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CT Elektronik Revision 4 Manual
DCC Sound Decoders

English Translation and annotation by YouChoos (www.youchoos.co.uk)

Combined Edition, August 2013

Technical data

	SL51-4	SL75	SL76	SL82 2.5A	SL82 4A	GE75	GE76
							
Track voltage DCC	7-24V	8-21V	10-21V	10-36V	10-36V	8-21V	10-21V
Maximum continuous current to motor	1.5A	1.6A	1A	2.5A	4A	n/a	n/a
Maximum peak current to motor 5sec	2A	1.2A	2A	5A	8A	n/a	n/a
Number of aux function outputs	8	4	4	9	9	2	4
Maximum continuous current aux. functions	500mA each	250mA each	250mA each	1A each	1A each	250mA each	250mA each
Maximum total current all aux. functions	1.5A	0.8A	1A	2.5A	4A	0.8A	1A
High frequency motor control	32kHz or 16kHz	32kHz or 16kHz	32kHz or 16kHz	32kHz or 16kHz	32kHz or 16kHz	n/a	n/a
Low frequency motor control	30-150Hz	30-150Hz	30-150Hz	30-150Hz	30-150Hz	n/a	n/a
Dimming frequency	1.2kHz	1.2kHz	1.2kHz	1.2kHz	1.2kHz	1.2kHz	1.2kHz
Maximum continuous output sounds	11kHz or 22kHz 1W/8Ohm	11kHz or 22kHz 1W/8Ohm	11kHz or 22kHz 1.7W/8Ohm	11kHz or 22kHz 2x6W/8Ohm	11kHz or 22kHz 2x6W/8Ohm	11kHz or 22kHz 1W/8Ohm	11kHz or 22kHz 1.7W/8Ohm
Maximum sound memory capacity at 11kHz, 16 bit (mono) 16Mbit (2Mb)	170 seconds	170 seconds	170 seconds	170 seconds	170 seconds	170 seconds	170 seconds
Operating temperature	-10 to 90˚C	-10 to 90˚C	-10 to 90˚C	-10 to 90˚C	-10 to 90˚C	-10 to 90˚C	-10 to 90˚C
Dimensions	L*W*D 26/14/3.3mm	L*W*D 24/9/3.3mm	L*W*D 16.7/7.7/2.3mm	L*W*D 46/26/15mm	L*W*D 65/50/20mm	L*W*D 24/9/3.3mm	L*W*D 16.7/7.7/2.3mm
Connector Variations (other plugs/harnesses may be added to wires-only versions)	Wires-only 8pin wired 21pin MTC	Wires-only	Wires-only 6pin direct	Screw terminals	Screw terminals	Wires-only	Wires-only

Safety Disclaimer & Warranty Information

Not suitable for children under three years of age because of the danger of their swallowing the small constituent pieces. Improper use can result in injury from sharp edges. For use only in dry areas. CT reserves the right to make changes in line with technical progress, product maintenance or changes in production methods. CT accepts no responsibility for error that may occur of use of transformers or other electrical equipment that is not authorised for use with model railways or transformers and other electrical equipment that has been altered, adapted or are faulty. Nor can we accept responsibility for damage that results from unsupervised adjustments to equipment or from acts of violence or from overheating or from effects of moisture etc. Furthermore in all such cases the guarantee becomes invalid.

There should be no contact between metal parts such as locomotive chassis or housing and the decoder. Insulate all metal parts with insulation tape so that short-circuit is avoided. Never cover the decoder completely with insulation tape as this will reduce the air circulation around the decoder which could harm it. Never touch the decoder when it is under power as this may damage both the software or hardware of the decoder.

Wiring Colours

All CT decoders follow the same wire colouring convention:

Red		Track right
Black		Track left
Orange		Motor right
Grey		Motor left
Blue		Common Positive
White		AUX0 Negative – normally for forward motion lights
Yellow		AUX1 Negative – normally for reverse motion lights
Green		AUX2 Negative
Purple		AUX3 Negative
Brown x2		Speaker

Stay-Alive Capacitors

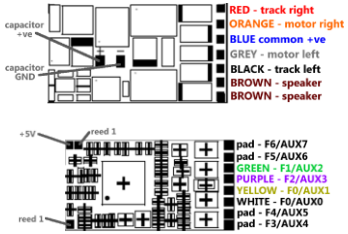
If adding a stay-alive capacitor, ensure its' voltage rating is at least as high as the DCC track voltage. Normally this is around 16V.

If possible, it is recommended that you use a capacitor between 25-35V. Any size will help, even as small as 100uF, but the bigger the better, up to 2200uF. Electrolytic and Tantalum capacitors may be fitted directly as shown in the decoder layouts section below.

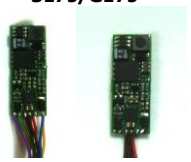
Gold Caps require additional circuitry.

