(0xE2)	91 (0x5B)		23:2
92	Speed Step 26	236	(0xEC)	92 (0x5C)		23:3
93	Speed Step 27	245	(0xF5)	93 (0x5D)		24:0
94	Speed Step 28	255	(0xFF)	94 (0x5E)		24:1
95	Reverse Trim	128	(0x80)	95 (0x5F)		24:2
105	User Identifier #1	0		105 (0x69)		27:1
106	User Identifier #2	0		106 (0x6A)		27:2

Note1: Paged mode address is shown as PP: RR where PP is the page number and RR is the data register 0-3.

The various CV`s of this decoder can be set or programmed as indicated in the following modes. When setting (programming) your decoder using the ZTC 511 OR 505 Paged Mode is always the preferred method.

AD = Address Mode.
RM = Register Mode.
PM = Paged Mode.
DM = Direct Mode.
OPS = Ops Mode Short Form.
OPL = Ops Mode Long Form.

CV 1 PRIMARY ADDRESS CONTROL

Programmable in:- AD, RM, PM, DM.

Description
Contains the decoder's primary address between 1 and 127:

bit7							bit 0
0	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

Bit 0-6: A0-A6, Decoder Address **Bit 7:** Not used. Must be set to 0

The decoder will process all valid instruction packets containing an address that matches the value contained in this register when CV 29, bit 5 is set to 0.

Programming this register with a new value will automatically clear the Consist Address (CV 19) to 0 and clear the Extended Address Enable bit in CV 29 (bit 5).

The decoder will ignore commands that attempt to program this register with values outside the range of 1 to 127.

Note that this CV cannot be changed in operations mode.

Default Value: 03

Related CVs: See also CV 29, Consist Address, Extended Address

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CV 2 V START

Programmable in:- RM, PM, DM, OPL.

Description
V start defines the initial voltage level applied to the motor at speed step 1 as a fraction of available supply voltage:

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Motor Start Voltage

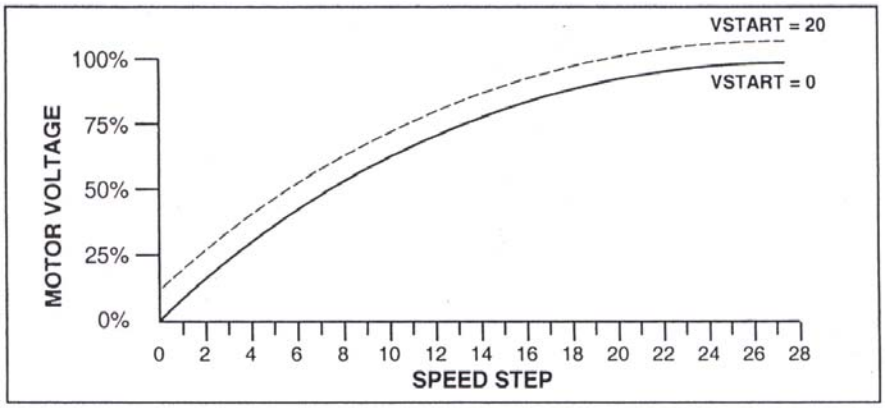
V start may contain any value from 0 to 255 (0 - 0xFF).

The starting voltage applied to the motor may be computed as:

Starting Voltage = Supply Voltage X CV2/255

where CV 2 is the contents of the V start register. A value of 0 corresponds to a zero starting voltage and 255 corresponds to the maximum available voltage.

For speed steps greater than 1, the RDSD will continue to sum the initial starting voltage level into the regulator computations which has the effect of offsetting all points on a given speed curve by the level set by V start as illustrated in the figure below.



Default value: **07**

CV 3 BASELINE ACCELERATION RATE

Programmable in:- RM, PM, DM, OPL.

Description
Contains a value between 0 and 255 (0 - 0xFF) that sets the decoder's acceleration rate:

bit 7 bit 0

D7	D6	D5	D4	D3	D2	D1	D0

D0-D7: Baseline Acceleration Rate

Acceleration rate may be computed as:

Seconds/speed step = CV3x0.0896/Number of speed steps

When this CV is set to 0, the locomotive speed will respond nearly instantly to *increases* in the regulator setting. When set to 255, it will take approximately 3.8 minutes to accelerate to full speed from a standing stop.

It is recommended that this CV be set to a nonzero value when operating the RDSD in 14 or 28 speed step modes as the regulator will interpolate between speed steps during acceleration to produce a smoother overall response. The Dynamic Digital Exhaust sound effect will also be more prevalent with higher acceleration settings.

Default value: 0

Related CVs: See also Baseline Braking Rate, Consist Acceleration Rate, Consist Brake Rate.

CV 4 BASELINE DECELERATION (BRAKING) RATE

Programmable in:- RM, PM, DM, OPL.

Description
Contains a value between 0 and 255 (0 - 0xFF) that sets the decoder's braking rate:

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Baseline Braking Rate

Braking rate may be computed as:

$$\textbf{seconds/speed step} = \frac{\text{CV 4} * 0.896}{\text{Number of Speed Steps}}$$

When this CV is set to 0, the locomotive speed will respond nearly instantly to decreases in the regulator setting. When set to 255, it will take approximately 3.8 minutes to brake to a stop from full speed.

It is recommended that this CV be set to a non zero value when operating the RDSD in 14 or 28 speed step modes as the regulator will interpolate between speed steps during braking to produce a smoother overall response. The Dynamic Digital Exhaust sound effect will also be more prevalent with higher braking rates.

Default value: 0

Related CVs: See also Baseline Acceleration, Consist Acceleration Rate, Consist Brake Rate.

CV 7 MANUFACTURER VERSION ID

Read Only in:- PM, DM, OPL.

Description
Contains 8 bit software version identifier.

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Version Code

06 = RDSD-050 Steam Decoder, Release 1.2
07 = RDSD-150 Steam Decoder, Release 1.2
09 = RDSD-150 Diesel Decoder, Release 1.0
11 = RDSD-150 Diesel Decoder, Release 1.1
14 = RDSD-150 Diesel Decoder, Release 1.2

This CV is read only and cannot be modified.

CV 8 MANUFACTURER ID

Read Only :- PM, DM, OPL.

Description
Contains the NMRA issued Manufacturer ID code assignment

bit7							bit 0
1	**0**	**0**	**0**	**1**	**1**	**0**	**1**

Value shown for ZTC Controls Ltd and Soundtraxx. This value is read only and fixed at 141 (0x8D).

CV 9 PWM PERIOD

Programmable in:- PM, DM, OPL.

Description
Determines the PWM period of the motor drive signals:

bit7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: PWM Period

The motor PWM period in milliseconds is computed as:

Period = (255 - CV9) x 204.8

This CV may be programmed with any value between 0 and 230 corresponding to a PWM period range of 52.2mS to 5.12mS. The motor drive frequency can be found by taking the reciprocal of the period. The drive frequency can thus be programmed from 19.1 Hz to 195 Hz.

The decoder will ignore commands that attempt to program this register with values greater than 230.

The correct value for this register will vary depending upon the locomotive the RDSD is installed in and it may take some experimentation to find the optimal value. Generally, the selected value will require a trade-off decision between motor torque and audible noise. Lower numbers will produce more torque but may cause the motor and gearbox to resonate and buzz loudly. On smaller engines that lack traction, sufficient torque can be produced to cause the drive wheels to slip. Higher numbers, on the other hand, will tend to reduce the buzzing noise but there may be some loss in power, especially at low speeds. The following values are provided as a guide line to help establish a starting point for determining the best PWM period value:

Scale	CV9 Value
N, HOn3	180-200
HO, S	175-185
O	160-175
G	120-160

Note: CV 9 also affects the modulation period of the various lighting effects. When using the these effects, it is recommended that CV 9 be programmed with values greater than 155 as an annoying F0 (FL) flicker may otherwise result.

Default Value: 180 (0xB4), Corresponds to 65Hz drive frequency.

CV 11 PACKET TIME OUT VALUE

Programmable in:- PM, DM, OPL.

Description
Contains a value between 0 and 255 corresponding to the time period that is allowed to elapse between receipt of a valid packet addressed to the RDSD before a regulator shutdown occurs.

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Packet Time-out Value

The time out period is computed in seconds as:

Time Out Period = CV11 x 10

A CV value of 0 disables the time out period and the locomotive will run indefinitely without receiving another packet.

For all other values, the RDSD maintains an internal timer which is reset every time the RDSD receives a valid broadcast address packet or other valid packet whose address matches its primary address or, if enabled, the extended address or consist address.

In the event no valid packets are received within the prescribed time period, the RDSD will bring the locomotive to a stop at the rate set by CV 4 and CV 24. The state of the auxiliary function outputs will remain unchanged.

Default value: 00

CV 17,18. EXTENDED ADDRESS

Programmable in:- PM, DM.

Description
CV 17 and 18 make up a ‘paired’ CV, meaning that the two CV registers taken together hold one piece of data, in this case, the 14 bit extended decoder address:

CV 17 Extended Address MSB

bit7							bit 0
15	**A14**	**A13**	**A12**	**A11**	**A10**	**A09**	**A08**

CV 18 Extended Address LSB

bit 7							bit 0
A7	**A6**	**A5**	**A4**	**A3**	**A2**	**A1**	**A0**

A0-A15: Extended Address Value

The extended address allows the decoder to be assigned one of 10,179 addresses ranging from 0xC000 to 0xE7FF (Note however, that most command stations will only recognise addresses 0000 through 9999.). The extended address will only be recognised by the decoder when CV 29, bit 5 is set to 1. Once this bit is set, the decoder will no longer recognise its primary address until CV 29, bit 5 is cleared.

CV 17 contains the most significant byte and must be loaded with values within the range of 0xC0 and 0xE7. CV 18 contains the least significant byte and may contain any value.

To determine the extended address value, add the desired four digit address to the number 49152. Divide this number by 256 and record the quotient and the remainder. CV 17 is then programmed with the quotient value and CV 18 is programmed with the remainder value.

Example: Compute CV 17 and 18 register values for extended address 7152.

1. Add 7152 to 49152: Sum = 56304.
2. Divide 56304 by 256: Quotient = 219 Remainder = 240
3. Program CV 17 to 219 (0xDB)
4. Program CV 18 to 240 (0xF0)

Note: Most command stations will handle these computations automatically when setting the extended address. However, it's still nice to know how to derive them.

Because CV 17 and 18 make up a paired CV, programming order is important. CV 17 must be written to first, followed by a write CV 18. The decoder will ignore commands that attempt to program these register out of order or with values outside the allowed range of 0xC000 to 0XE7FF

Note:- These CVs cannot be changed in operations mode.

Default Value: 0xC003

Related CVs: See also Primary Address, CV 29, Consist Address.

CV 19 CONSIST ADDRESS

Programmable in:- PM, DM, OPL.

Description
Contains address and direction data for consist operation:

bit 7 bit 0

CDIR	A6	A5	A4	A3	A2	A1	A0

Bit 0-6: A0-A6, Consist Address Value **Bit 7:** CDIR, Consist Direction
0 = Normal Direction
1 = Reverse Direction

The CDIR bit defines orientation of the locomotive within a consist and specifies whether the direction bit in a speed/direction data packet should be inverted.

