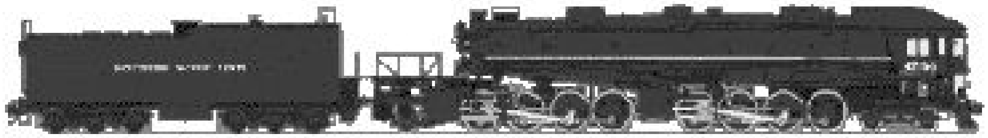

RAILROADER'S

C/MRI
APPLICATIONS

HANDBOOK

Volume 1 – System Extensions

Version 3.0(1)

By Dr. Bruce A. Chubb, MMR

Chapter 2: TRACK OCCUPANCY DETECTION FUNDAMENTALS

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Chapter 2

TRACK OCCUPANCY DETECTION FUNDAMENTALS

Paramount to most C/MRI applications is the need for the computer to be able to determine which sections of track are occupied. For example, knowing the occupancy status of each signaled block is essential to keep signals at red when the blocks ahead are occupied. The computer needs to know train location if it is automatically to control train speed, as in display mode operations. Being able to monitor train location at street and highway crossings is essential to controlling crossing flashers, bells and gates. Also, occupancy detection is mandatory to having the dispatcher monitor train location as traffic moves across his or her CTC panel or monitor screen.

Even for model railroads not employing signals and not using a computer, adding occupancy detection can be worthwhile. Example applications include directly lighting LEDs on a control panel to monitor train movement in hidden trackage and to show the occupancy status of staging tracks.

THE PROTOTYPE TRACK CIRCUIT

The prototype uses what is called the "Track Circuit" to detect when a given stretch of track is occupied. Quoting from the ***Third Annual Report of the Block Signal and Train Control Commission*** dated November 22, 1910, *"Perhaps no single invention in the history of the development of railway transportation has contributed more toward safety and dispatch in that field than the track circuit. By this invention, simple in itself, the foundation was obtained for the development of practically every one of the intricate systems of railway block signaling in use today wherein the train is, under all conditions, continuously active in maintaining its own protection."*

Although Dr. William Robinson patented the original closed-circuit concept in 1872, the track circuits resulting from his patent are still fundamental to railway signaling. Fig. 2-1 illustrates the elementary nature of the prototype track circuit.

Starting from the positive terminal on the track battery and its current limiting resistance, the current flows through one rail, through the track relay and its series resistance and back through the opposite rail to the negative terminal on the track battery. This closed circuit path results in the track relay being energized when the block is clear. In this simplified signaling example, when the track relay is energized, "picked-up" in signal maintainer terminology, the front contact (the one closest to the relay coil) closes and lights the signal green, i.e. the block is clear. The resistance placed at the battery limits the track current drain with shorts placed across the rails and the resistance at the track relay sets circuit sensitivity.

Fig. 2-2 shows the situation when the block becomes occupied. As the wheels and axles of cars and engines move onto the track circuit, they provide a path from rail to rail through which the track current flows. This action robs the track relay of its current, causing it to become de-energized, or "drop away" in signal maintainer terminology. This opens the front contact and closes the back contact (the one furthest from the coil) causing the signal to change from green to red. In summary the prototype's track relay picks-up, i.e. is energized, when the block is clear and it drops-out, i.e. becomes de-energized, when the block becomes occupied.