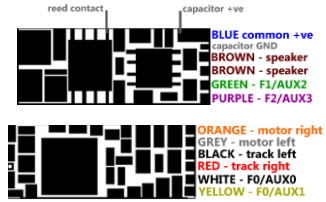
Decoder Layouts

SL51-4



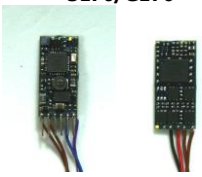
SL75/GE75

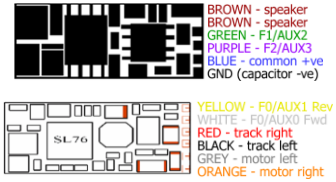




NOTE: GE75 has no motor outputs or AUX2/AUX3

SL76/GE76

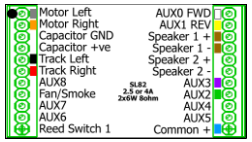




NOTE: GE76 has no motor outputs

NOTE: Capacitor may be added between BLUE and GND

SL82



NOTE: Black mark by Motor Left terminal gives orientation

Understanding and Calculating Binary Values

In order to successfully understand and program some CVs, you will need a basic understanding of binary. Each CV contains what is called a *byte* of information. This is computer-speak for 8 *bits* of information, each of which can be ON or OFF. A *bit* is therefore a *toggle*, ON or OFF. A *1* represents ON and a *0* represents OFF. If you have just 1 bit, then you can have a maximum of 2 values i.e. on and off. Adding more bits means you can have more combinations, for example, 2 bits gives you 4 possible combinations: OFF+OFF; OFF+ON; ON+OFF; ON+ON, or 0,0; 0,1; 1;0; 1;1. Read this as 0,1,2,3 since computers always start at 0 instead of 1.
By convention, bits are read with the least significant to the right i.e. "bit 0" is the right-most bit. A byte, as mentioned previously has 8 bits, so bits 0 to 7, giving a possible range of 0-255 (2^8 –1 being the maximum value, 256 combinations). Use the table below for reference to see what value each bit can represent.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
128	64	32	16	8	4	2	1

An example: if bit 6 is ON and bit 1 is also ON, then this is 64+2, so the value represented is 66. Simple really!

Many of the CVs in your decoder use individual bits to control different aspects, so it is useful to understand binary in order to a) work out how the decoder is currently configured, and b) to understand how to modify the CVs to change the decoder's behaviour.

Hard Reset

A *HARD RESET* is performed by setting CV1=0. This resets all CVs to factory setting, depending upon the setting of CV109. By *factory*, we mean the last project loaded into the decoder (by YouChoos, or other vender). This process will NOT wipe the sounds themselves! After a value of 0 is sent to CV1, a short beep is usually heard from the speaker – you should then remove power from the decoder, and when power is reapplied, a series of beeps is normally emitted.

Speakers

The connected speaker must have an impedance of 8Ohm. Alternatively, you can connect 2x 4Ohm speakers in parallel, which will give 8Ohm overall impedance. Any other impedance will void warranty and may cause damage to the decoder and/or speaker. SL76/GE76 is designed for speakers between 1W and 1.7W. SL82 is designed for speakers between 1W and 6W. All other decoders are designed for speakers with exactly 1W.

Reed Switch – Synchronising Steam Chuffs

For use of a Reed Contact for synchronised steam chuffs, the Reed Contact 1 should be connected to the positive function output (BLUE). CV49 must have Bit 0 set (value 1). Also see CV133 for further calculation.

Analog/DC Operation

By switching CV29 Bit 2 (value 4) ON, DC/Analog operation is possible. However, only the motor control is available – no sound or function outputs are activated.

Reading and Writing CVs

All CT decoders are capable of working with a DCC programming track as well as accepting new CVs values via *Programming-On-The-Main* (POM). However, certain DCC systems are not tolerant of the levels of sensitivity required, particularly where smaller decoders are involved (SL76). In any case, any feedback (reading CVs) will require a load to the decoder such as an attached motor, or lighting, as an electrical load is used to send back information to the DCC controller.

Addressing

Decoders will normally be supplied with their DCC 'address' set to a default of 3. If you have multiple locos fitted with DCC, then you will need to change this quite soon.

Most DCC controllers provide automatic facilities to change a decoder's address, but it may be useful to understand how this works under the covers. The full range of addresses goes from 1 up to 10239, although most DCC controllers are limited to 9999 (4 digits), and some are limited to just 2, or even a single digit!

If your chosen address falls in the range from 1 to 127, then this is known as a 'short' address, and is stored in CV 1. With bit 5 (value 32) of CV 29 switched OFF, the short address is active, and the decoder will respond to commands on the address stored in CV 1.

For addresses between 128 and 10239, a formula is used to calculate and store the address in CVs 17 and 18. This is required because the largest number you can store in a single CV is restricted to 255. The long address is active when bit 5 of CV 29 is switched on.

CV 19 is used when you add your loco into a Consist. Refer to your DCC controller's manual for more information on Consisting (temporarily placing multiple locos together, such as double-heading).

Configuration Variables (CVs)

The table below is a translation of the original CT Elektronik documents, plus some notes on usage and experiences by YouChoos. It is not intended to be exhaustive, particularly in those areas not utilised by YouChoos, such as LGB engines, or automatic braking systems features.

All CVs are described here, but some will not be relevant for certain decoders where a physical feature is not present. For example, the SL76 has only 4 function outputs, so any CVs relating to additional function outputs are not relevant.