Bits A0-A6 assigns the consist address from 0 to 127 (0-0x7F).

If A0-A6 = 00, consist commands are ignored. Otherwise, if the decoder receives a valid command packet whose address matches the consist address, the packet will be processed as any other packet with the following exceptions:

Long Form CV Access instructions will be ignored.

The direction bit in a speed/direction or advanced operation packet is inverted if CDIR = 1.

Only the auxiliary functions enabled in CV 21 and CV 22 are allowed to change.

When the consist address is active, speed/direction and advanced operations packets sent to the decoder's primary address (or extended address, if enabled) will be ignored. All other instruction packets sent to the decoder's primary (or extended) address including CV access and function control will continue to be processed as normal.

In summary, setting CV 19 to 00 or 128 (0x80) disables consist addressing. Setting CV to a value between 1 and 127 (0x01-0x7F) enables consist addresses 1 to 127 (0x01-0x7F) with the locomotive oriented facing *forward* in the consist. Setting CV to a value between 129 and 255 (0x81-0xFF) enables consist addresses 1 to 127 with the locomotive oriented facing backwards in the consist.

Default Value: 00

Related CVs: See also Primary Address, Consist Function Active, Consist F0 (FL) Function Active.

CV 21 CONSIST FUNCTION ACTIVE

Programmable in:- PM, DM, OPL.

Description

Defines which functions may be controlled by packets sent to the decoder's consist address. Disabled functions may be controlled only from decoder's primary or extended address:

bit 7							bit 0
F8	**F7**	**F6**	**F5**	**F4**	**F3**	**F2**	**F1**

Bit 0: F1, Consist Function 1 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 1: F2, Consist Function 2 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 2: F3, Consist Function 3 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 3: F4, Consist Function 4 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 4: F5, Consist Function 5 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 5: F6, Consist Function 6 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 6: F7, Consist Function 7 Enable Bit

0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 7: F8, Consist Function 8 Enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

This register is useful for differentiating the lead engine in the consist from the other engines. For example, by setting this register in the lead locomotive to 02 and the same register in all other engines to 00, only the whistle on the lead locomotive will blow when the command to turn on Function 2 is sent to the consist.

Default Value: 00

Related CVs: See also Consist Address, Consist F0 (FL) Function Active.

CV 22 CONSIST F0(FL) FUNCTION ACTIVE

Programmable in:- PM, DM, OPL.

Description
Defines whether the F0 (FL) function may be controlled by packets sent to the decoder's consist address. Disabled functions may be controlled only from decoder's primary or extended address:

bit 7							bit 0
0	**0**	**0**	**0**	**0**	**0**	**FL (r)**	**FL(f)**

Bit 0: F0 (FL)(f), F0 (FL) Forward enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

Bit 1: F0 (FL)(r), F0 (FL) Reverse enable Bit
0 = function is disabled for consist operation.
1 = function is enabled for consist operation.

This register is useful for differentiating the Front light and Backup Light functions in the lead engine of the consist from the other engines. For example, by setting this register in the lead locomotive to 01 and the same register in all other engines to 00, only the front light in the lead engine will be on and only when the consist is moving forward.

Default Value: 00

Related CVs: See also Consist Address, Consist Function Active.

CV 23 CONSIST ACCELERATION RATE

Programmable in:- PM, DM, OPS, OPL.

Description
Contains a value between -127 to +127 corresponding to the decoder's consist acceleration offset:

bit 7							bit 0
sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

Bits 0-6: D0-D6, Consist Acceleration value **Bit 7:** Sign
0 = positive value
1 = negative value

When the consist address is active, the consist acceleration rate is added to or subtracted from the decoder's base acceleration rate depending on the sign bit. The acceleration is then computed as:

$$\text{Seconds/speed step} = \frac{\textbf{(CV 3 + CV 23)* 0.896}}{\textbf{Number of Speed Steps}}$$

If the sum of CV 3 and CV 23 is negative, then the acceleration rate is set to 0 (i.e., acceleration is instant.) If the sum of CV 3 and CV 23 exceeds 255, then the acceleration rate is set to the maximum value of 255.

This CV has no effect when the consist address is set to 0.

In summary, a CV value between 0 and 127 (0x7F) will increase the decoder's base acceleration rate. Values between 128 (0x80) and 255 (0xFF) will decrease the decoder's base acceleration rate.

Default value: 0

Related CVs: See also Baseline Acceleration Rate, Baseline Braking Rate, Consist Brake Rate.

CV 24 CONSIST BRAKING RATE

Programmable in:- PM, DM, OPL.

Description
Contains a value between -127 to +127 corresponding to the decoder's consist braking offset:

bit 7							bit 0
sign	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

Bits 0-6: D0-D6, Consist Braking value **Bit 7:** Sign
0 = positive value
1 = negative value

When the consist address is active, the consist braking rate is added to or subtracted from the decoder's baseline braking rate depending on the sign bit. The braking rate is then computed as:

$$\text{Seconds/speed step} = \frac{\textbf{(CV 4+CV 24)X0.896}}{\textbf{Number of speed steps}}$$

If the sum of CV 4 and CV 24 is negative, then the braking rate is set to 0 (i.e., braking is instant.) If the sum of CV 3 and CV 23 exceeds 255, then the braking rate is set to the maximum value of 255.

This CV has no effect when the consist address is set to 0.

In summary, a CV value between 0 and 127 (0x7F) will increase the decoder's base braking rate. Values between 128 (0x80) and 255 (0xFF) will *decrease* the decoder's base braking rate.

Default value: 0

Related CVs: See also Baseline Acceleration Rate, Baseline Braking Rate, Consist Acceleration Rate.

CV 25 SPEED TABLE SELECT REGISTER

Programmable in:- PM, DM, OPL.

Description
Used to select one of 15 Speed Curves:

bit 7							bit 0
0			**USER**	**TBL3**	**TBL2**	**TBL1**	**TBL0**

Bits 3-0: TBL3:TBL0, Preset Speed Curves Select Bits.

0000	=	Speed Curves not used
0001	=	Speed Curves not used
0010	=	Linear Speed Curve
0011	=	Logarithmic Curve 1
0100	=	Logarithmic Curve 2
0101	=	Logarithmic Curve 3
0110	=	Logarithmic Curve 4
0111	=	Logarithmic Curve 5
1000	=	Logarithmic Curve 6
1001	=	Logarithmic Curve 7
1010	=	Exponential Curve 1
1011	=	Exponential Curve 2
1100	=	Exponential Curve 3
1101	=	Exponential Curve 4
1110	=	Exponential Curve 5
1111	=	Exponential Curve 6

Bit 4: USER, User Loadable Speed Table Select

0	=	Enable Speed curve defined by TBL3:TBL0
1	=	Enable Speed curve defined by CVs 67-94.

Bits 5-6: Not Used. These bits are ignored.

Bit 7: Mid Range Speed Step
This bit is not implemented and always reads as 0.

CV 25 may be programmed with any value between 0 and 31 (0x1F). Values between 02 and 15 (0x0F) allow the user to select from one of 14 predefined speed curves as depicted below. The logarithmic curves provide a shallower speed response as the regulator is increased. These curves are useful for locomotives that require a high starting voltage to get moving or matching a

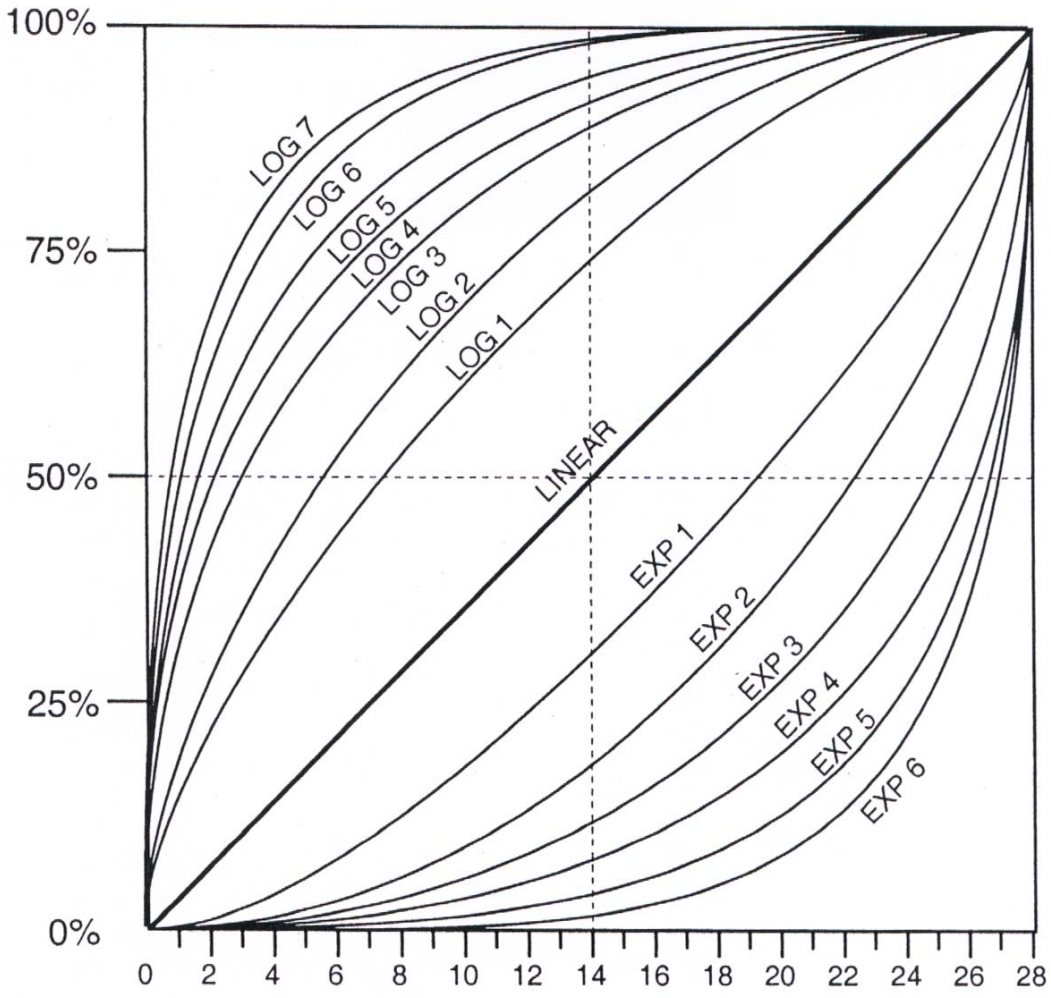
highly geared locomotive to one that has less gearing. The exponential curves are useful for slowing down locomotives that have a “slot car” response.

Setting this CV to a value between 16 and 31 (0x10-0x1F) will enable the speed curve programmed into CVs 67-94. This curve may modified by the user to get virtually any response desired.

Note that in order for the selected curve to be active, bit 4 of CV 29 must also be set to 1. If CV 29, bit 4 is 0, the regulator response will be linear (straight line).

The speed curves can be used in 14, 28 and 128 speed step modes.