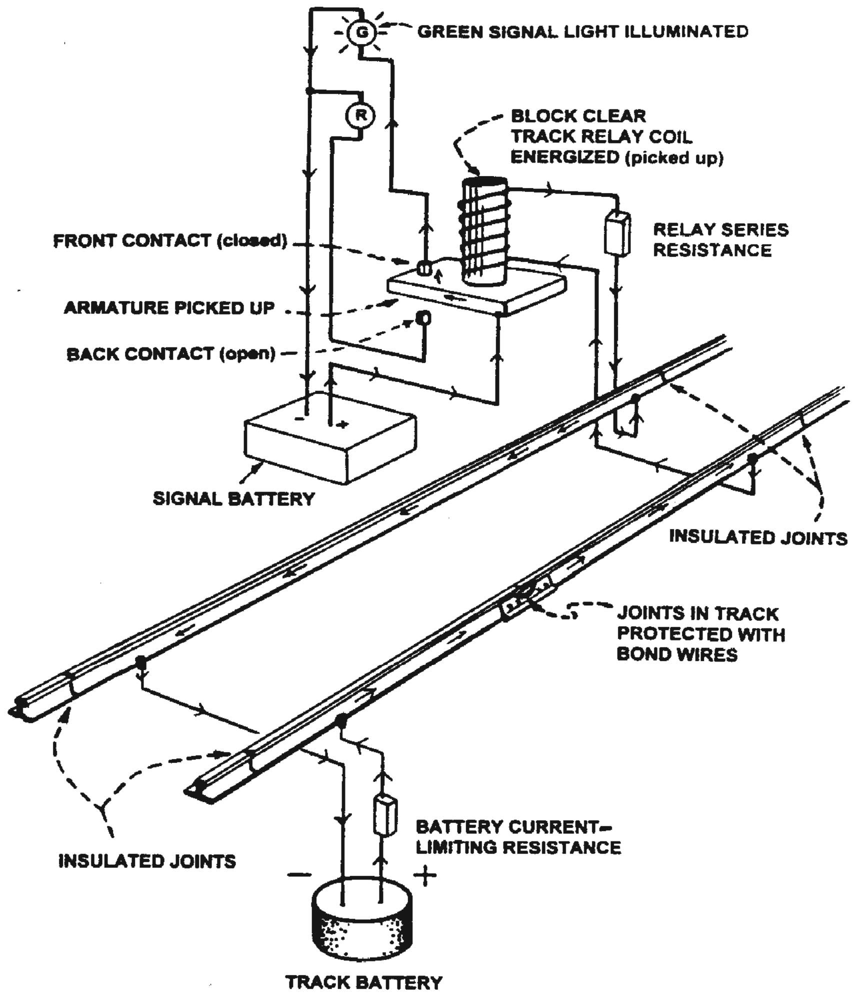

Fig. 2-1. Simplified diagram of a prototype track circuit – **unoccupied**

The track circuit is designed to maximize fail safe features. For example, by placing the track relay at one end of a signaled block and the track battery at the opposite end, any broken rail within the signal block will de-energize the track relay and set the signal(s) leading into the block at red. The same is true for a broken wire bond and a rusty joint, a dead track battery, a loose connection anywhere in the track circuit and an open track relay coil.

The track relay is constructed with a heavy armature positioned such that gravity, rather than the usual spring that can fail, causes the contact to fall, or drop-out, when not energized. Furthermore, the front contacts employ silver-impregnated graphite against silver, a combination which has low resistance for normal operation but will not weld together should a very heavy current be encountered, such as might be associated with a lightning strike. All moving points are sealed in a glass case for protection as well as providing easy inspection by signal maintenance personnel. In fact, all relays and associated components used in line, i.e. trackside, circuits, in which they control the actual displaying of signals, are defined as “vital” components and are designed and manufactured to an exceptionally high standard of reliability.

For simplicity, Figures 2-1 and 2-2 show the track relay directly controlling the signal aspect. However in reality this is seldom, if ever, the case. As we will see in subsequent chapters, there is much more to effective signaling than simply looking at block occupancy. The track circuit provides a vital input to other vital circuitry that checks for the alignment of turnouts, previously cleared train movements, along with a multitude of other functions that must be checked before a signal can be cleared. To achieve an effective signal system on our model railroads we must make many of the same checks.

