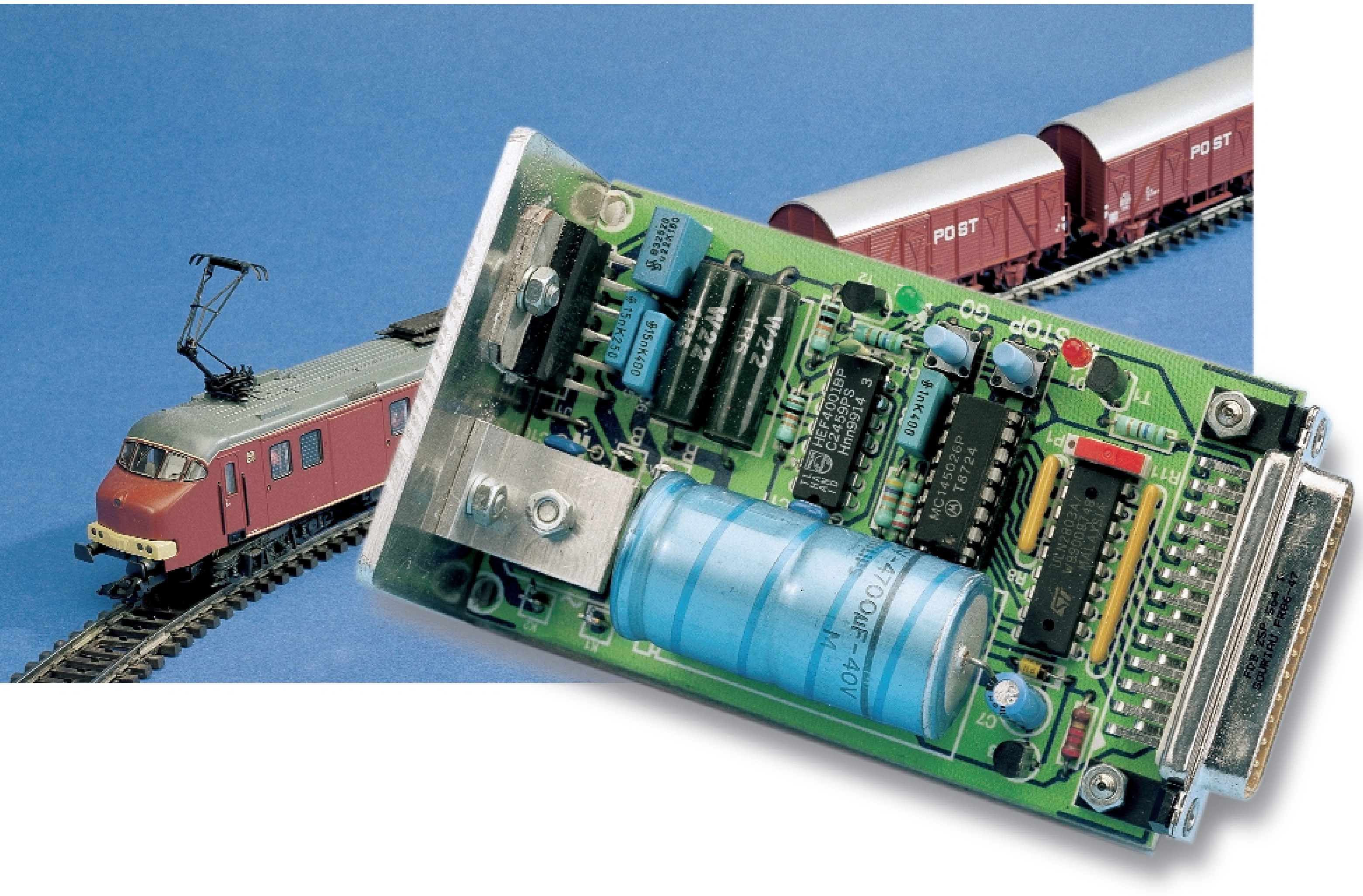
Märklin Digital Model Train Control (1)

A low-budget approach

From an idea by J. Schröder

This circuit provides an excellent opportunity to upgrade your Märklin model train system from 'traditional AC' to digital control.