Bit 7 is defined by the NMRA RPs as the Mid Range Speed Step select bit. The RDSD does not implement this feature and will ignore commands that attempt to program this bit with a 1 (i.e., data values between 128-255 or 0x80-0xFF).



Default value: 0

Related CVs: See also CV 29, Loadable Speed Table.

CV 29 CONFIGURATION REGISTER 1

Programmable in:- RM, PM, DM, OPL.

Description
CV 29 contains miscellaneous decoder configuration bits:

bit 7							bit 0
0	**N/A**	**EAM**	**STE**	**ACK**	**APS**	**F0 (FL)**	**DIR**

Bit 0: DIR, Direction Bit
0 = normal operation

1 = direction bit in Speed/Direction instruction is inverted
before processing.

Bit 1: F0 (FL), F0 (FL) Location
0 = F0 (FL) state is controlled by bit 4 of Speed/Direction Instruction.
(14 Speed Step Mode)
1 = F0 (FL) state is controlled by bit 4 of Function Group 1 Instruction
(28 and 128 Speed Step Modes)

Bit 2: APS, Alternate Power Source enable (not used)
0 = NMRA Digital Only
1 = Alternate Power Source enabled as set by CV 12

Bit 3: ACK, Advanced Acknowledge Mode enable (not used)
0 = Advanced Acknowledge mode disabled.
1 = Advanced Acknowledge mode enabled.

Bit 4: STE, Speed Table Enable
0 = Speed Table not used.
1 = Use custom speed table selected by CV 25.

Bit 5: EAM, Extended Address Mode enabled
0 = Decoder responds to Primary Address in CV 1
1 = Decoder responds to Extended Address in CV 17-18

Bit 6: Reserved. Set to 0 for future use.

Bit 7: Multifunction Decoder - Always reads as 0.

When the DIR bit is set, the locomotive and front light will run in a direction opposite to the speed/direction instruction received.

The F0 (FL) bit should be cleared to 0 if you are using the decoder in 14 speed step mode. If you are using 28 or 128 speed step modes, this bit should be set to 1.

The STE bit must be set to 1 in order to enable any of the speed curves selected using CV 25. Otherwise, the RDSD will provide a linear (straight-line) regulator response.

The EAM bit must be set to 1 in order to activate extended address capability. Note that once this bit is set, the decoder will respond to commands sent to the extended address only and commands sent to the primary address will be ignored. This can be a problem if you are using a command station that does not support extended addressing and the bit gets accidentally set. In

such a case, you must connect the RDSD to a programming track to gain access to the CV and clear the bit.

The RDSD does not support advanced acknowledgement or alternate power conversion and the ACK and APS bits will always read as 0.

Default value: 0X02

Related CVs: See also Extended Address, Loadable Speed Table.

CV 30 ERROR INFORMATION

Read Only in:- PM, DM, OPL.

Description
Contains manufacturer defined error codes and provides feedback in the event an operational failure occurred within the RDSD:

bit 7							bit 0
				I2C	**ROMCS**	**EEROM**	**WDOG**

Bit 0: WDOG, Watch Dog Timer Reset
0 = System normal.
1 = Watchdog time-out occurred.

Bit 1: EEROM, EEROM Data Corrupted
0 = System normal.
1 = CV Data in EEROM has become corrupted. All CVs will be reset to default values.

Bit 2: ROMCS, Program Checksum Failure
0 = System Normal
1 = Program Checksum Test Failed

Bit 3: I2C, I2C Bus Acknowledge Failure
0 = System Normal
1 = No acknowledge detected from I2C bus.

If the RDSD is operating properly, all error bits should read as 0. If an error is detected, it is usually a good idea to reset the decoder (tip the locomotive) and verify the error has recurred.

A WDOG error usually occurs when the RDSD experiences a large electrical glitch or static electricity discharge. It is not cause for concern unless it occurs frequently (several times within an operating session) in which case you should contact the factory for further assistance.

An EEROM error indicates that the CV data somehow became corrupted. If such an event occurs, the RDSD will reset all CV data to the default settings, F0 (FL)ash both front lights for 30 seconds, and resume normal operation. If this occurs, reprogram the CVs as needed. If the problem recurs repeatedly, this could indicate a problem with the RDSD. Contact the factory for further assistance. This bit can also be used to deliberately reset all other CV values to their default values with a single operation. This is done by programming CV 30 with 02 in service mode and turning power to the RDSD off and back on. *Note:* This bit can be programmed only in service mode. Writing any data value during operations mode will clear all error bits to 0.

A ROMCS error indicates a hardware failure has occurred and will usually be accompanied by strange sounding noises. Contact the factory for further assistance.

Decoder Reset

An I2C error also indicates a hardware failure and the RDSD will be unable to remember any changes made to the CV settings. Contact the factory for further assistance.
CV30 Default=0. Set default to 2. This implements a reset. After 30 seconds turn off the power, wait 10 seconds then turn the power on again. CV30 Auto resets to 0. Then Set CV30 to 4 to reset

Decoder using the ZTC 511 OR 505.

CV 33-42 FUNCTION OUTPUT MAPPING.

CVs 33-42 allow the user to customise which RDSD outputs or sound effects are controlled by which function keys. Each function input, F0 (FL) through F8, is assigned a unique CV that allows the corresponding function control to be redirected to up to eight different RDSD function outputs or sound effects. This allows a single function key to control more than one output if desired.

This feature is especially useful when the RDSD is used with a controller that has less than eight function keys as the user can select which RDSD outputs and sounds are important and re-map them to the available function keys. Some outputs or sounds can be sensibly tied to another output thus freeing up a function. For example, the dynamo sound could be configured to turn on whenever the front light or back light was on.

It is also possible to control a given output with more than one function key. In this case, the output will be turned on when any of the corresponding function inputs are active. The output will turn off only when all relevant inputs have also been turned off.

The F0 (FL) function has two CVs - one for forward direction and one for reverse. Function outputs mapped to these registers will be directional unless the same output is mapped to both CVs.

Note that all function inputs cannot be mapped to all outputs. The matrix below graphically indicates which inputs can control which outputs:

		RDSD OUTPUT													
CV	FUNCTION INPUT	Mute					Coupler		F5 Output	Hiss	Short Whistle	Long Whistle	F1 Output	Back Light	Front Light
33	FL (Fwd)	■	■	■	■	■	■								d
34	FL (Rev)	■	■	■	■	■	■							d	
35	Function 1	■	■	■	■	■	■						d		
36	Function 2	■	■	■	■	■	■					d			
37	Function 3	■	■	■							d		■	■	■
38	Function 4	■	■	■						d			■	■	■
39	Function 5	■	■	■					d				■	■	■
40	Function 6	■	■	■									■	■	■
41	Function 7						d			■	■	■	■	■	■
42	Function 8	d								■	■	■	■	■	■

Note: d = default setting.

Default Functions are assigned as follows.

F0 not available
F2=Hi-Lo Horn
F3=Coupling.
F4 Brake Squeal.
F5=High Horn,
F6=Low Horn,
F7 Not available
F8= Mute.

CV 33 F0 (forward) OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F0 (FL)(fwd) function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
	F5	**HISS**	**SWH**	**LWH**	**F1**	**BL**	**FL**

Bit 0: FL, Front light output
0 = Output is unaffected by F0 (FL)(fwd).
1 = Output is activated when F0 (FL)(fwd) is on.

Bit 1: BL, Back light output
0 = Output is unaffected by F0 (FL)(fwd).
1 = Output is activated when F0 (FL)(fwd) is on.

Bit 2: F1, Function 1 Output
0 = Output is unaffected by F0 (FL)(fwd).
1 = Output is activated when F0 (FL)(fwd) is on.

Bit 3: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F0 (FL)(fwd).
1 = Sound is activated when F0 (FL)(fwd) is on.

Bit 4: SWH, Short whistle Sound Effect
0 = Sound is unaffected by F0 (FL)(fwd).
1 = Sound is activated when F0 (FL)(fwd) is on.

Bit 5: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F0 (FL)(fwd).
1 = Sound is activated when F0 (FL)(fwd) is on.

Bit 6: F5, Function 5 Output
0 = Output is unaffected by F0 (FL)(fwd).
1 = Output is activated when F0 (FL)(fwd) is on.

Bit 7: Reserved. Set to 0

A value of 00, sets F0 (FL)(fwd) to control FL output.

Default Value: 1

Related CVs: See also CVs 33-42.

CV 34 F0 (reverse) OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F0 (rev) function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
	F5	**HISS**	**SWH**	**LWH**	**F1**	**BL**	**FL**

Bit 0: FL, Front light output
0 = Output is unaffected by F0 (rev).
1 = Output is activated when F0 (rev) is on.

Bit 1: BL, Back light output
0 = Output is unaffected by F0 (rev).
1 = Output is activated when F0 (rev) is on.

Bit 2: F1, Function 1 Output
0 = Output is unaffected by F0 (rev).
1 = Output is activated when F0 (rev) is on.

Bit 3: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F0 (FL)(rev).
1 = Sound is activated when F0 (FL)(rev) is on.

Bit 4: SWH, Sort whistle Sound Effect
0 = Sound is unaffected by F0 (FL)(rev).
1 = Sound is activated when F0 (FL)(rev) is on.

Bit 5: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F0 (FL)(rev).
1 = Sound is activated when F0 (FL)(rev) is on.

Bit 6: F5, Function 5 Output
0 = Output is unaffected by F0 (FL)(rev).
1 = Output is activated when F0 (FL)(rev) is on.

Bit 7: Reserved. Set to 0.

A value of 00 sets F0 (FL)(rev) to control BL output.

Default Value: 2

Related CVs: See also CVs 33-42.

CV 35 F1 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F1 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
	F5	**HISS**	**SWH**	**LWH**	**F1**	**BL**	**HL**

Bit 0: FL, Front light output
0 = Output is unaffected by F1.
1 = Output is activated when F1 is on.

Bit 1: BL, Back light output
0 = Output is unaffected by F1.
1 = Output is activated when F1 is on.

Bit 2: F1, Function 1 Output
0 = Output is unaffected by F1.
1 = Output is activated when F1 is on.

Bit 3: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F1.
1 = Sound is activated when F1 is on.

Bit 4: SWH, Short Whistle Sound Effect
0 = Sound is unaffected by F1.
1 = Sound is activated when F1 is on.

Bit 5: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F1.
1 = Sound is activated when F1 is on.

Bit 6: F5, Function 5 Output
0 = Output is unaffected by F1.
1 = Output is activated when F1 is on.

Bit 7: Reserved. Set to 0

A value of 00 sets F1 to control F1 output.

Default Value: 4

Related CVs: See also CVs 33-42.

CV 36 F2 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description

Maps the F2 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7								bit 0
		F5	**HISS**	**SWH**	**LWH**	**F1**	**BL**	**FL**

Bit 0: FL, Front Light output
0 = Output is unaffected by F2.
1 = Output is activated when F2 is on.

Bit 1: BL, Back light output
0 = Output is unaffected by F2.
1 = Output is activated when F2 is on.

Bit 2: F1, Function 1 Output
0 = Output is unaffected by F2.
1 = Output is activated when F2 is on.

Bit 3: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F2.
1 = Sound is activated when F2 is on.