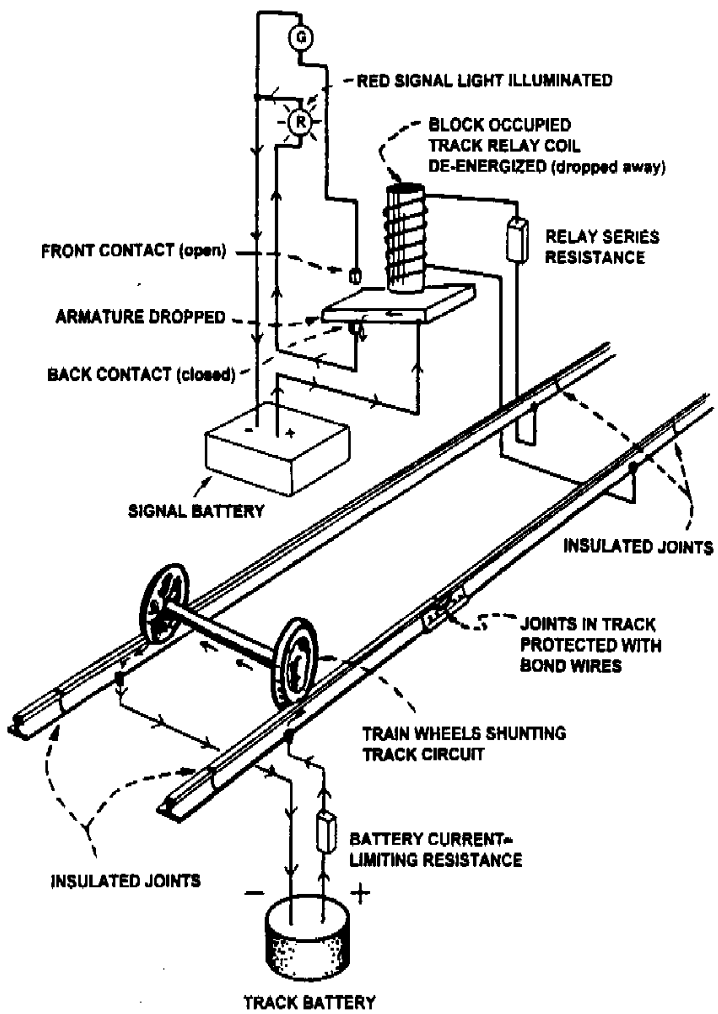

Fig. 2-2. Simplified diagram of a prototype track circuit – **occupied**

Although the first exposure to the track circuit can easily leave one with the false conclusion that all is understood, there are many factors that make prototype track circuit design a complicated engineering challenge. Each factor affecting track circuit performance must be thoroughly considered to insure safe operation over wide extremes in temperature, dampness, rail joint tightness, type of ballast used, foreign material imbedded in the ballast, rust on rail and wheels, etc.

A typical track battery has an output between 1 and 2 volts. Typical track relays have a coil resistance of approximately 4Ω with drop-away and pick-up currents of say 50 and 100mA, respectively. Typical rail resistance varies from .015 to .05Ω per 1,000 ft of track with rail joints providing an even bigger impact. Ballast leakage resistance can vary from less than one ohm to hundreds of ohms per 1,000 ft of track.

The federally legislated requirement is that a shunt (short circuit) across the track of .06Ω or less must show up as block occupied. Resulting from all of this, complete engineering theses and books are written describing how to optimize track circuit components. To manage the wide parameter variations, while maintaining high reliability of avoiding a false clear or a false occupied indication, track circuits are usually restricted to less than 4,000 ft. When longer signal blocks are needed, the prototype typically divides the block into "cut sections" with a separate battery and track relay used per section. Relay contact logic combines the two or more cut sections into a single signal block.

Although not as severe as on the prototype, model railroaders can also experience wild changes in the resistance between the rails. For example, Stephen Bartlett, an active user of the C/MRI on his basement located O-scale railroad, reports that during the dry season his blocks can easily measure 4,000,000Ω or greater and during the wet season they can easily drop to around 40,000Ω – a 100 to 1 range! Dampness, as well as the type of ballast and glue used, can play havoc with some commercial signal systems. To obtain maximum performance out of your detectors while avoiding climate change problems, it is best always to select an occupancy detector with easily adjustable sensitivity.

Some commercial detectors achieve their "adjustment capability" by advising you to unsolder and insert a different resistor or to wind a different number of wire-turns through a transformer core. To me these are extremely poor substitutes (making the detector nearly worthless) compared to supplying a sensitivity adjustment potentiometer. Detectors with low sensitivity and those not including a potentiometer for adjusting the sensitivity should be avoided.

There have been a countless number of times that railroaders have called or emailed me with their false clear or false occupied detection problems using brand-x detectors – those with either low sensitivity and/or without an easy sensitivity adjustment. Many similar problem declarations have been posted on the various command control user groups as well as on the C/MRI User's Group.

The fundamental truth is that replacing brand-x with a truly optimized detector like the DCCOD or an OD – with their high sensitivity and built-in sensitivity adjustment – quickly cures the problem. To take advantage of these important features and numerous other benefits, most of this handbook will be based on using the DCCOD and the OD.