Note that only CVs can be changed by the user – sound projects cannot be altered, except by a full reload using a CT SoundProg device.

CV	Explanation	Default	Range
1	Locomotive address: For short addresses when CV29 Bit 5 is set at 0.	3	1-127
2	Starting voltage: Voltage to motor at speed step 1. Tune this if your motor requires a little more *umph* to get it going, or you may find that the start-off sounds are not totally synchronized with the actual physical moving off of the loco.	3	0-255
3	Rate of acceleration – adjust to affect the *inertia* effect of speeding up. Set to 0 if you want no inertia effect – you control the speed immediately with your controller instead.	4	0-255
4	Rate of deceleration – similar to the above CV3, but for slowing down	4	0-255
5	Maximum speed: 0 for no artificial limit (maximum 255 has same effect as 0).	0	0-255
6	Middle speed: together with CV2 and CV5 a three-point speed curve can be set. Set CV6 = 0 to give a linear speed curve.	0	0-255
7	Version Number – read-only	-	variable
8	Manufacturer ID: CT Elektronik=117 – read-only	117	0-255
9	Motor PWM: 13-63 stepless from 30-150Hz, 141-191 16kHz for coreless and bell anchor motors	134	60-63 134-191
13	Analog mode: Use bits 0-3 to determine which function outputs (1-4) are switched on when operating on DC. Note that this feature is not implemented, so has no effect in reality.	0	0-255
17+18	Extended address: CV29 bit 5 must be set in order to use a long address. CVs 17+18 are used to specify the long address. Please refer to NMRA standards for how this value is calculated.	0	128-10240
19	Multi-Unit (Consist) address	0	1-127
29	Miscellaneous configuration bits: Bit 0 (1) – Direction: OFF=normal; ON=inverted Bit 1 (2) – Speed steps: OFF=14/27; ON=28/128 Bit 2 (4) – Operating mode: OFF=digital only; ON=DC and Digital. Note that only the motor can be controlled under analog/DC operation – not function outputs or sound will be activated. Bit 3 (8) – not used Bit 4 (16) – Speed curve: OFF=default speed curve using CVs 2, 5 & 6; ON=free speed curve using CVs 67-94. Bit 5 (32) – Address selection: OFF allows addresses 1-127 defined in CV1; ON allows addresses 128-10240 defined in CV17 & 18 Bit 6 (64) – not used Bit 7 (128) – not used	2	0-255
30	Error diagnosis: 1=motor; 2=light; 3=both short-circuit	0	0-3
33-42	Function mapping: according to NMRA for F0-F7, CV33-42=0. Please refer to CT extended function mapping document for more information.		0-255
43-46	Function mapping: according to NMRA for F8-F11 CV43-46=0. Please refer to CT extended function mapping document for more information.		0-255
49	Configuration bits for sound: CV49=0 gives 4 cylinder steam engine Bit 0 (1) – set if you use a Reed switch for wheel synchronising for steam engines - see also CV133=number of Reed Contacts – pulses per stroke e.g. CV133=1 means 1 stroke/pulse Bit 1 (2) – set for Diesel or Electric loco (for use with the AUTO sound slots) Set both Bits 0 & 1 (value 3) for diesel and electric sounds that use Sound Slots 00 to 11 (must all be filled with sounds) – this is deprecated by the use of the AUTO sound slots (also known as Slots 1000-3000), so is not recommended. Bit 2 (4) gives 2 cylinder steam Bit 3 (8) gives 3 cylinder steam **NOTE: for diesel, a special value of 10 should be used to achieve smooth transitions between engine steps.** Bit 4 (16) – no steam strokes during downhill/deceleration (only idle sound) Bit 5 (32) – evaluate the LGB pulse from F1 Bit 6 (64) – play no sound between stand-still and running e.g. whistle (Slots 21-23 and Slots 24-26) Bit 7 (128) – no sound between running and stand-still e.g. brakes (Slots 27-29 and Slots 30-32)	0	0-255
50	EMF intensity: how strong is EMF effect: 0=no influence; 255=maximum. If you plan to use locomotives in a consist then use a lower value. This reduces the effect of locos working against each other if they cannot be configured to perform equally. Combine this value with CV51 and CV52 to cater for different motor types – often very smooth running can be achieved by experimenting with these values, even on motors that are apparently jerky to begin with under DCC.	255	0-255
51	P-Value: optimises EMF characteristics. Modify this to adapt to specific motor requirements (proportional part).	80	0-255
52	I-Value: optimises EMF characteristics. Modify this to adapt to specific motor requirements (integral part).	40	0-255
53	Special CV for programming beyond CV99 on old system PLUS decoder LOCK/UNLOCK feature For Roco Lokmaus users and any other systems which can only address CVs up to 99. Set bits 0 or 1 to address CVs over 99. Not necessary on most DCC systems. CV53=66: programming and feedback off (**LOCK** decoder from accidental re-programming…set to 77 to UNLOCK) CV53=77: programming and feedback on (**UNLOCK** decoder for programming… after setting to 66 previously) CV53=1: 100+ programmed CV value CV53=2: 200+ programmed CV value	0	0-255
54	PWM for function output: specifies the level of dimming applied to any function output with dimming selected via CV 57. Note that any function outputs with dimming switched on have the same dimming level applied – they are not individually dimmable by different amounts. Useful for reducing brightness of lights, or level of smoke generator for example. CV54=50 means 50% power output on function.	50	0-100
55	PWM for decoupler: represents the 'holding' current for the decoupler i.e. the reduced power for holding after the uncoupling impulse. Any function output defined as a decoupler (CV58) will initially get a higher-current pulse sent to that output when the function is activated, designed to 'kick' the magnet of a decoupler into motion, but then after a period (defined in CV56) it will be reduced to the level specified by this CV55 to hold it. Specified as a percentage.	32	0-100
56	Decoupler pulse time: how long is the impulse on the decoupler with full power until it is reduced to the value defined in CV55. Time is set in 0.1 second units.	60	0-255
57	Dimming mask: turns dimming (level defined in CV54) on and off for each function output. Each bit represents one function output, up to 8	0	0-255