Bit 4: SWH, Short Whistle Sound Effect
0 = Sound is unaffected by F2.
1 = Sound is activated when F2 is on.

Bit 5: HISS, Cylinder Blowdown/Hiss Sound Effect
0 = Sound is unaffected by F2.
1 = Sound is activated when F2 is on.

Bit 6: F5, Function 5 Output
0 = Output is unaffected by F2.
1 = Output is activated when F2 is on.

Bit 7: Reserved. Set to 0.

A value of 00 sets F2 to control the WHISTLE sound effect.

Default Value: 8

Related CVs: See also CVs 33-42.

CV 37 F3 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F3 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
		CPLR		**F5**	**HISS**	**SWH**	**LWH**

Bit 0: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F3.
1 = Sound is activated when F3 is on.

Bit 1: SWH Sound Effect
0 = Sound is unaffected by F3.
1 = Sound is activated when F3 is on.

Bit 2: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F3.
1 = Sound is activated when F3 is on.

Bit 3: F5, Function 5 Output
0 = Output is unaffected by F3.
1 = Output is activated when F3 is on.

Bit 4: Reserved. Set to 0

Bit 5: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F3.
1 = Sound is activated when F3 is on.

Bit 6: Reserved. Set to 0

Bit 7: Reserved. Set to 0

A value of 00 sets F3 to control the Short Whistle (SWH) sound effect.

Default Value: 2

Related CVs: See also CVs 33-42.

CV 38 F4 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F4 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit7						bit 0
		CPLR		**F5**	**HISS**	**SWH LWH**

Bit 0: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F4.
1 = Sound is activated when F4 is on.

Bit 1: SWH Short Whistle Sound Effect
0 = Sound is unaffected by F4.
1 = Sound is activated when F4 is on.

Bit 2: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F4.
1 = Sound is activated when F4 is on.

Bit 3: F5, Function 5 Output
0 = Output is unaffected by F4.
1 = Output is activated when F4 is on.

Bit 4: Reserved. Set to 0

Bit 5: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F4.
1 = Sound is activated when F4 is on.

Bit 6: Reserved. Set to 0

Bit 7: Reserved. Set to 0

A value of 00 sets F4 to control the HISS sound effect.

Default Value: 4

Related CVs: See also CVs 33-42.

CV 39 F5 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F5 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
		CPLR		**F5**	**HISS**	**SWH**	**LWH**

Bit 0: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F5.
1 = Sound is activated when F5 is on.

Bit 1: SWH Short Whistle Sound Effect
0 = Sound is unaffected by F5.
1 = Sound is activated when F5 is on.

Bit 2: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F5.
1 = Sound is activated when F5 is on.

Bit 3: F5, Function 5 Output
0 = Output is unaffected by F5.
1 = Output is activated when F5 is on.

Bit 4: Reserved. Set to 0

Bit 5: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F5.
1 = Sound is activated when F5 is on.

Bit 6: Reserved. Set to 0

Bit 7: Reserved. Set to 0

A value of 00 sets F5 to control the F5 function output.

Default Value: 8

Related CVs: See also CVs 33-42.

CV 40 F6 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F6 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7							bit 0
		CPLR		**F5**	**HISS**	**SWH**	**LWH**

Bit 0: LWH, Long Whistle Sound Effect
0 = Sound is unaffected by F6.
1 = Sound is activated when F6 is on.

Bit 1: SWH Short whistle Sound Effect
0 = Sound is unaffected by F6.
1 = Sound is activated when F6 is on.

Bit 2: HISS, Cylinder Blow-down/Hiss Sound Effect
0 = Sound is unaffected by F6.
1 = Sound is activated when F6 is on.

Bit 3: F5, Function 5 Output
0 = Output is unaffected by F6.
1 = Output is activated when F6 is on.

Bit 4: Reserved

Bit 5: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F6.
1 = Sound is activated when F6 is on.

Bit 6: Reserved. Set to 0

Bit 7: Reserved. Set to 0

A value of 00 sets F6 to control nothing in this case.

Default Value: 16 (0x10)

Related CVs: See also CVs 33-42.

CV 41 F7 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F7 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7 bit 0

MUTE					**CPLR**		**F5**

Bit 0: F5, Function 5 Output
0 = Output is unaffected by F7.
1 = Output is activated when F7 is on.

Bit 1: Reserved. Set to 0

Bit 2: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F7.
1 = Sound is activated when F7 is on.

Bit 3: Reserved. Set to 0

Bit 4: Reserved. Set to 0

Bit 5: Reserved. Set to 0

Bit 6: Reserved. Set to 0

Bit 7: MUTE, Audio Mute Function
0 = Sound is unaffected by F7.
1 = Sound is muted when F7 is on.

A value of 00 sets F7 to control the COUPLING sound effect.

Default Value: 4

Related CVs: See also CVs 33-42.

CV 42 F8 OUTPUT LOCATION

Programmable in:- PM, DM, OPL.

Description
Maps the F8 function to any of eight RDSD auxiliary function outputs as defined by a 1 in the corresponding bit position:

bit 7 bit 0

MUTE					**CPLR**		**F5**

Bit 0: F5, Function 5 Output
0 = Output is unaffected by F8.
1 = Output is activated when F8 is on.

Bit 1: Reserved. Set to 0

Bit 2: CPLR, Coupling Sound Effect
0 = Sound is unaffected by F8.
1 = Sound is activated when F8 is on.

Bit 3: Reserved. Set to 0

Bit 4: Reserved. Set to 0

Bit 5: Reserved. Set to 0

Bit 6: Reserved. Set to 0

Bit 7: MUTE, Audio Mute Function
0 = Sound is unaffected by F8.
1 = Sound is muted when F8 is on.

A value of 00 sets F8 to control the MUTE function.

Default Value: 128 (0x80)

Related CVs: See also CVs 33-42.

CV 49 LIGHTING CONFIGURATION

Programmable in:- PM, DM, OPS, OPL.

Description
Used to reconfigure the F1 and F5 lighting outputs to one of four Hyperlight lighting effects:

bit 7							bit 0
				F5.1	**F5.0**	**F1.1**	**F1.0**

Bits 1-0: F1.1:F1.0, Function 1 Output Configuration
00 = Standard On/Off output
01 = Beacon Light Effect
10 = Firebox flicker Effect
11 = Synchronised Firebox F0 flicker - Turns on and off with sound effect of firebox door opening and closing.

Bits 2-3: F5.1:F5.0, Function 5 Output Configuration
00 = Standard On/Off output
01 = Beacon Light Effect
10 = Firebox flicker Effect
11 = Synchronised Firebox flicker - Turns on and off with sound effect of firebox door opening and closing.

Bit 4-7: Reserved. Set to 0
Note: the selected lighting effect will not turn on until the appropriate function key is on as well.

Default Value: 0, F1 = On/Off Output, F5 = On/Off Output

CV 50 VOLUME CONTROL

Programmable in:- PM, DM, OPL.

Description
Contains a value between 0 and 15 (0x0F) to used to set the overall volume level of the RDSD sound effects:

bit 7							bit 0
				D3	**D2**	**D1**	**D0**

Bits 0-3: D0-D3, Volume Control

Bit 4-7: Reserved. Set to 0

Setting this CV to 15 will provide maximum volume. A setting of 0 will mute all sound effects.

Default Value: 08 (0x08), 50% Volume

CV 51 BACKGROUND SOUND CONFIGURATION BYTE

Programmable in:- PM, DM, OPL.

Description
This CV is used to selectively enable the RDSD's various background sound effects:

bit 7							bit 0
AUTO	**ABD**	**BPR**	**PGG**	**PETE**	**BLWR**	**VPUMP**	**RTC**

Bit 0: RTC, Real Time Clock Mode
0 = Background sound effects are spaced at scale time intervals ranging typically between 2-20 minutes.
1 = Background sound effects are spaced at real time intervals ranging typically between 20 minutes to several hours

Bit 1: VPUMP, Vacuum pump Sound Enable
0 = Vacuum pump sound effect is turned off.
1 = Vacuum pump sound effect is turned on.

Bit 2: BLWR, Firebox Blower Sound Enable
0 = Blower sound effect is disabled.
1 = Blower sound effect is enabled.

Note: Blower sound is always on. This bit enables the effect of increasing blower draft while the engine is idle.

Bit 3: PETE, Fireman Pete shovelling coal Sound Enable
0 = Fireman Pete sound effect is disabled.
1 = Fireman Pete sound effect is enabled.

Bit 4: Reserved. Set to 0
Bit 5: BPR Boiler Pressure Relief Valve, Blow off Sound Enable
0 = Pressure Relief Valve sound effect is disabled.
1 = Pressure Relief Valve sound effect is enabled.

Bit 6: ABD, Automatic Cylinder Blow Down Enable
0 = Blow down effect is activated by function key.
1 = Blow down effect is activated by engine stops.

Bit 7: BGND, Background sound effect global enable
0 = All background sound effects are disabled.
1 = All selected background sound effects are enabled.

Default Value: 190 (0xBE), All sound effects are enabled. Auto Blow-down is disabled.

CV 52 FOREGROUND SOUND CONFIGURATION BYTE

Programmable in:- PM, DM, OPL.

Description
This CV is used to configure the RDSD's foreground sound effects:

bit 7							bit 0
				VPS	**CAM**	**DDE**	**AECS**

Bit 0: AECS, Articulated Exhaust Cadence Select
0 = Exhaust Timing emulates 2 cylinder locos.
1 = Exhaust Timing emulates articulated locos.

Bit 1: DDE, Dynamic Digital Exhaust Enable
0 = DDE sound processor is disabled.
1 = DDE sound processor is enabled.

Bit 2: CAM Enable
0 = Exhaust Chuff is synchronised to regulator.
1 = Exhaust Chuff is synchronised with cam.

Bit 3: VPS, Vacuum Pump Select
0 = Single Vacuum pump sound effect.
1 = Dual Vacuum pump sound effect.

Note: CV 51, Bit 1 must be set for this sound to be heard.

Bit 4-7: Reserved. Set to 0

Default Value: 02
Auto-Exhaust Cadence set for 2 Cylinder Locomotive.
Dynamic Digital Exhaust (DDE) enabled
Vacuum pump enabled
Exhaust Cam disabled (Set to 06 for cam sync)

Related CVs: See also Auto Exhaust Sync Rate (CV 54).

CV 53 SOUND CONFIGURATION BYTE #3

Programmable in:- PM, DM, OPL.

Description

This CV controls the power-up state of the sound effects:

bit 7							bit 0
							QUIET

Bit 0: QUIET
0 = Sound turns on a few seconds after power is turned on.
1 = Sound turns on only when the RDSD receives a packet with a matching address.

Bits 1-7: Reserved. Set to 0

The Quiet bit is used for "noise control' when many RDSD equipped engines are on a layout. When set to 1, locomotives not in use will remain quiet until they are called into service.

Default Value: 0

CV 54 AUTO EXHAUST SYNC RATE

Programmable in:- PM, DM, OPL.