ADAPTING THE TRACK CIRCUIT TO OUR MODEL RAILROADS

Because most two-rail model railroads use the rails to supply the power essential for train operation, the prototype's track circuit is not directly applicable. We can not have our rolling stock introduce direct shorts across the track to activate the signal system. In contrast, at age ten on my original Lionel O-27 Sunset Valley 3-rail setup, I did insulate one of the outside rails and use the shorting action across the wheelsets to activate my signaling system.

A specialized detector for 3-rail AC powered railroads has been developed by C/MRI user John Shankland. This detector takes advantage of the situation where each wheelset has a direct electrical connection between the wheels. For those interested, John is willing to share his design and because he is a frequent contributor to the C/MRI Users Group, he is very easy to reach. Alternatively you can check out his railroad and C/MRI setup at www.jnstrains.com. By contrast, in most two-rail model railroading applications, live steam and operation with overhead wire being exceptions, if a direct short is placed across the track, train operation will cease.

Early attempts to implement two-rail detection used mechanically activated contacts or magnets attached to engines to activate reed relays mounted in the roadbed, or photo detectors that triggered as trains passed overhead. There are still some specialized applications where the photo detector proves useful, the most notable being detection where the gap between two cars is precisely centered over an electro-magnet for computer controlled uncoupling. Therefore, in Chapter 30, I will show how Don Wood recommends assembling different components using the JLC provided standard SMC12 circuit board to create 12 photo detector circuits.

With the introduction of the transistor, the Twin-T detector (introduced by Linn Westcott in the June, July and August 1958 issues of **Model Railroader)** became the most popular means of two-rail detection. I long ago replaced the Twin-T detectors used on the original HO scale Sunset Valley with the OD. Then, later on when the SV was converted to DCC, the ODs were sold and replaced with DCCODs. Nevertheless, there are still many modelers making use of the Twin-T, and many have their Twin-T detectors interfaced into the C/MRI.

Optimized Detection Using DCCOD and OD

If you do not yet have track occupancy detectors installed, give serious consideration toward using the OD for DC equipped layouts and the newer DCCOD for DCC equipped layouts. Both designs are well optimized, with over 60 years experience in model railroading and with over 50 years experience in industrial and aerospace electronics applied to their development. The DCCOD and OD both work extremely well and provide 100 percent guaranteed compatibility with the C/MRI. The DCCOD is also guaranteed 100 percent compatible with all brands of DCC equipment.

The DCCOD and OD are two of the most popular JLC circuit cards. Their application to show block occupancy is basic to any signal system. Tens of thousands of the DCCODs and ODs are installed on railroads, many of which do not yet have a computer. However I like to think that each of these railroads is a prime candidate for adding a computer.

Due partly to the high sensitivity of the DCCOD and OD, their performance is reported by users as exceptional. For example, with the sensitivity control turned up, a finger placed across the track will show the block as occupied. If you find that current leakage through the ties and ballast, especially in times of high humidity, causes a clear block to show as occupied, simply turn down the sensitivity control until the block shows clear. Conversely, if you have an occupied block that shows up as clear, simply turn up the detector's sensitivity.

Prototype railroads have infinitely more problems with false clear and false occupied indications than we do with our models. Whole chapters in prototype signaling books deal with the subject of how to make the track circuit highly reliable over wide ranges of climate and ballast conditions. Years of research have been expended to optimize the track circuit design. But how many times have you approached a grade crossing on a rainy day and found the red lights flashing and the bell ringing and not a train in sight? An even more serious problem on the prototype is to have an unloaded flat car with rusty wheels setting on rusty track and the track circuit showing the block as clear.

I consider the application of the OD and DCCOD so important that I have devoted a complete chapter to each. Chapter 3 covers the OD and Chapter 4 the DCCOD. However, at this point a brief introduction showing each detector is appropriate:

- **Optimized Detectors (OD).** Installing the JLC OD cards, designed for DC railroads, is a great way to start building toward a more complete computer interface. You can use ODs to indicate occupancy status of hidden trackage and/or drive LEDs on your track diagram as trains progress, or automatically to control polarity in reverse blocks. With detectors installed it is a natural step to use the C/MRI for signaling. You can use the ODs with DCC but for systems employing more than one DCC booster, the wiring with ODs can become more complex. Therefore, if you are starting from scratch on a DCC equipped railroad, I recommend that you use the new special DCC version of the OD – the DCCOD.