Main Features

- Direct connection to PC parallel port.
- Simple to operate software (Windows 3.1x, 95, 96, NT) for individual control of up to 15 model trains.
- Controls Märklin Digital H0 stock using classic Motorola data format and Delta decoders.
- Integrated compact booster, max. 3.5 A output current, with overload protection.
- Powered by original Märklin transformer or single 15-VAC
- Manual on/off control of extra function.

Beginning model train enthusiasts may have more digital-ready (Märklin) locomotives moving about on the track than they are aware of. Usually, these locomotives are simply powered by the speed regulator on the main transformer. These days, model locomotives with an internal digital decoder are hardly more expensive than traditional types. That is not surprising because electronic circuits are easier and cheaper to produce in large volumes than any of the traditional reversing relays. Märklin always continued to produce decoders capable of working in 'AC' mode as well, allowing them to be used without problems with the famous Märklin transformer. Upgrading to all-digital control is then possible at a later stage. Possible, yes, but admittedly at a price because the cost of the upgrade will easily exceed that of all rolling stock.

Several attempts have been made to lower the threshold. From 1987 roughly to 1991, *Elektor Electronics* published items to create the all-home-made EEDTs (*Elektor Electronics Digital Train System*), a hugely successful series! Some time ago, Märklin introduced their Delta system, which is actually a stripped down version of the original Digital H0 with limited addressing options (4 instead of the usual 80). In fact, the Delta system triggered the author to design the circuit and software described in this article. Many Märklin locomotives come with a Delta decoder fitted as standard, instead of the traditional reversing relay. These locomotives, too, are controlled in old-fashioned AC mode (i.e., by transformer speed regulator), by the vast majority of model train fans. The Digital Control discussed in this article allows anyone and an old PC in the attic, and capable of handling a soldering iron, to get the feel of digital model train control at a very small outlay. So, if you do not yet have a locomotive with a Delta (or regular) decoder, you have a perfect excuse to step inside a model building shop when it's not December…

Recapping

Newcomers to the hobby can, of course, not be expected to know all the ins and outs of digital control for model trains. Hence, a brief recap is given of what we already described in the long series of articles on the EEDTs, plus a short description of the latest developments in the field.

The crux of digital model train control is that several trains on the track can be controlled independently. As opposed to traditionally operated tracks, where turning the speed governor on the transformer puts all rolling stock in motion at the same time, the digital track is marked by each locomotive having its own control element, allowing its speed and direction to be controlled individually. In addition to this function, there is often a plethora of options of the 'bells and whistles variety, including control of turnouts and signals via the track. Unfortunately, however, these extras and their control are outside the scope of this article.

How does it all work, you may wonder. With traditional control systems, a voltage is