Description
This CV contains a value n between 0 and 255 that specifies the chuff synchronisation rate as a proportion of the regulator for Auto-Exhaust operation.

bit 7							bit 0
CAM	**AE6**	**AE5**	**AE4**	**AE3**	**AE2**	**AE1**	**AE0**

Bits 0-7: AE7:AE0, Auto Exhaust/Cut-off Control Rate

For Auto-Exhaust synchronisation, the chuff rate will be generated in proportion the regulator setting. To select Auto-Exhaust mode, the CV is loaded with any value between 0 and 255 (0xFF). Higher values will yield higher chuff rates for a given regulator setting. A value of 0 will disable the exhaust sound.

The correct synchronisation rate may be computed as:

$$\text{CV Value} = 115.9 \times \frac{\text{SPD}}{\text{DIA}}$$

Where SPD is the locomotive’s speed in scale miles-per-hour at maximum regulator and DIA is the locomotive’s driver wheel diameter in scale inches.

(For geared steam engines such as Shays etc, the CV value should also be multiplied by the locomotive's gear ratio).

When using cam synchronisation, this CV will control the exhaust cut-off rate. To get optimal performance over the entire regulator range, the CV value should be calculated using the same formula above.

Default Value: 94 (0x5E)

Related CVs: See also Foreground Sound Configuration.

CV 55 EXHAUST TONE CONTROL

Programmable in:- PM, DM, OPL.

Description.
This CV contains a value between 0 and 63 that sets tone of the exhaust chuff:

bit 7 bit 0

		TONE5	**TONE4**	**TONE3**	**TONE2**	**TONE1**	**TONE0**

Bits 0-5: TONE5: TONE0, Exhaust Tone Control

Bits 6-7: Reserved. Set to 0

This CV controls the overall tone of the exhaust chuff. Higher values increase the high-frequency component of the sound.

Default Value: 08

CV 56 EXHAUST VOLUME CONTROL For Steam

Programmable in:- PM,DM.OPL.

Description
This CV contains a value between 0 and 255 that controls the exhaust chuff volume:

bit 7 bit 0

VOL7	**VOL6**	**VOL5**	**VOL4**	**VOL3**	**VOL2**	**VOL1**	**VOL0**

Bits 0-7: VOL7: VOL0, Exhaust Volume Control

This CV controls the overall volume of the exhaust chuff when the Dynamic Digital Exhaust processor is disabled. Higher values will increase the volume level. When the DDE processor is on, this CV will have no effect.

Default Value: 255 (0x255)

See Also: Foreground Sound Configuration

CV 56 SOUND CONFIGURATION BYTE#1 For Diesel

Programmable in:- PM,DM.OPL.

Description
This CV is used to set the quiet mode and enable/disable background sounds:

bit 7							bit 0
						POP	**QIIET**

Bit 0: QUIET, Quiet mode Enable.
0=Sound turns on a few seconds after the power is turned on.
1=Sound turns on only when the RDSD receives a packet with a matching address

Bit 1: POP Compressor Pop valve sound effect enabled.
Used to enable the or disable the vacuum pop valve effect.

0= Effect Off
1= Effect On

The quiet bit is used for “noise control” when many RDSD equipped engines are on a layout. When set to 1 the locomotives not in use will remain quiet until they are called into service. Similarly, if the locomotive is de-commissioned, it will also cause the sound to be turned off after a period of time as set by CV11. Note the quiet bit will only work when auto notching is disabled. See CV58.

Bit 2-7 Reserved.

Default Value: 3

See Also: CV11

CV 58 ENGINE CONTROL CONFIGURATION BYTE

Programmable in:- PM,DM.OPL.

Description
This CV specifies the number of speed steps needed to advance the engine rpm notches, as well as selecting between manual or automatic engine notching:

bit 7							bit 0
			LOCK	**AN3**	**AN2**	**AN1**	**ANO**

BIT 0-3 ANO0-3 Auto Notching Enable
0000 = Auto Notching Disabled
0001 = One speed step per Throttle Notch For 128 speed step mode.
1111 = 15 Speed steps per Throttle Notch For 28 speed step mode.

These bits specify the percentage of throttle needed to advance or retard the engine exhaust sound one Throttle Notch.

When auto notching is enabled, engine will start-up when throttle is first increased. It will increase in proportion to the throttle speed. The engine RPM`s may be shutoff by pressing the emergency stop once.

When auto notching is disabled, the engine RPM`s+ (function 3) and RPM`s- (Function 4) are used to manually increase/decrease the engine RPM sound.

Bit 4 LOCK = Engine RPM Interlock
0 = Interlock disabled.
1 = Interlock enabled.

This bit is used to interlock the engine RPM`s and the throttle setting when manual notching is used such that:

1. The locomotive cannot be moved unless the engine has been started.
2. Engine cannot be shutoff unless throttle is zero.

Besides the fun of forcing the engineer to follow the correct operating protocol, this bit is also useful in preventing inadvertent engine shut down while the train is still in motion.

Bit 5 Reserved

Bit 6 Reserved.

Bit 7 Reserved

Default Value 7

Related CV See also CV 60

CV 60 HORN VOLUME CONTROL.

Programmable in:- PM, DM, OPL.

Description
This CV is used to independently set the volume level of the Horn/ Background sounds. The upper four bits set the sound level for the coupler and compressor sounds and has a range of 0-15. The lower four bits set the Horn volume level over the range of 0-15

bit 7 bit 0

CV3	CV2	CV1	CV0	HV3	HV2	HV1	HV0

Bit 0-3: HV0-HV3 Horn Volume Control
0000 = Minimum Volume
1111 = Maximum Volume.

Bit 4-7: BV0-BV3 Background Volume Control
0000 = Minimum Volume
1111 = Maximum Volume.

Default Value: 104, Background Volume 40%, Horn Volume = 50%

Related CVs: See also CVs 33-42.

CV 66 FORWARD TRIM

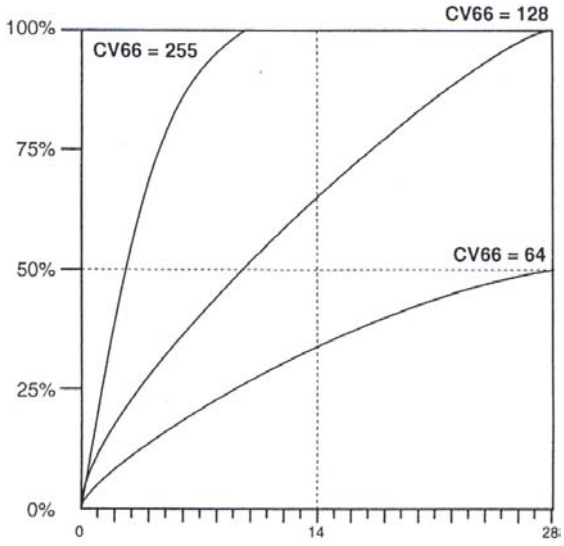
Programmable in:- PM, DM, OPL.

Description
Contains a value, n, between 0 and 255 that specifies a scaling factor interpreted as N/128 by which the forward drive voltage is multiplied.

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Forward Trim Scalar

The forward trim scalar allows the decoder's overall regulator response in the forward direction to be adjusted up or down for the purpose of matching one locomotive's speed curve to another. See graph below.



A trim value of 128 (0x80) yields a scaling factor of 1.0 which will have no net effect on the speed response.

Trim values between 129 and 255 (0x81-0xFF) have the effect of increasing the motor voltage by a factor ranging between 1.01 to 1.99.

Trim values between 1 and 127 (0x01-0x7F) will decrease the motor voltage by a factor between 0.008 and 0.99.

A trim value of 0 disables the trim scalar computation.

This CV is used only when speed tables are enabled (CV 29, Bit 4 = 1). Otherwise, this CV will have no effect.

Default Value: 128 (0x80)

Related CVs: See also Reverse Trim, CV 95.

CV 67-94 LOADABLE SPEED TABLE

Programmable in:- PM, DM, OPL.

Description
The loadable speed table is made up of 28 CVs. Each CV contains a value, n, between 0 and 255 that specifies the percentage of the maximum regulator voltage interpreted as n/255 that is to be applied to the motor when the speed step in use corresponds to that CV.

bit 7							bit 0
D7	**D6**	**D5**	**D4**	**D3**	**D2**	**D1**	**D0**

D0-D7: Speed Table Data

The loadable speed table may be used in the 14, 28 and 128 speed step modes. When 14 speed step mode is in effect, the RDSD will use a curve defined by every other speed table value starting with speed step 1.

When 28 step mode is enabled, the RDSD will simply use one table value for each speed step.

When 128 step mode is enabled, the RDSD will interpolate 4-5 points between each speed table entry to build a 128 point curve.

Note that the RDSD will not use the loadable speed table until bit 4 in *both* CV 25 and CV 29 are set to 1.

Default values: The default values provide a linear (straight line) response. Individual CVs are loaded as follows:

CV 67	(Speed Step 1):	0 (0x00)
CV 68	(Speed Step 2):	9 (0x09)
CV 69	(Speed Step 3):	18 (0x12)
CV 70	(Speed Step 4):	28 (0x1C)
CV 71	(Speed Step 5):	37 (0x25)
CV 72	(Speed Step 6):	47 (0x2F)
CV 73	(Speed Step 7):	56 (0x38)
CV 74	(Speed Step 8):	66 (0x42)
CV 75	(Speed Step 9):	75 (0x4B)
CV 76	(Speed Step 10):	85 (0x55)
CV 77	(Speed Step 11):	94 (0x5E)
CV 78	(Speed Step 12):	103 (0x67)
CV 79	(Speed Step 13):	113 (0x71)
CV 80	(Speed Step 14):	122 (0x7A)
CV 81	(Speed Step 15):	132 (0x84)
CV 82	(Speed Step 16):	141 (0x8D)
CV 83	(Speed Step 17):	151 (0x97)
CV 84	(Speed Step 18):	160 (0xA0)
CV 85	(Speed Step 19):	170 (0xAA)
CV 86	(Speed Step 20):	179 (0xB3)
CV 87	(Speed Step 21):	188 (0xBC)
CV 88	(Speed Step 22):	198 (0xC6)
CV 89	(Speed Step 23):	207 (0xCF)
CV 90	(Speed Step 24):	217 (0xD9)
CV 91	(Speed Step 25):	226 (0xE2)
CV 92	(Speed Step 26):	236 (0xEC)
CV 93	(Speed Step 27):	245 (0xF5)
CV 94	(Speed Step 28):	255 (0xFF)

Related CVs: See also CV 29, Speed Table Select Register.

CV 95 REVERSE TRIM

Programmable in:- PM, DM, OPL.

Description
Contains a value, n, between 0 and 255 that specifies a scaling factor interpreted as N/128 by which the reverse drive voltage is multiplied.

bit 7 bit 0

D7	D6	D5	D4	D3	D2	D1	D0

D0-D7: Reverse Trim Scalar

The reverse trim scalar allows the decoder's overall regulator response in the reverse direction to be adjusted up or down for the purpose of matching one locomotive's speed curve to another.

A trim value of 128 (0x80) yields a scaling factor of 1.0 which will have no net effect on the speed response.

Trim values between 129 and 255 (0x81-0xFF) have the effect of increasing the motor voltage by a factor ranging between 1.01 to 1.99.