	functions (bit 0 for white wire, bit 1 for yellow wire etc.)		
58	Dimming mask for decoupler function: defines which outputs should have decoupler processing applied. Each bit represents one function output. Any output specified here will have the effects of CV55 and 56 applied.	0	0-255
59	Signal controlled speed: "L" only available in ZIMO environment	168	0-255
60	Signal controlled speed: "U" only available in ZIMO environment	84	0-255
61	Signal controlled acceleration reaction time: only available in ZIMO systems	1	0-255
62	Braking threshold: indicates the number of speed steps that need to be reduced within 1 second in order for the *rapid braking* noise to trigger (Sound Slots 120 to 122). If the sounds are in three parts, the middle section is played in a loop until the delay is over, or the end threshold defined in CV107 is reached.	10	0-255
64	Reference voltage: EMF 100 = 20V track voltage	100	0-255
67-94	Free speed curve: activated with CV29 bit 4 is set. Default values: 9, 18, 27, 36, 45, 54, 63, 72, 81, 90, 99, 108, 117, 126, 135, 144, 153, 162, 171, 180, 189, 198, 207, 216, 225, 234, 243, 252		0-252
96	Zimo Signal controlled speed : "FL" speed selected between F-L (or MX9 HLU) is in version 52, see CV59, 60	212	0-255
97	Zimo Signal controlled speed : "LU" speed selected between L-U (or MX9 HLU) is in version 52, see CV59, 60	126	0-255
98	Zimo Signal controlled speed : "U-Stop" speed selected U-Stop (or MX9 HLU) is in version 52, see CV59, 60	42	0-255
104	End sequence braking threshold: determines at what point during deceleration the 'come to halt' sounds are triggered (slots 27-29 and slots 30-32). For example, if CV104 = 50 (= desired speed step *2) then the 'come to halt' sounds are triggered as the speed decreases from step 25 to 24. From SW Version 100, you can set CV104 = 0, which causes this sequence to be calculated automatically depending on the length of the recorded sound. See also CV62 and CV107.	0	0-255
105	User CV: free for remembering purchase date or similar user information	0	0-255
106	User CV: free for remembering purchase date or similar user information	0	0-255
107	Rapid braking end threshold: if a rapid braking sound is defined as looping in Slots 120-122 (also see CV62 for when rapid braking sound is triggered), it will continue to loop until the desired speed step is reached, or when the speed step defined here in CV107 is reached. This gives the possibility to stop the rapid braking sound below a certain speed. CV107=50 (= desired speed step *2) stops the rapid braking sound below speed step 25. Applies to SW Version 40 onwards.	0	0-255
108	Bitmask for endless manual sound: ONLY operational when CV49 bit 5 is set. For use with LGB pulse chains. Bit 0 for sound 1; bit 1 for sound 2 etc.	0	0-255
109	Selection of CV set: bit 0=0 gives CV set 1; bit 0=1 gives CV set 2. Can be used for various purposes – CV set for home layout + CV set for club layout for example. Hard reset will only affect the currently selected CV set. CV109 will be unchanged by a hard reset.	0	0-1
110	Load-dependent sound variation: set to 0 to give no load-dependent variation; then a range from 1 (high dependency) to 15 (low dependency on load). If configured carefully, this feature can be used to detect a heavy train, or uphill climbs and cause the sound (chuffs for steam) to use the 'acceleration' sounds under that load. However, beware – using an excessive value here will cause the train to produce unnecessarily loud chuffs at unwanted time e.g. travelling around a curve.	4	1-15
111	Intensity of acknowledgement pulse (ACK): improves the programming capability, 128 is approx 50% of max acknowledgement pulse (motor dependent) 200 = normal.	255	0-255
112	Random sounds at standstill: chooses which sounds may occur randomly while idling. Set to 0 for no random sounds at standstill or set bits 0-7 to control which sounds are included in random play (Effects 1-8). See also CV131. It is not possible to specify sounds 9-16 for random play.	255	0-255
113	Random sounds during motion: chooses which sounds may occur randomly while the loco is moving. Set to 0 for no random sounds while moving or set bits 0-7 to control which sounds are included in random play (Effects 1-8). See also CV131. It is not possible to specify sounds 9-16 for random play.	255	0-255
114	PWM for effects – some of the lighting effects pulse between a high point and a low point. This CV specifies the level of the low point in those cycles. See also CV154 to 161.	0	0-100
115	Cycle time for flashing light effects, as specified by CV154-161	0	0-255
116	Shunting function (yard mode) configuration (shunting mode may be switched on/off via appropriate function mapping – see CT extended function mapping document for more information): Only active if bit0-bit2 set Bit 0 (1) – effects of CV3 and CV4 are disabled when shunting mode activated Bit 1 (2) - maximum speed is halved Bit 2 (4) – reverse is 65% of maximum speed (regardless of shunting mode) - applies from SW Version 40 or later Bit 3 (8) - brakes with diode 4:1 is active – see also CV 162 Bit 4 (16) - brakes without diode Bit 5 (32) - not used, must always be 0 Bit 6 (64) - means that the "Rangierfunktion" acts as a command button that is, that the automatic train control system (brake or diode and HLU) - (equivalent to the MAN key = manual) Bit 7 (128) – short burst of idling, returning to normal speed	0	0-255