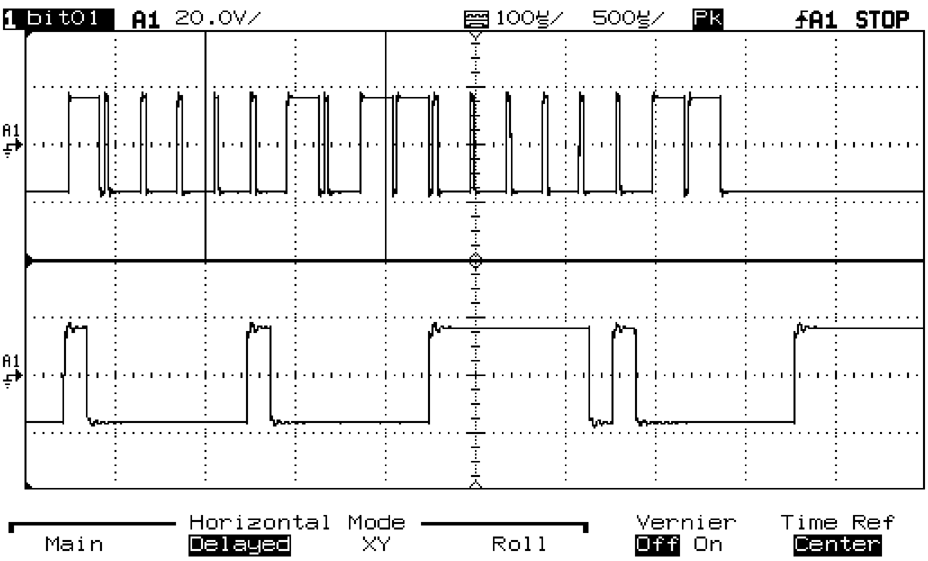


Figure 1. Two trinary signals on the 'scope: The top trace shows loco address 56 (X00X), function bit = 1, speed = 7 (0001).Below, in stretched-display mode, logic 0 (00), logic Open (10) and the start of a logic 1 (1…)