Trim values between 1 and 127 (0x01-0x7F) will decrease the motor voltage by a factor between 0.008 and 0.99.

A trim value of 0 disables the trim scalar computation.

This CV is used only when speed tables are enabled (CV 29, Bit 4 = 1). Otherwise, this CV will have no effect.

Default Value: 128 (0x80)

Related CVs: See also Forward Trim, CV 66.

CV 105 USER IDENTIFIER #1

Read Only:-

Description
Provides storage for user supplied data such as purchase date, serial numbers, spouse's birthday, etc. This CV otherwise has no effect on the RDSD operation.

bit 7 bit 0

D7	D6	D5	D4	D3	D2	D1	D0

D0-D7: User Identifier data

This CV may be programmed with any value between 0 and 255 (0x00-0xFF).

Default Value: 0

Related CVs: See also User Identifier #2.

CV 106 USER IDENTIFIER #2

Programmable in:- AD, RM, PM, DM, OPS, OPL.

Description
Provides storage for user supplied data such as purchase date, serial numbers, spouse's birthday, etc. This CV otherwise has no effect on the RDSD operation.

bit 7 bit 0

D7	D6	D5	D4	D3	D2	D1	D0

D0-D7: User Identifier data

This CV may be programmed with any value between 0 and 255 (0x00-0xFF).

Default Value: 0
Related CVs: See also User Identifier #1.

ACKNOWLEDGEMENTS

In the process of recording the many locomotive sounds used in the creation of the RealFeel™ Digital Sound Decoders, we'd like to gratefully acknowledge the assistance of the following groups and organisations and their staff:-

The West Somerset Railway PLC.
The Railway station,
Minehead,
Somerset.
TA24 5BG
Tel;- 01643 704996.

Soundtraxx™
210 Rock Point Drive
Durango, CO 81301
USA
Tel:- + 1 970 259 0690. Fax:- + 1 970 259 0691
Email:- Sales@soundtraxx.com

TROUBLESHOOTING.

If you should have any difficulties with the operation of your ZTC Controls Ltd RealFeel™ Digital Sound Decoder, first check this section for hints on troubleshooting. If you cannot isolate the problem, we suggest that you call the ZTC help line on 0870 241 8730 between 9 am and 5-30pm weekdays. Alternatively you can write to us with a note describing the problem in as much detail as possible, before you returning the unit to us. (Please see our Service and Warranty Policy).

1.0 The locomotive runs for awhile and then stops.

The decoder may be overheating. Be sure the decoder is located where it can dissipate excess heat. You may also try lowering your command station's track voltage setting.

2.0 The sound works for awhile and then stops.

The decoder amplifier may be overheating. Be sure the decoder is located where it can dissipate excess heat. You can also try lower the volume using CV 50 or your command station's track voltage setting.

3.0 The locomotive doesn't move.

Be sure the locomotive address matches that of your controller. If the acceleration CVs are loaded with very large values, the locomotive may be also be very slow to accelerate taking almost four minutes to reach full speed.

4.0 The decoder and lights work OK but there is no sound.

Check that the CV 50, volume control is not set to zero or that the mute function (F8) has not been set to ON.

5.0 The locomotive buzzes when moving at slow speeds.

This is a normal characteristic of virtually all DCC decoders and is an unavoidable side effect of using PWM (Pulse Width Modulation) to drive the motor. The buzzing can be minimised by adjusting the drive frequency via CV 9

6.0 The lights won't turn on and off.

This is caused when the decoder is set up for 14 speed step operation and the Controller or command station is sending 28 or 128 speed step packets. Reprogram the decoder and/or command station so the speed step modes match. For more information, see CV 29.

An alternate cause may be that the decoder functions have been improperly mapped to another function key. See CVs 33 to 42 for more information.

7.0 The lights flicker ON and OFF as the throttle increases.

This occurs when the decoder is set up for 14 speed step operation and the Controller or Command station is sending speed and direction commands for 28 speed step mode. Reprogram the decoder and/or command station so the speed step modes match. For more information, see CV 29.

8.0 The Hiss function does not work.

If the auto blow down feature is enabled, the hiss function cannot be manually controlled. See CV 51 for more information.

9.0 The Exhaust Chuff does not work.

If you are using the exhaust cam, be sure the wiper is making contact with the synchroniser disk and there is no buildup of dirt or grease. If you are using the Auto-Exhaust feature, be sure bit 2 in CV 52 is set to 0. See CV 52 for more information. If the DDE is disabled (CV 52, bit = 0), be sure exhaust volume (CV 56) is not 0.

10. The Locomotive Just Sits and Flashes both front and back lights.

This indicates that the CV data has become corrupted and all CVs have been reset to their default values. The RDSD will return to normal operation after about 30 seconds, or if power is turned off and back on. You will need to reprogram any CVs you previously modified.

APPENDIX A

ZTC CONTROLS LTD DCC OPTIONS AND ACCESSORIES

Wiring Aids
Shrink tubing and miniature connectors make wiring easy and protect your connections. We offer a variety of items designed to make your installation a simpler procedure.

ZTC 113 Sound Decoder Manual

ZTC 152 22 Ohm Resistor.
Pack of 10 resistors with a value 22 ohm quarter watt resistors required to limit the supply voltage to the RDSD in the larger scales, 0 Gauge and above.

ZTC 153 560 Ohm Resistor.
Pack of 10 resistors with a value 560 ohm quarter watt resistors required to limit the supply voltage to the micro bulbs in the larger scales, 0 Gauge and above.

ZTC 154 680 Ohm Resistor.
Pack of 10 resistors with a value 680 ohm quarter watt resistors required to limit the supply voltage to the micro bulbs in the larger scales, 0 Gauge and above.

ZTC 160 Acoustic wool.
This product has been especially designed to reduce the acoustic resonance found in thin wall enclosures such as tenders etc. It ensures that higher audio output levels can be achieved before speaker distortion occurs and ensures a much better quality signal to the ear. We strongly recommended this product for the installation in miniature speaker enclosures.

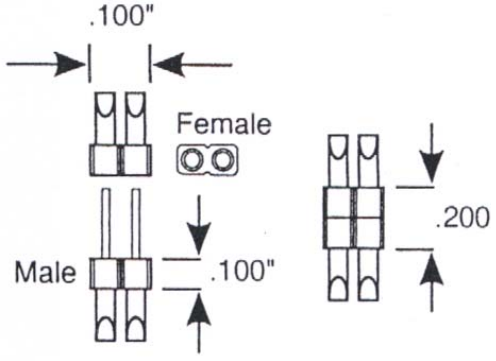
ZTC 161 Black Acoustic Matting.
This is ideal for closing the top of tenders where a high quality miniature loudspeaker is housed. It stops the ingress of dust and other debris which will damage the cone of the loudspeaker. Lightly spray (**Before Installation**) with a lacquer or similar adhesive then sprinkle with real or synthetic coal to simulate a tender load, without obstructing the passage of the sound signal.

ZTC 162 1.3mm Micro bulbs
These brilliant and long-lasting tiny incandescent bulbs measure just 1.3mm (0.053") diameter by 3.2 mm (0.125") Long. They are rated for 1.5V and are used for RDSD lighting effects and as replacements.

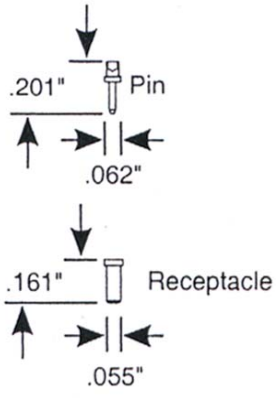
ZTC 163 2.5mm Micro bulbs
This larger version of the above measures 2.5mm (0.094") diameter by 4.72mm (0.186") Long. They are rated for 1.5V and are useful for larger scales or effects where a larger bulb would be more effective (Beacon lights or other Function units), and again as replacements.

ZTC 164 Small Pin Connectors
These miniature dual connectors are useful between the locomotive and tender for easy disconnection.

ZTC 165 Micro Pin Connectors
Single pin micro connectors are useful for connecting single wires together. Pack of ten with mating halves.

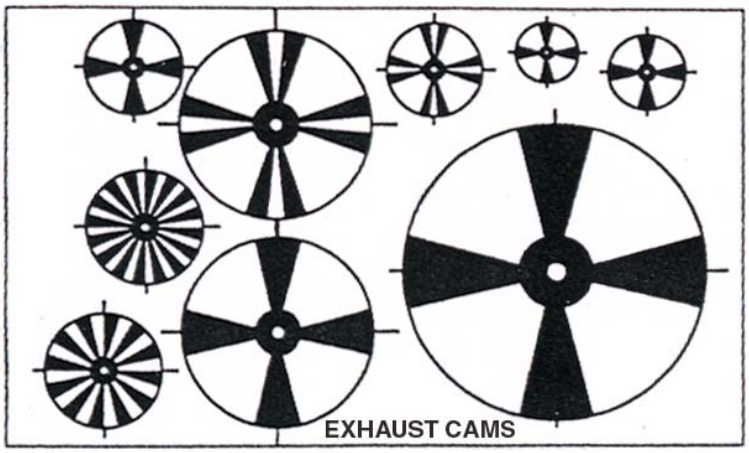


ZTC 164 Small Pin Connectors



ZTC 165 Micro Pin Connectors

ZTC 166 Exhaust Switch Disc.
The Exhaust Switch Kit provides an assortment of exhaust synchronisation discs that can be mounted quickly and easily to the inside face of the driver wheel, often without disassembly of the locomotive. IT includes cams for 2-cylinder 3 and 4 cylinder steam locomotives.



ZTC 167 Exhaust Cam Switch .
The Exhaust Cam switch Kit provides an axial mounted cam for exhaust synchronisation that can be mounted on the axial along with a nickel silver contact spring.

ZTC 168 Conductive paint.
This provides a simple and effective path to connect the wheel axial to the track which the provides the return path of the exhaust cam or switch disc to the track.

ZTC 170 to ZTC 199.
A range of small high quality Acoustic loudspeakers specially selected for use with the ZTC RealFeel Sound Decoders. Please see the separate sheet for full details and prices.

ZTC 399 Zippi Pack
This pack contains a selection of heat shrink sleeves of insulating tubing useful for covering exposed component leads and wires. The pack contains a variety of lengths and diameters.

ZTC 606 Decoder Test Kit
Test your decoder before installing in your locomotive to verify proper operation! This easy to construct kit will provide the confidence to complete your installation without unforeseen problems. Not Required for use with the ZTC 450.

ZTC Loudspeakers.
For a complete range of Loudspeakers available from ZTC Controls Ltd see Appendix D

APPENDIX B - RDSD FUNCTIONAL TEST

Although each RDSD has been fully tested prior to shipment and is ready for installation, we urge you to test your decoder before installing in your locomotive! We have developed a simple procedure that assures you that the RDSD is functioning as it should before you do the installation. If this is your first sound or decoder installation, it will give you an added boost of confidence, knowing that as long as you follow the installation instructions...it **will** work!

In the event you do have a problem, please contact your dealer or ZTC Controls Ltd for technical assistance before sending the unit back. We will gladly refund payment or replace any decoder that does not pass the functional test free of charge provided that none of the decoder wires have been cut short.