117	Defines the Function key that causes the *Low-Beam* dimming effect to be applied. 1=F1, 2=F2 … 12=F12. See also CV118, 119 and 120.	0	1-12
118	Mask to specify which function outputs have *Low-Beam* dimming applied when activated by the function key specified in CV 117. Each bit represents 1 function output (0-7). 1 = white wire, 2 = yellow wire, 4 = green wire, 8 = purple wire, 16 = 5th output, 32 = 6th output, 64 = 7th output, 128 = 8th output	0	0-255
119	PWM dimming level for *Low-Beam* dimming as defined by CV117 and CV118. A value of 50 = approximately 50% of full brightness, 100 = 100% i.e. no dimming. 0 also means no dimming.	0	0-100
120	Cycle duration of how long the *Low-Beam* dimming will last – see CVs 117, 118 and 119.	0	0-255
121	Volume for main sound on. Values depend upon software version: Old versions have range 0-3 only (0 gives no sound, 3 gives maximum volume). Newer versions have range 0-63 (63 being maximum). Expect that future versions may range from 0-255.	63	0-63
122	Volume & Repetitions for sound effect 1 (Slots 37-41): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 39); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 9 instead (Slots 77-81)	3	0-255
123	Volume & Repetitions for sound effect 2 (Slots 42-46): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 44); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 10 instead (Slots 82-86)	3	0-255
124	Volume & Repetitions for sound effect 3 (Slots 47-51): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 48); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 11 instead (Slots 87-91)	3	0-255
125	Volume & Repetitions for sound effect 4 (Slots 52-56): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 54); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 12 instead (Slots 92-96)	3	0-255
126	Volume & Repetitions for sound effect 5 (Slots 57-61): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 59); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 13 instead (Slots 97-101)	3	0-255
127	Volume & Repetitions for sound effect 6 (Slots 62-66): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 64); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 14 instead (Slots 102-106)	3	0-255
128	Volume & Repetitions for sound effect 7 (Slots 67-71): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 69); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 15 instead (Slots 107-111)	3	0-255
129	From SW version 40 onwards CV 129 has this meaning: Volume & Repetitions for sound effect 8 (Slots 72-76): bits 0-1 specify volume; bits 2-4 for number of repetitions of middle sound (Slot 74); bits 5-7 define number of repetitions of sound effect overall. If the 'Alternate' sounds are activated, this applies to sound effect 16 instead (Slots 112-116) Note that it is not possible to individually control the volume or looping of sound effects 9-16 (Slots 77-116) – they take on the settings for the equivalent effect in sounds 1-8.	3	0-255
	Prior to SW version 40, CV 129 had the following meaning: Strong time when the sound after acceleration is being strongly reduced (0.5 second units), valid for sounds in Slots 0-3 (this has moved to CV 146 from SW Version 40 onwards)		
130	Weak time – how long the deceleration chuffs (Slots 8-11)) should continue for after reducing speed (0.5 second units).	4	0-255
131	Random time: minimum time between 2 random sounds (0.5 second units)	20	0-255
132	Stroke speed at full speed: Time between 2 strokes/chuffs at full speed	100	0-255
133	Stroke speed at Step 1 (LOW byte): time between two steam strokes at speed step 1 in seconds. This can be a large number, so is defined using 2 CVs (133 and 134 with the LOW byte in CV133 and HIGH byte in CV134). Calculated via the formula: K = 1476 / time (1476 is a constant always used for this calculation by the decoder) Example 1: K=153 gives approximately 9.6 sec between chuffs Example 2: if 20 seconds wanted between chuffs, so K = 1476 / 20 = 73.8 rounded to 74 gives CV133 = 74, CV134 = 0 Example 3: if 3 seconds wanted between chuffs, so K = 1476 / 3 = 492. Since K > 256 we need to use 2 bytes, so split low byte and high byte: 492 / 256 = 1.927875 thus CV134 = 1 (rounded down), CV133 = remainder i.e. 492 - (256 * 1) = 236	153	0-255
134	Stroke speed at Step 1 (HIGH byte): time between two steam strokes at speed step 1 in seconds – see also CV133.	0	0-255
135	Frequency min: reduces the pitch of chuffs or engine sounds at lower speed steps. 128 is default pitch (sounds played as originally recorded). Use this CV along with CV136 to define how engine pitch or chuff pitch increases with the speed of the loco.	128	0-255
136	Frequency max: increases the pitch of chuffs or engine sounds at higher speed steps. 128 is default pitch (sounds played as originally recorded).	128	0-255
137	Special CV Bit 0 (1) - OFF = 8 functions, ON = 14 functions (MAN-bit) refers to F0-F12, btw CV33-CV46 free assignment. Bit 1 (2) - ZIMO train number impulse on / off Bit 2 (4) - strong / normal / weak switched with F1, effective only when CV110 is active, and dimmable via CV54 Bit 3 (8) - strong / normal / weak switched with F2, effective only when CV110 is active, and dimmable via CV54CV137 Bit 4 (16) – ZIMO speed contrl - dependent train control 0 = off 1 = on Bit 5 (32) - Start sequence (Sound Slots 21-23) is played before motor starts to spin – useful for diesel engines in particular as a rev-up sound before physically setting off Bit 6 (64) – Set ON if you want to control additional functions using F4 – press twice for F5, 3x for F6, 4x for F7 (useful if your controller does not have access to many functions directly) Bit 7 (128) - 32kHz frequency motor control from software version 41, factory Bit7 = 0 16kHz	0	0-255