- **DCC Optimized Detectors (DCCOD).** This is a new version of the OD, designed specifically for Digital Command Control (DCC) applications. The DCCOD takes advantage of the bi-polar pulse inputs available from DCC. The detector's power and ground connection plus the detector's output are totally isolated from the track wiring. This way the DCCOD works independently of whether or not your railroad is set up for common rail wiring. The DCCOD is also the preferred choice for other pulse-type command control systems such as CTC-16e, CTC-80 and Railcommand.

Fig. 2-3 shows the OD, Fig. 2-4 the DCCOD and Fig. 2-5 shows how the detectors plug into the Optimized Detector Motherboard (ODMB).

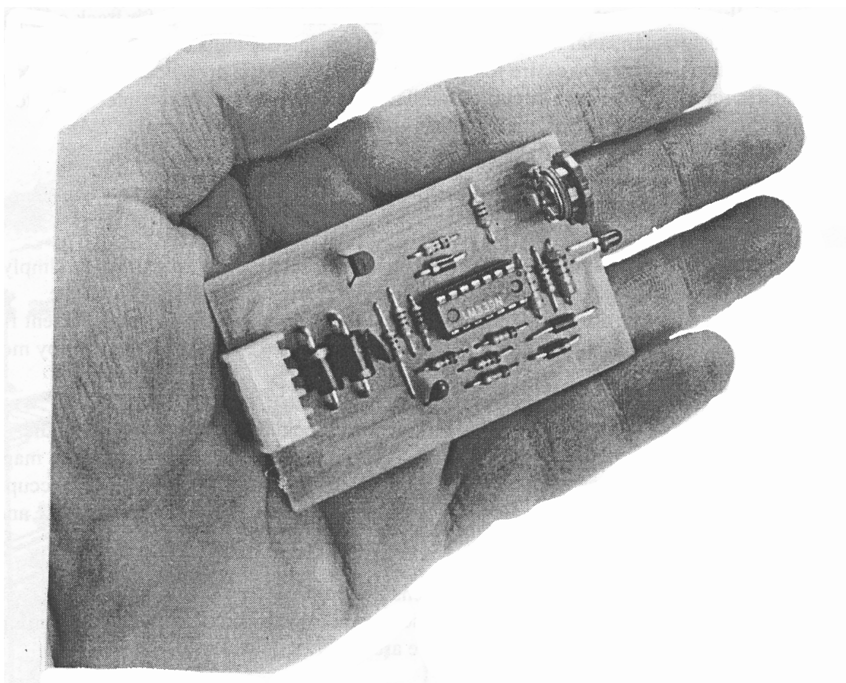

Fig. 2-3. OD provides optimized block occupancy detection for DC equipped railroads – Rev J

The DCCOD looks much like the OD and you can easily hold both units in the palm of your hand. The one significant difference in appearance is that the DCCOD uses a special pulse-type current-sensing transformer in place of the dual high-current diodes used to sense current flow with the OD. This transformer is rated at handling input currents up to 20A so there is little concern about short circuits overloading the DCCOD. Although the DCCOD is specifically optimized for DCC layouts, we will see in Chapter 4, where we will cover the DCCOD in detail, that it is also the preferred choice for other pulse-based command control systems, such as Railcommand, PMP-112, CTC-80 and CTC-16e.