Before you get started, we must reiterate - **do not shorten any decoder leads** until you have verified that the decoder is functioning properly. **Do not install any decoder that does not pass the Functional Test.**

Items Needed for the Functional Test

To perform the Functional Test, you will need:
- A Decoder Test Kit - ZTC 606
- An NMRA-compatible DCC system
- One 1 watt 8 ohm speaker

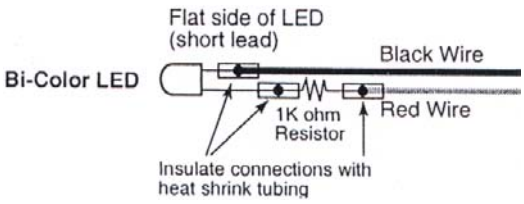
Creating a Test Circuit

For your convenience, ZTC Controls Ltd offer a test kit, Item No. ZTC 606 which includes all of the items needed for testing the RDSD, including detailed instructions. If you prefer, you can make up your own kit with some simple parts purchased from your local electronics supplier. If you decide to create your own test kit, you will need:

Oty.	Description
1	Resistor, 22 ohm, 2 Watt
1	Resistor, IK ohm, 1/4 Watt
1	Bicolor LED
1	Black Wire
1	Red Wire
1	Length of small diameter shrink tubing

Preparing the Test Fixture

1. Connect the black wire to the short lead of the LED.
2. Connect one lead of the IK ohm resistor to the long lead of the LED.
3. Connect the other lead of the 1 K ohm resistor to the red wire.
4. Insulate the connections with heat shrink tubing.
5. Verify the LED is working properly by connecting the red lead 10 the positive (+) terminal of a fresh 9 volt battery and the black lead to the battery's negative terminal. The LED should glow red. Reverse the leads and note that the LED colour changes to green.



Preparing the Decoder Test Kit

RDSD Functional Test Procedure
Follow directions carefully, working on a *non-metallic surface.*

Any NMRA-compatible DCC system will work for the test. Consult your system manual for appropriate operating instructions.

It isn't necessary to solder any wires together during the test. Simply twisting the wires together will suffice, but better still mount all the wires in a suitable “Chocolate Block” screw connector.

We recommend insulating the ends of the decoder leads with electrical tape to prevent accidental shorts during the testing.

General Connections.

1. Turn the power to the Track using the isolation switch.
2. Select the lowest possible output voltage setting, usually the N-scale setting.
3. Connect the decoder's purple (pin 10) lead to the negative (-) terminal of the speaker.
4. Connect the other purple lead (pin 12) to the positive (+) speaker terminal. A 33µF, 16V capacitor must be wired in series as shown in Figure 2.
5. Connect the red lead of the test LED to the decoder's orange lead.
6. Connect the black lead of the test LED to the decoder's grey lead.
7. Connect the 22 ohm resistor to one of your DCC system's track outputs.
8. Connect the free end of the resistor to the Decoder's red wire.
9. Connect the Decoder's black wire to your DCC system's other track output.

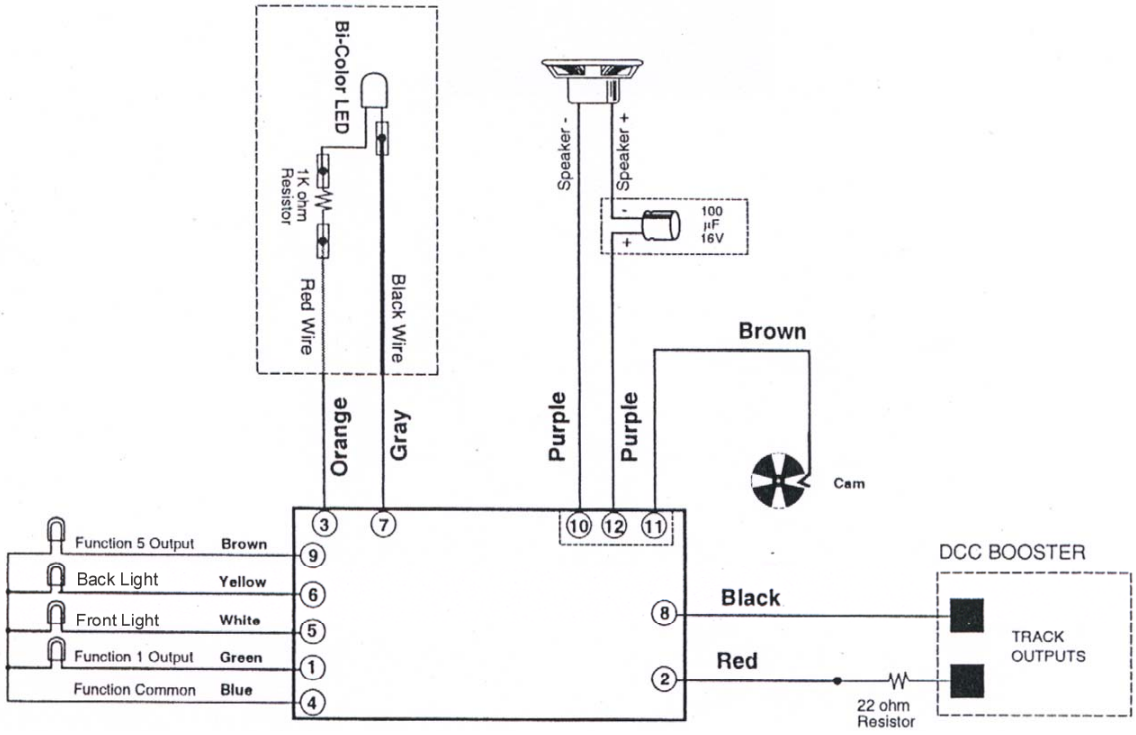


Figure 2 - General connection diagram

Speaker Test.

The objective of the Speaker Test Is to ensure that the RDSD is generating sound.

1. Make sure no other decoder leads are shorted to any other leads. The best way to do this is to simply tape the other leads out of harm's way while you are performing the test. Tape them to the non-metallic surface you are working on until they are needed.

2. Turn on power to the system.

3. Configure your DCC system to send commands to locomotive address 03 using 28 *spec* step mode.

4. After a moment, you should hear the background sound.

5. If you do not, turn off power to the system and recheck your connections.

6. Activate Auxiliary Function 2. The Short Whistle should blow. Activate Auxiliary Function 3 and the Long Whistle should begin to blow, pressing F3 a second time will stop the whistle.

If the whistle functions do not work, verify that your DCC system is indeed set to address 03. If your system has dedicated whistle keys, check that they are properly mapped to control Auxiliary Functions 2 and 3.

Note: If the sound becomes erratic or cuts out when the whistle is activated, you may need to change the command station's track voltage setting to a higher level. If this is not practical or does not solve the problem, you may try wiring the decoder's red wire directly to the DCC system's track output and bypass the 22 ohm resistor. However, you must be extra careful performing the rest of the test as the resistor serves to protect the decoder from accidental short circuits.

If the RDSD still does not produce any sound it is possible that the CV settings may have been altered. You may skip ahead to the Programming Test section and program the following CV to reset all CVs to their default settings:

CV 30 = 02

If this does not work, contact ZTC Controls Ltd.

Motor Operational Test.

The purpose of this test is to verily that the decoder correctly interprets the speed and direction commands that are received from the command station.

1. Make sure that none of the decoder leads are shorted to any other leads.

2. Turn on power to the system.

3. Configure your DCC system to send commands to locomotive address 03.

4. After a moment, you should hear the background sounds running in the background.

5. Select the forward direction and slowly increase the Regulator setting. The Bipolar LED will begin to glow red.

6. Now select the reverse direction and slowly increase the Regulator. The Bipolar LED should now begin to glow green. If the LED does not light or change colour, first check that the DCC system is set to address 03. Next, verify the LED is working properly as outlined under **Preparing the Test Fixture**.

If the LED still does not light or change colour, contact ZTC Controls Ltd.

Exhaust Cam Test
The purpose of this test is to verify proper operation of the RDSD's cam sensor.

1. Turn on power to the system.

2. After a moment, you should hear the background sounds.

3. Locate the brown cam wire (pin 11 of the 3-pin Speaker/Cam connector.

   Do not confuse with the brown wire of the 9-pin connector!).

4. Tap this wire against either rail. As the cam wire makes contact, you should hear a chuff sound.

If you do not hear a chuff, it is possible that the CV settings may have been altered in which case you should have noted a chuffing sound when performing the Motor Operations Test. If this is the case, you may skip ahead to the Programming Test section and program the following:

CV 30 = 02, to reset the CVs.

Then repeat steps 1,2,3 and 4 above. If you still do not get a response, contact ZTC Controls Ltd.

Auxiliary Function Output Test.

The purpose of this test is to verify that the decoder correctly interprets the commands for the four auxiliary output functions.

1. Turn the power to the system OFF.

2. Disconnect the test LED from the grey and orange leads of the decoder. Insulate the ends of the grey and orange wires with electrical tape.

3. Attach the black lead of the test LED to the decoder's blue lead.

4. Connect the red lead of the test LED to the decoder's white lead (Front light). Make sure no other decoder leads are shorted to any other leads.

5. Turn on power to the system.

6. Using your DCC controller. Turn Function 0 ON and set the regulator direction to forward. The Bipolar LED should light. Turn Function 0 OFF and the LED should turn out.

7. Turn power to the system OFF. Disconnect the decoder's white wire from the red lead of the test LED. Now connect the red lead to the yellow decoder wire (reverse light).

Turn on power to the system. turn ON Function 0 and set the throttle direction to reverse. The

8. Bipolar LED should illuminate. Turn Function 0 OFF and the LED should turn out.

9. Turn power to the system OFF.

10. Disconnect the yellow lead of the decoder from the red wire of the test LED. Connect the red lead of the test LED to the decoder's green lead (F1 output). Make sure no other decoder leads are shorted to any other leads.

11. Turn ON power to the system. Using your DCC controller, turn Function 1 ON. The Bipolar LED should illuminate. Turn Function 1 OFF and the LED should turn out.

12. Turn power to the system OFF.

13. Disconnect the green lead of the decoder from the red wire of the test LED. Connect the red lead of the lest LED to the decoder's brown lead (F5 output). Make sure no other decoder leads are shorted to any other leads.
14. Turn ON the power to the system. Using your DCC controller, turn ON Function 5. The Bipolar LED should light. Turn Function 5 OFF and the LED should turn out.

Programming Test.
The purpose of this test is to verily that the decoder correctly accepts programming commands.

1. Turn power to the system OFF.

2. Connect the red lead of the test LED to the decoder's orange lead.

3. Connect the black lead of the test LED to the decoder's grey lead. Make sure no other decoder leads are shorted to any other leads.

4. If your DCC system requires the use of a programming track, disconnect the red and the black lead of the decoder and reconnect to your system's programming track outputs.

5. Turn ON power to the system.

6. The RDSD supports register, paged, and direct CV access modes. The mode you use will be entirely dependent upon the DCC system you are using and you should refer to your owner's manual for further information. Using your system controller, reprogram CV1, decoder address, to an address other than 03 that is within the range of your system's capability. Write down the address that you select.