138	Break time (HLU): break delay for HLU section (for ZIMO systems only)	3	0-255
139	Short-circuit threshold 1: direct cut-off at overload of function outputs	15	0-255
140	Short-circuit threshold 2: fast cut-off at overload of function outputs	12	0-255
141	Short-circuit threshold 3: slow cut-off at overload of function outputs	10	0-255
142	Short-circuit threshold 1: direct cut-off at overload of motor output	90	0-255
143	Short-circuit threshold 2: fast cut-off at overload of motor output	80	0-255
144	Short-circuit threshold 3: slow cut-off at overload of motor output	70	0-255
145	Activation of sound looping - if the corresponding sound function is activated, it will first play its 1st and 2nd Slots. After that, Slot 3 is repeated until the feature is turned off. After requesting off, it plays closing 4th and 5th Slots. Bit 0 (1) - for looping of Sound 1 (Slots 37-41) Bit 1 (2) - for looping of Sound 2 (Slots 42-46) Bit 2 (4) - for looping of Sound 3 (Slots 47-51) Bit 3 (8) - for looping of Sound 4 (Slots 52-56) Bit 4 (16) – for looping of Sound 5 (Slots 57-61) Bit 5 (32) - for looping of Sound 6 (Slots 62-66) Bit 6 (64) - for looping of Sound 7 (Slots 67-71) Looping for Sound effects 8-16 cannot be configured – they are not looping.	0	0-255
146	From SW Version 40 onwards, CV146 has the following meaning (used to be in CV129): Strong time: time that the acceleration chuffs sounds (Slots 0-3) continue after strong acceleration (0.5 seconds units). OLD: SW Version 39 and earlier CV146 had this meaning: CV146 = 1 means: Z3 (switching function) is connected with F7, 0 means inactive Z3 CV146 = 2 means: Z4 (switching function) is switched with F8, 0 means inactive Z4 CV146 = 4 means: Sound3 is connected with F7, 0 means inactive Sound3 CV146 = 8 means: Sound4 is connected with F8, 0 means inactive Sound4 CV146 = 16 means: Z5 (switching function) is switched with F9, 0 means inactive Z5 CV146 = 32 means: Z6 (switching function) is switched with F10, 0 means inactive Z6 CV146 = 64 means: Sound5 is connected with F9, 0 means inactive Sound5 CV146 = 128 means: Sound6 is connected with F10, 0 means inactive Sound6	12	0-255
147	Discharge of the coupling: a kickback effect causing the locomotive to run backwards slightly – a tiny jerk of the motor to achieve uncoupling.	20	0-126
148	Away from wagons: speed when driving away from wagons, locomotive runs in the current direction, 126 = max. Speed under. Take into account the time set in CV3.	50	0-126
149	Discharge time: the time for the unit pushed back. 0.1 seconds, 10 = 1 seconds	10	0-255
150	Drive away: the time for driving away unit 0.1 seconds, 30 = 3 seconds	30	0-255
151	Selection of automatic disconnection: 0 = off, 1 = F1 2 = F2 3 = F3, 4 = F4, etc.	0	1-12
152	Uncoupling mask forwards: Select the function to be used, 4 = F2, 8 = F3, 16 = F4, 32 = F5, 64 = F6 128 = F7	8	0-255
153	Uncoupling mask backwards: Select the function to be used, 4 = F2, 8 = F3, 16 = F4, 32 = F5, 64 = F6 128 = F7	8	0-255
154	Lighting effect for front light (output 0 white wire): 0 - No effect 1 - Flashing 2 - Flash-pull 3 - Single pulse strobe 4 - Double Flashing strobe 5 - Headlight (brightness between maximum and PWM value in CV 114) 6 - Ditch light left (brightness between maximum and PWM value in CV 114) 7 - Ditch light right (brightness between maximum and PWM value in the CV 114) 8 - Rotary beacon (brightness between maximum and PWM value in the CV 114) 9 - Gyralite (brightness between maximum and PWM value in the CV 114) – can also be used for firebox glow 10 - Mars light 11 - Soft-start 12 – Brake sparks (short flash activated only when the loco comes to a stop) For output when forward only, add 64 to the above value e.g. 1 + 64 = 65 flashing on Forward only. For output when in reverse only, add 128 to the above value e.g. 1 + 128 = 129 flashing on Reverse only. If neither 64 nor 128 is added, it is assumed that the effect should be active for both forwards and reverse. CVs 155 -161 provide the same effects for each of the other function outputs.	0	0-255
155	Lighting effect for function output 1 (yellow wire) - see CV154	0	0-255
156	Lighting effect for function output 2 (green wire) - see CV154	0	0-255
157	Lighting effect for function output 3 (purple wire) - see CV154	0	0-255
158	Lighting effect for function output 4 (solder pad) - see CV154	0	0-255
159	Lighting effect for function output 5 (solder pad) - see CV154	0	0-255
160	Lighting effect for function output 6 (solder pad) - see CV154	0	0-255
161	Lighting effect for function output 7 (solder pad) - see CV154	0	0-255
162	Sensitivity of the diode voltage: see also CV116. Value of 10-20 is generally well tolerated, the smaller the value the more sensitive.	10	0-255
163-176	Extended function mapping: Please refer to CT extended function mapping document for more information.	0	0-255
177	Trigger for rapid acceleration: indicates the number of speed levels that must be attained within any 100 msec period in order to trigger the	0	0-252