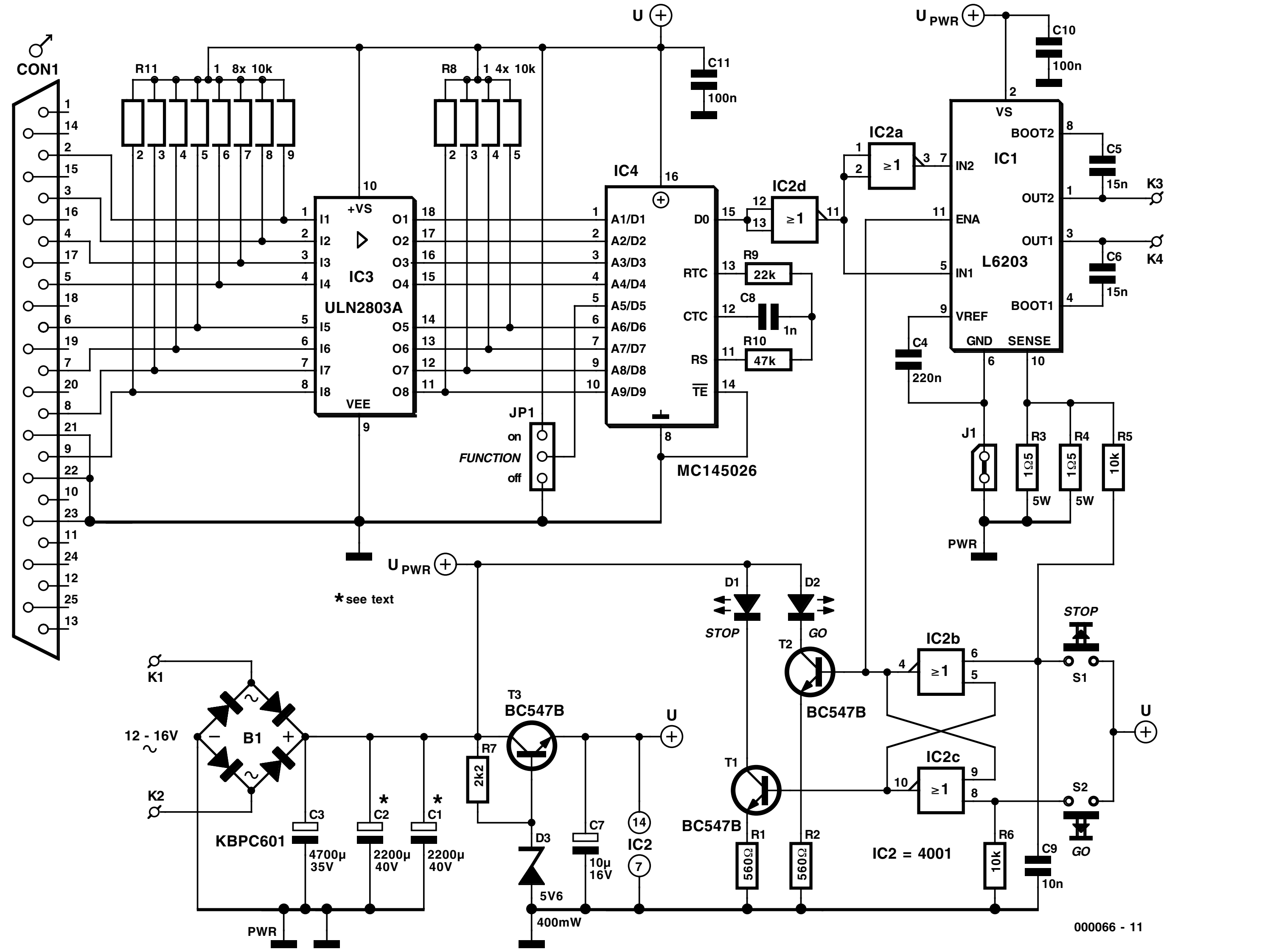


Figure 2. Circuit diagram of the Märklin Model Train Control System. The control elements, a mouse and your PC keyboard, are not shown here.

simply applied to the rails (alternating voltage in Märklin systems, direct voltage in most others), where overvoltage (Märklin) or polarity (other brands) provides information about the direction the locomotive has to travel in. With digitally controlled tracks, the rails carry a signal that alternates between a fixed positive and a fixed negative level. Depending on the model train brand and gauge, this voltage usually lies between ±12 V and ±18 V. The rate at which the voltage swings from + to – represents control information for individual locomotives and, if applicable, other devices like signals.

As with too many other products, the industry did not succeed in agreeing on a common standard in this field. Of the four digital systems originally available (Märklin Digital H0, Lenz, Fleischmann and Selectrics), only the first two actually got a foothold. In addition, Märklin Digital H0 is now flanked by several ‘dialects’ including the EEDTs data format and the ‘New Motorola Dataformat’. Other brands, too, have variants. In this article, we will limit ourselves to Märklin Digital H0, because that is the format recognized by the system described here.

Märklin Digital H0 employs a switching sequence once designed by Motorola for use in remote controls. Information is bundled into packs of 18 pulses. In fact, these pulses are pairs of two pulses each. Three of the four combination possibilities of the pulse pairs are actually employed. 00 equals logic zero, 11 equals logic 1, and 10 is logic open. In the original Motorola data format, the combination 01 is not used — in the New Motorola Dataformat, you guessed it, it is.

A single data burst or packet consists of nine pulse pairs. The first four are used as (locomotive) addresses, supplying $3^4 = 81$ addresses of which only 80 are used by Märklin. The remaining five pairs are only decoded in binary fashion: 00 or 11; with bit 5 flagging the on/off state of the extra function, and bits 6-9 containing speed and engine reversing commands.

Some time ago, Märklin introduced the so-called New Motorola' data format, in which all four combination options are allowed (00, 01, 10 and 11). The extra combinations in the function bit and the remaining four bits are used for non-volatile direction information and extra switching functions. The standard Motorola encoders and decoders, however, are unable to process these pulse pair combinations.

Finally, we should mention that a pause with a certain length is inserted between the 18-pulse packets. This is done to synchronize the transmitter and the receiver. The packet has length of about 3.8 ms, while the pause takes about 2 ms. As an extra safety measure, Motorola have built in a protocol that arranges for the receiver to be supplied with the same data packet twice in sequence for it to be recognized as valid. This protocol appears to be surprisingly effective for all rolling stock moving at considerable speed across the track.

The circuit

The circuit diagram shown in **Figure 2** is of an attractive simplicity. The core is formed by IC4, a Motorola encoder chip type MC14026 which looks after all converting into serial digital format of data received from the PC parallel port. In a way, the encoder IC also restricts the operation of the circuit: it is capable of generating the old (traditional) data format only. This allows standard and Delta locomotives to be controlled. Decoders from other brands (for example, Lenz) or decoders having the four extra function outputs utilizing the New Motorola data format can not be used in conjunction with this circuit.