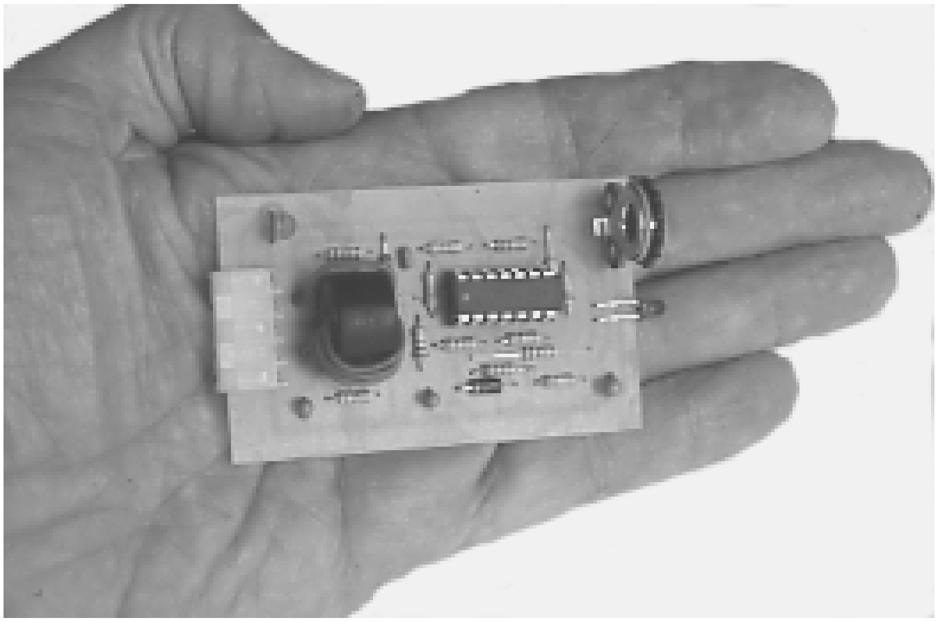

Fig. 2-4. DCCOD provides optimized block occupancy detection for DCC equipped railroads – Rev E

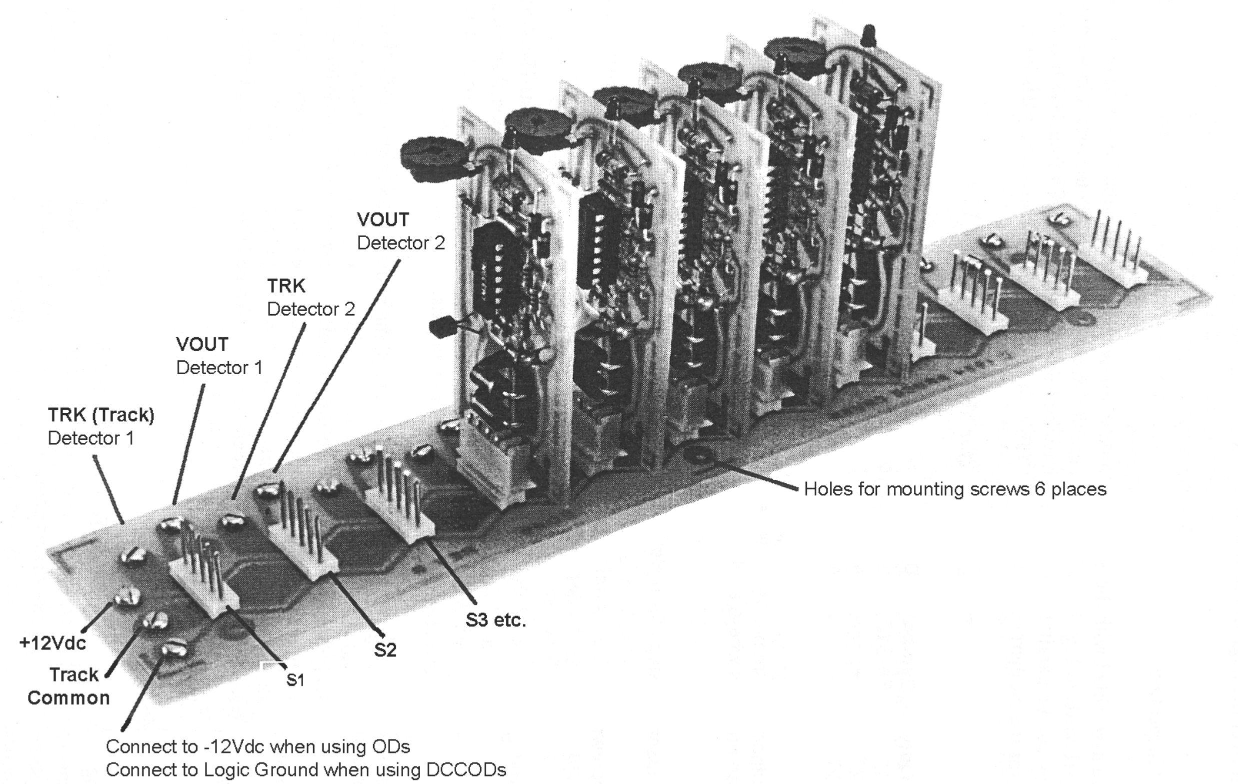

Fig. 2-5. Both OD and DCCOD plug into same ODMB for easy wiring (ODs illustrated here)

The OD, designed specifically for DC layouts, is also usable with DCC layouts. However, in doing so, the layout wiring can become more complex, i.e. unless you have optoisolated boosters. We will cover this topic in detail when we focus on the OD in Chapter 3.