	sound in Slots 123-125). If the sounds are in three parts, the middle part is played in a loop until the requested speed is reached. See also CV 107 for trigger to rapid braking sound.		
179	SL82 only – PWM for smoke generator – 'ON' level of output from 0-10 – determines how much power goes to the smoke generator output during a chuff	10	0-10
180	SL82 only – PWM for smoke generator – 'OFF' level of output from 0-10 – determines how much power goes to the smoke generator output between chuffs. This needs to be tuned so that it is low enough for the smoke to reduce between chuffs, but not too long, or the smoke won't cut back in quickly enough on the next chuff i.e. keep it hot, but not quite hot enough to smoke.	5	0-10
181	SL82 – smoke generator chuff period measured in 2.5msec units. This determines the length of time that the smoke generator output is kept switched on after each chuff, before reducing to the level defined in CV 180.	5	0-255

Extended Function Mapping

Control of decoder features, such as lighting and sound, can be configured flexibly to different Function Keys. Use the table below to help calculate what CV values to set to achieve your desired configuration. Note that not every feature can be mapped to any key, but a wide choice is possible nevertheless. Only Function Keys F0-F12 are supported by CT decoders, but to help with this restriction, you can use the ALT feature to allow switching between different sounds, so up to 16 'callable' sounds can be made available.

	Sound 8 (or Sound 16 with ALT on)	Sound 7 (or Sound 15 with ALT on)	Sound 6 (or Sound 14 with ALT on)	Sound 5 (or Sound 13 with ALT on)	Sound 4 (or Sound 12 with ALT on)	Sound 3 (or Sound 11 with ALT on)	Sound 2 (or Sound 10 with ALT on)	Sound 1 (or Sound 9 with ALT on)	ALT – switch to Alternate Sounds	Main Sounds on/off	Shunting Mode	AUX7	AUX6	AUX5	AUX4	AUX3 (purple)	AUX2 (green)	AUX1 (yellow – REV)	AUX0 (white – FWD)	CV
Function Key	Aux Sound 8	Aux Sound 7	Aux Sound 6	Aux Sound 5	Aux Sound 4	Aux Sound 3	Aux Sound 2	Aux Sound 1	Alternate Sounds	Main Sounds	Shunting Mode	Output 7 (solder pad)	Output 6 (solder pad)	Output 5 (solder pad)	Output 4 (solder pad)	Output 3 (purple)	Output 2 (green)	Output 1 (yellow)	Output 0 (white)	CV
F0 fwd												128	64	32	16	8	4	2	1	CV33
				128	64	32	16	8	4	2	1									CV163
F0 rev												128	64	32	16	8	4	2	1	CV34
				128	64	32	16	8	4	2	1									CV164
F1												128	64	32	16	8	4	2	1	CV35
				128	64	32	16	8	4	2	1									CV165
F2												128	64	32	16	8	4	2	1	CV36
				128	64	32	16	8	4	2	1									CV166
F3												128	64	32	16	8	4	2	1	CV37
				128	64	32	16	8	4	2	1									CV167
F4									128	64	32	16	8	4	2	1				CV38
	128	64	32	16	8	4	2	1												CV168
F5									128	64	32	16	8	4	2	1				CV39
	128	64	32	16	8	4	2	1												CV169
F6									128	64	32	16	8	4	2	1				CV40
	128	64	32	16	8	4	2	1												CV170
F7									128	64	32	16	8	4	2	1				CV41
	128	64	32	16	8	4	2	1												CV171
F8									128	64	32	16	8	4	2	1				CV42
	128	64	32	16	8	4	2	1												CV172
F9						128	64	32	16	8	4	2	1							CV43
	16	8	4	2	1															CV173
F10						128	64	32	16	8	4	2	1							CV44
	16	8	4	2	1															CV174
F11						128	64	32	16	8	4	2	1							CV45
	16	8	4	2	1															CV175
F12						128	64	32	16	8	4	2	1							CV46
	16	8	4	2	1															CV176

Each function key may control multiple outputs, although there is some restriction on which function keys can access which outputs as can be seen where the matrix entry is blank. There are 2 CVs relating to each function key to define the key's action. Add the values shown in the corresponding cells to get the function mapping you want.