Darlington array IC3 acts as an interface between the parallel port on the PC and the encoder chip. The first four outputs are used to set the locomotive address on the decoder. Because the open-collector outputs are not fitted with pull-up resistors, the status of the address lines is always Low or High-Z. The ability to set a High-Z status is essential because the Delta addresses defined by Märklin all have 'logic open' bits. If the encoder were connected directly to the parallel port, it would not have been possible to activate any Delta decoder at all!

The second nibble of the parallel port is used for setting bits 6-9 on the encoder. These bits contain speed information and the reversing command: the bit combination is 1000.

Bit 5, the function bit, is given a fixed state with the aid of a jumper or switch (JP1) and is therefore on or off for all locomotives to be addressed. That should not be a problem because this bit usually controls the lighting function, which is preferably on by default. Only the oldest EEDTs decoder employs bit 5 for (non-volatile) direction information. Hence that decoder can not be used with this circuit, because changing the state of JP1 would cause all trains to reverse. Later EEDTs loco decoder variants, including the most recent EEDTs Pro, are fully compatible with the present system.

Components R9, R10 and C8 determine the timing of the encoder. Resistor R9 determines the length (duration) of one packet of 18 pulses (3.8 to 4 ms), while R10 takes care of the synchronisation pauses between pulse packets.

Originally, the circuit was designed for direct connection to the EEDTs Booster. However, the Booster, with its 10-amp output current capacity and considerable cost and effort of building may be too much of a good thing, and beyond the reach of beginners. That is why the present circuit comes with its own mini booster, IC1, which is short-circuit as well as overload resistant. To keep the cost of building the project down to the absolute minimum, it is possible to connect the existing Märklin transformer and use it as a power supply. Using B1 and C1/C2 (or C3, see construction details), a single direct voltage is derived from the transformer's secondary voltage. A full bridge output stage has to be chosen to enable a single-rail input voltage to be turned into an output voltage that switches between a positive and a negative value. The L6203 from ST Microelectronics combines the required functions in a single IC. Plus, because the IC is manufactured in DMOS technology, we need not concern ourselves too much with switching speeds or power dissipation. At the maximum output current of 3.5 A chosen for this circuit, the L6203 remains reasonably cool. With insufficient cooling, an internal overheating protection arranges for the IC to be switched off once a certain temperature limit is exceeded. Components C5 and C6 are so-called 'bootstrap capacitors' which serve to ensure a sufficiently high gate voltage on the two power MOSFETs in the upper section of the bridge.

The output current flows to ground via the sense connection and R3-R4. These resistors serve to monitor the maximum output current because the L6203 is not wholly and truly short-circuit proof. The voltage developed across R3 and R4 is fed to the input of NOR gate IC2b via R5-C9, a low-pass filter to suppress inevitable switching pulses. Together with IC2c, the NOR gate forms a bistable with a special 'treat' in that IC2b is (mis-)used as an analogue comparator. Standard CMOS circuits are designed to switch at about half the supply voltage. If the voltage at pin 6 of IC2b reaches 2.5 V (which happens at 2.5 V / 0.75 Ω or 3.5 A), IC2b and IC2c toggle.

The enable input of the L6203 is then pulled low, the bridge is switched off, and the tracks are disconnected from the supply. The green GO LED, D2, also goes out and its red counterpart, D1, marked STOP, lights. When this happens, switch S2 may be used to rerestart the circuit. A stop condition may be forced by operating switch S1.

The two remaining gates in IC2 are used to supply the bridge with the normal and inverted digital signal.

The 5-V logic supply voltage is derived from the unregulated power supply. A zener diode is used in combination with emitter follower T3 acting as a power buffer, because the input voltage conditions are rather uncertain. If, for example, a Märklin transformer is connected and the speed control knob is turned back to the train reversing position, an alternating input voltage of 24-30 V appears at the supply inputs. When rectified, that would produce an input voltage surge that is sure to endanger the life of a 7805 voltage regulator. With D3 and T3 included, the circuit will withstand this abnormal condition. The output bridge can also safely handle this voltage surge of up to 52 volts.

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Next month's second and final instalment will cover the system software and hardware construction.