The OD and the DCCOD incorporate many advantages over all other detectors on the market. These include such features as very high sensitivity, built-in potentiometer sensitivity adjustment, and separately built-in turn-on and turn-off delays to minimizing dirty track problems. A built-in monitor LED activates without delays to provide instant occupancy indication, for easier setting of sensitivity.

Both the OD and the DCCOD detectors are modular units for easy plug/un-plug system debug and their open collector outputs drive almost any load. Both easily fit any budget and are available as bare boards only, complete kits or fully assembled and tested. Alternatively, artwork has been provided via Model Railroader for those who wish to etch and drill their own boards.

Additional features provided by the DCCOD include transformer isolation to keep all track wiring totally separate from all signal logic wiring, it works with all brands of DCC equipment, independently of whether the DCC boosters are optoisolated, and it handles track currents up to 20A. Using it is a snap to provide detection in any type of reverse loop and it is fully compatible with all brands of electronic circuit breakers such as Tony's Power Shield™ and NCE EB1™ and EB3™.

Because the ODMB motherboard works with both detectors, its application is covered in this chapter. Alternatively, if you prefer, you can forget the ODMB altogether and wire each detector directly into the block it detects.

Non-JLC Brands of Detectors and Compatibility with the C/MRI

Facsimile adaptations of the ODs, with several being almost direct copies, are produced by several manufacturers while other manufacturers produce their own designs. Fortunately, most known detectors will work directly with the C/MRI.

Detector brands that interface directly to the C/MRI, to the best of my knowledge, include the Ataras Engineering BD8 and BD16, Circuitron BD-2, Integrated Signal Systems DTA, NCE BD-20, Parkdale Hobby Products D-1000 and TracTronics DetectTrain.

In rare instances an adapter circuit may be required for interfacing a particular brand of detector to the C/MRI. Such examples include the Digitrax BD1, BD4, BDL162 and BDL168, all designed to interface into Digitrax's proprietary LocoNet™. The best way to interface these detectors to the C/MRI, or to any other 5Vdc TTL compatible system, is to make use of the detector's "external LED connection." In Chapter 5, I will show how to make this connection, using an appropriate adapter circuit.

Most manufacturers can tell you if their products readily interface with the C/MRI. For example, if the detector outputs are defined as being TTL logic compatible you most likely can use them with the C/MRI. Alternatively, if the detector's output is an open collector transistor, as are most of the above listed detectors, excluding those from Digitrax, it may be connected directly to an input pin on one of the C/MRI input cards.

Most detectors provide a logic low output when the block is occupied, Digitrax being an exception. However, it does not matter if "occupied" is represented by a logical high. The C/MRI software can be configured to handle either logic case.

The majority of current sensing detectors on the market today incorporate a pair of parallel connected opposing diodes in series with the track feeder. When track current passes through either diode it creates a voltage drop that is sensed by the remaining detector circuitry to show that the block is occupied. Diodes are used rather than a resistor because the corresponding reduction in track voltage is never greater than one diode drop, about 0.7V, even at high track currents. With the OD, a potentiometer is placed in parallel with the diodes, followed by a high-gain voltage-comparator IC, the LM339, to give the OD high detector sensitivity that is user adjustable.

It is very important that the detector diodes are rated at more current than your track power pack, or cab supply, can provide. When a derailment, or something else causes a short circuit, all the track current passes through the detector's front-end diodes. If this current exceeds their rating, the diodes will overheat and be destroyed. Also, when applied to DCC, fast recovery type diodes should be used so as not to distort the approximate 8kHz waveform passing through the diodes.