Example: if you want F5 to operate Sound 3 and also to switch on Function Output 3, you should set CV39=1 and CV169=4.

Note that if you map a function key to the 'ALT' action, this means that while that function is activated, any sounds played will be from the alternate set of sounds(sounds 9-16) instead of the first set (sounds 1-8).

Note that, as well as the Function Key assignments shown in the above table, Function Keys may also be configured for other specialise purposes by other CVs, such as auto-coupling sequence activation.

For the SL76/GE76, a special 'volume' feature is available – if you do not assign F2 and F3 to any other features, these keys will act as DOWN and UP volume keys, on the fly.

Auto-Decoupling Devices

CT decoders provide comprehensive support for auto-decoupling devices, providing tuning for function output strength, and hold time, as well as triggering of automatic sequences where a single Function Key press can push the loco toward a wagon, activate the decoupling device, pull away from the wagon, then switch off the device.
Front and rear coupling devices can be given their own tuning, and different Function Keys can activate front and rear decouplers.

CVs 152 and 153 determine which Function Keys activates the decoupling sequence for front and rear.

CVs 147 to 151 control the movement of the loco during this sequence.
CVs 55 and 56 define the strength of the decoupler's holding current, and the period to hold the decoupling device on.
CV 58 determines which of the AUX outputs have decoupling devices attached.

Experimentation will often be required to determine what values work best for a particular decoupling device, and motion configuration will vary depending upon the motor's characteristic, and the momentum CVs.

Smoke Generators

As long as your smoke generator device draws less current than the AUX outputs for your decoder (check the Technical Specifications earlier in this document), you can connect it directly between the common positive (blue wire) of the decoder and one of the AUX function outputs (typically the purple wire is used for this purpose). No other components are required. Seuthe #22 and #27 units are suitable for direct connection in OO/HO scale in particular.

For smoke generators that draw high currents, you can use a relay, where the power is taken directly from the track/pickups but the relay is switched using an AUX Function Output on the decoder.

Lighting

LEDs and bulbs may be powered and controlled by the AUX function outputs of the decoder. In general it is recommended to use LEDs, as these have very long lives and do not generally get hot.

LEDs should always have their positive terminal connected via a resister to the decoder's common positive (blue), and their negative terminal to one of the AUX function outputs e.g. white, yellow, green, purple etc.

Configuration of what Function Key controls each AUX output is detailed in the section on Extended Function Mapping.

In addition, a variety of lighting effects can be applied individually to each AUX output, as detailed in CVs 154 to 161. In addition, dimming may be applied to one or more AUX outputs using CV 54 to choose the dimming level and CV57 to choose which AUX outputs to apply this dimming to. You cannot dim different AUX outputs by different amounts – they are either 100%, or they have the value in CV54 applied.

Motor Control and Tuning

CT decoders offer very flexible tuning for motor control, supporting a wide variety of motor types, and it is normally possible to achieve excellent smooth, and slow running performance with any well maintained motor.

Speed Curves

CVs 2, 6 and 5 provide a simple method of defining the motor's speed curve from initial set-off to maximum speed. With CV 6 set to 0, the speed curve is linear, but with CV 6 set to something between 0 and 255, a rough 3-point curve is applied. This assumes that CV 29 bit 4 (value 16) is switched off.

With CV29 bit 4 switched on, the speed curve is taken from CVs 67 to 94, allowing you a much finer control of the motor output through the speed range.

Momentum / Inertia

One of the great features of DCC decoders is the ability to automatically apply gradual acceleration and deceleration, making the motion of the loco much more realistic than would be possible with an analog control. CT decoders are particularly good at applying these gradual effects, and the strength of the momentum effects can be easily configured using CV 3 (acceleration) and CV 4 (deceleration).

Motor Characteristics and Back EMF

Smooth running is achieved using a technique called Back EMF, whereby the decoder regularly detects feedback from the draw of the motor in order to work out if the requested speed is actually being maintained. It is a very sophisticated technique, and the frequency and strength of the feedback must closely match the characteristics of the motor in order for it to work effectively. Bad configuration will result in jerky motion, and noisy operation.

CT decoders will normally be shipped with Back EMF settings appropriate for most modern motors, so there will be little tuning, if any required.

CV 9 defines the type of motor, effectively defining the frequency at which Back EMF readings are performed.
The intensity of this reading is configured using CV 50, often best set at the maximum of 255.
CVs 51 and 52 allow for fine-tuning of the read-back. It will often be necessary to experiment with a range of values in order to get the motor working just right.