7. Turn OFF power to the system.

8. Reconnect the RDSD's red and black leads to your DCC system's track outputs.

9. Turn on power to the system and reconfigure it to send commands to the address you programmed in step 6.

10. Now slowly increase the throttle. The Bipolar LED should now begin to glow. This indicates that the decoder has accepted the address change. If the LED does not light, verify that the locomotive address is programmed to the address you selected. If it still does not light, contact ZTC Controls Ltd help desk.

The Functional Decoder Test is complete. You have verified that your decoder is operating as it should and you can now proceed to locomotive installation.

BINARY/HEX CONVERSION CHART - APPENDIX C

DECIMAL	HEX	BINARY (76543210)	DECIMAL	HEX	BINARY (76543210)	DECIMAL	HEX	BINARY (76543210)	DECIMAL	HEX	BINARY (76543210)
0	00	00000000	64	40	01000000	128	80	10000000	192	C0	11000000
1	01	00000001	65	41	01000001	129	81	10000001	193	C1	11000001
2	02	00000010	66	42	01000010	130	82	10000010	194	C2	11000010
3	03	00000011	67	43	01000011	131	83	10000011	195	C3	11000011
4	04	00000100	68	44	01000100	132	84	10000100	196	C4	11000100
5	05	00000101	69	45	01000101	133	85	10000101	197	C5	11000101
6	06	00000110	70	46	01000110	134	86	10000110	198	C6	11000110
7	07	00000111	71	47	01000111	135	87	10000111	199	C7	11000111
8	08	00001000	72	48	01001000	136	88	10001000	200	C8	11001000
9	09	00001001	73	49	01001001	137	89	10001001	201	C9	11001001
10	0A	00001010	74	4A	01001010	138	8A	10001010	202	CA	11001010
11	0B	00001011	75	4B	01001011	139	8B	10001011	203	CB	11001011
12	0C	00001100	76	4C	01001100	140	8C	10001100	204	CC	11001100
13	0D	00001101	77	4D	01001101	141	8D	10001101	205	CD	11001101
14	0E	00001110	78	4E	01001110	142	8E	10001110	206	CE	11001110
15	0F	00001111	79	4F	01001111	143	8F	10001111	207	CF	11001111
16	10	00010000	80	50	01010000	144	90	10010000	208	D0	11010000
17	11	00010001	81	51	01010001	145	91	10010001	209	D1	11010001
18	12	00010010	82	52	01010010	146	92	10010010	210	D2	11010010
19	13	00010011	83	53	01010011	147	93	10010011	211	D3	11010011
20	14	00010100	84	54	01010100	148	94	10010100	212	D4	11010100
21	15	00010101	85	55	01010101	149	95	10010101	213	D5	11010101
22	16	00010110	86	56	01010110	150	96	10010110	214	D6	11010110
23	17	00010111	87	57	01010111	151	97	10010111	215	D7	11010111
24	18	00011000	88	58	01011000	152	98	10011000	216	D8	11011000
25	19	00011001	89	59	01011001	153	99	10011001	217	D9	11011001
26	1A	00011010	90	5A	01011010	154	9A	10011010	218	DA	11011010
27	1B	00011011	91	5B	01011011	155	9B	10011011	219	DB	11011011
28	1C	00011100	92	5C	01011100	156	9C	10011100	220	DC	11011100
29	1D	00011101	93	5D	01011101	157	9D	10011101	221	DD	11011101
30	1E	00011110	94	5E	01011110	158	9E	10011110	222	DE	11011110
31	1F	00011111	95	5F	01011111	159	9F	10011111	223	DF	11011111
32	20	00100000	96	60	01100000	160	A0	10100000	224	E0	11100000
33	21	00100001	97	61	01100001	161	A1	10100001	225	E1	11100001
34	22	00100010	98	62	01100010	162	A2	10100010	226	E2	11100010
35	23	00100011	99	63	01100011	163	A3	10100011	227	E3	11100011
36	24	00100100	100	64	01100100	164	A4	10100100	228	E4	11100100
37	25	00100101	101	65	01100101	165	A5	10100101	229	E5	11100101
38	26	00100110	102	66	01100110	166	A6	10100110	230	E6	11100110
39	27	00100111	103	67	01100111	167	A7	10100111	231	E7	11100111
40	28	00101000	104	68	01101000	168	A8	10101000	232	E8	11101000
41	29	00101001	105	69	01101001	169	A9	10101001	233	E9	11101001
42	2A	00101010	106	6A	01101010	170	AA	10101010	234	EA	11101010
43	2B	00101011	107	6B	01101011	171	AB	10101011	235	EB	11101011
44	2C	00101100	108	6C	01101100	172	AC	10101100	236	EC	11101100
45	2D	00101101	109	6D	01101101	173	AD	10101101	237	ED	11101101
46	2E	00101110	110	6E	01101110	174	AE	10101110	238	EE	11101110
47	2F	00101111	111	6F	01101111	175	AF	10101111	239	EF	11101111
48	30	00110000	112	70	01110000	176	B0	10110000	240	F0	11110000
49	31	00110001	113	71	01110001	177	B1	10110001	241	F1	11110001
50	32	00110010	114	72	01110010	178	B2	10110010	242	F2	11110010
51	33	00110011	115	73	01110011	179	B3	10110011	243	F3	11110011
52	34	00110100	116	74	01110100	180	B4	10110100	244	F4	11110100
53	35	00110101	117	75	01110101	181	B5	10110101	245	F5	11110101
54	36	00110110	118	76	01110110	182	B6	10110110	246	F6	11110110
55	37	00110111	119	77	01110111	183	B7	10110111	247	F7	11110111
56	38	00111000	120	78	01111000	184	B8	10111000	248	F8	11111000
57	39	00111001	121	79	01111001	185	B9	10111001	249	F9	11111001
58	3A	00111010	122	7A	01111010	186	BA	10111010	250	FA	11111010
59	3B	00111011	123	7B	01111011	187	BB	10111011	251	FB	11111011
60	3C	00111100	124	7C	01111100	188	BC	10111100	252	FC	11111100
61	3D	00111101	125	7D	01111101	189	BD	10111101	253	FD	11111101
62	3E	00111110	126	7E	01111110	190	BE	10111110	254	FE	11111110
63	3F	00111111	127	7F	01111111	191	BF	10111111	255	FF	11111111

APPENDIX D. ZTC CONTROLS LTD RECOMMENDED LOUDSPEAKERS

	Dia/Length		Width		Depth		Power	Imp			Response Hz	
ZTC No	mm	inch	mm	inch	mm	inches	P Watts	Ohms	Cone	Frame	Min	Max
ZTC 171	10	0.39	N/A	N/A	4	0.18	0.2	8	RML	RP	750	3,500
ZTC 172	12	0.46	N/A	N/A	8.6	0.26	0.1	40	F	RBP	1,000	4,200
ZTC 174	22.5	0.9	N/A	N/A	8	0.25	0.8	8		RBP	500	4,000
ZTC 176	28	1.05	N/A	N/A	5	0.15	0.2	8	ML	RM	550	6,000
ZTC 177	29	1.1	N/A	N/A	5	0.15	0.2	8	ML	RP	600	3,200
ZTC 178	29.5	1.13	N/A	N/A	12.6	0.50	0.15	8	RML	RBP	700	5,000
ZTC 181	40	1.56	N/A	N/A	9.5	0.30	0.1	32	RML	RP	20	20,000
ZTC 182	45	1.82	N/A	N/A	9	0.28	0.1	8		RM	50	5,000
ZTC 186	66	2.58	N/A	N/A	20	0.17	3	8	ML	RM	350	7,000
ZTC 189	75	3	N/A	N/A			0.5	8	P	RM	240	7,000
ZTC 195	25	1	14.5	0.56	5	0.19	1	8	ML	EP	750	3,500
ZTC 196	35	1.38	16	0.63	7.2	0.28	1	8	ML	EP	500	12,000
ZTC 197	40	1.57	20	0.78	8.2	0.32	1	8	ML	EP	550	12,000

Key:

Frame Description		Cone Description	
B	Baffle	F	Foil
E	Elliptical	ML	Mylar
M	Metal	P	Paper
P	Plastic	RML	Ribbed Mylar
R	Round		

SERVICE AND WARRANTY POLICY.

The RealFeel™ ™ Digital Sound Decoder is warranted by ZTC Controls Ltd to be operative and free of defects in materials and workmanship for a period of ninety (90) days after original purchase date. Defective RealFeel Digital Sound Decoders which are received by ZTC Controls Ltd during the warranty period will be repaired or replaced free of charge at the option of ZTC Controls Ltd.

Exclusions.

This warranty does not cover damage resulting from negligent installation, improper operation, over voltage or over current damage, failure to follow instructions, misuse, unauthorised repairs or modifications, accidents, damage while in transit to service location, fire, floods, and other acts of God.

PLEASE NOTE THAT REMOVING THE PROTECTIVE SHRINK-WRAP TUBING FROM THE DECODER AUTOMATICALLY VOIDS YOUR WARRANTEE.

Due to their fragile nature, onboard locomotive speakers are not covered by this warranty. ZTC Controls Ltd certifies the speakers to be operational at time of sale. In the event that a speaker is damaged when received, we will replace them free of charge providing the defective speaker is returned to ZTC Controls Ltd within five (5) days of purchase. Prevailing retail and shipping charges will apply at our discretion.

Warranty Procedure

The product must be returned, postage prepaid and insured to the factory for repair. It is advisable to write or phone the factory for advice before returning the product for service. Include name, Customer number and private address (We cannot ship to P.O. Boxes!). Please include a daytime phone number, and of course a description of problem experienced.

Important!: Return only the RealFeel Digital Sound Decoder. Under no circumstances should you send your locomotive (or other model parts) to us, without our prior agreement, as we are unable to assume any liability for their safe return unless agreed in advance and a returns number issued.

Limits of Liability

The foregoing shall constitute the sole and exclusive remedy of any owner of this product for breach of warranty including the implied warranties of merchantability and fitness. IN NO EVENT SHALL ZTC CONTROLS LTD OR SOUNDTRAXX BE LIABLE FOR SPECIAL OR CONSEQUENTIAL DAMAGES OR FOR THE REPRESENTATIONS OF RETAIL SELLERS.

Non-Warranty Repairs

ZTC Controls Ltd RealFeel Digital Sound Decoders needing repairs after exceeding the warranty period or damaged during installation, will be repaired at modest cost for parts and labour. Customer will be advised in writing or by telephone of service charges before work is begun.

ZTC Controls Ltd
Canvin Court
Somerton Business Park
Bancombe Road
Somerton
Somerset
TA11 6SB

Telephone 0870 2418730

CE and FCC STATEMENT

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC and CE rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio interference energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and back on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the equipment and the receiver.
- Connect the equipment to an outlet or on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/ TV technician for help.

MANUFACTURER'S STATEMENT

This product is manufactured exclusively for ZTC Controls Ltd and to their specification by Throttle Up! Corp., (Soundtraxx™) in the USA. It is imported solely by ZTC Controls Ltd and is not available from any other source. Please direct any questions you may have on the product or its use to ZTC Controls Ltd.

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