This brings me to the topic of detector repairability. Detectors that use surface mounted components are difficult to repair and in my mind should be avoided. Detectors that use double-sided circuit boards are also more difficult to repair because with plated through holes each part lead is imbedded in solder all the way through each hole. Single sided boards that have wide thick traces for handling track current with a heavy-duty connector are important construction features to seek out when choosing between different detectors.

If you already have another brand detector, or a detector that you are not sure about, and the manufacturer can not seem to answer your questions, give me a call or better yet post a message to the C/MRI User's Group. It is likely someone in the User's Group is making use of the detector in question and can help you with interfacing to the C/MRI. If you already have a detection system installed on your railroad, you can almost certainly use it with the C/MRI.

RESISTANCE WHEELSETS

Current sensing detectors can do a great job detecting engines and lighted cars but to have them effective for all other pieces of rolling stock you need to add resistance to at least one wheelset in every non-lighted car. In the original C/MRI series in Model Railroader**,** I illustrated how I drilled holes in metal wheels to add a standard 11kΩ, 1/8W resistor to my HO-scale wheelsets. However, much easier methods are now available.

Using Commercial Resistance Wheelsets

At least three manufacturers provide replacement wheelsets with built-in resistance:

- Jay-Bee, P.O. Box 7031, Villa Park IL 60181
- Logic Rail Technologies, 21175 Tomball Parkway, Houston TX 77070.
- W.S. Ataras Engineering, PO Box 25, West Terre Haute, IN 47885-0025

Jay-Bee manufactures the wheelsets by incorporating a 1/8W wire-lead resistor that is compression mounted along a special split axle. Altaras and Logic Rail use a surface mount resistor chip mounted across the insulation gap. The wheelsets are available in HO- and N-scale in various wheel sizes and resistance values.

Replacing one resistor wheelset per car is sufficient, but many modelers use two resistor wheelsets in each caboose and I know of at least one who installs four per caboose. Incorporating these extra wheelsets builds in a bit of extra reliability for protecting the rear of your trains. Other modelers use two resistor wheelsets in every car – typically mounting one at each car end for maximized protection. Jay-Bee provides standard values of 1K, 5K, 10K, 20K and 39K ohms with about 70 percent of the sales going with the 20kΩ value.

However, 20kΩ is too high to activate many brands of detectors but more than adequate for the OD and the DCCOD. Jay-Bee also provides any other resistance value desired as a special order. Logic Rail Technologies wheelsets are all 15kΩ, which can be too high to provide reliable single wheelset protection with many brands of detector but work fine with the OD and DCCOD. The wheelsets from Ataras Engineering use 5.1kΩ which should work fine with all but the very lowest sensitivity detectors.

Determining Correct Resistance Value

Whether you use commercial wheelsets or you make your own, the main question is, “How can one go about determining which value resistance to use?” Most detector manufacturers, if asked, will tell you their detector’s sensitivity. This is defined as the maximum resistance value detected or more frequently as the threshold current detected.

Comparing the data with Table 2-1, which shows the relationship between wheelset resistance and the resulting current and power dissipated within the resistor, for both DC railroads at 12V and for DCC railroads at typically 14.2V, it is quite straightforward to determine the resistor requirement for each brand of detector.

Table 2-1. Wheelset resistance, current and power dissipation for DC and DCC applications

	DC Railroad at 12V		DCC railroad at 14.2V	
Resistance Value (Ω)	Current (mA)	Power Dissipated (W)	Current (mA)	Power Dissipated (W)
1K	12.0	.144	14.2	.202
2K	6.0	.072	7.1	.101
5K	2.4	.029	2.84	.040
7K	1.7	.021	2.03	.029
10K	1.2	.014	1.42	.020
15K	. 8	.010	.95	.013
20K	.6	.007	.71	.010

Note: The resistance listed above, in the case of DC railroads, must be the sum of the bias resistor and the wheelset resistance. Thus, for quality detection the wheelset resistance must be selected to be that obtained from the above table minus the bias resistor (used so that blocks where power is turned off are still detectable). See Chapters 3 and 26 for details.

As an example, let us look at the sensitivity data provided with the NCE BD-20 detector that uses the identical pulse-type current-sense transformer as used with the DCCOD. For the BD-20, NCE recommends that you run the track feed wire from the booster through the transformers core hole on its way to the track as illustrated in Fig. 2-6.

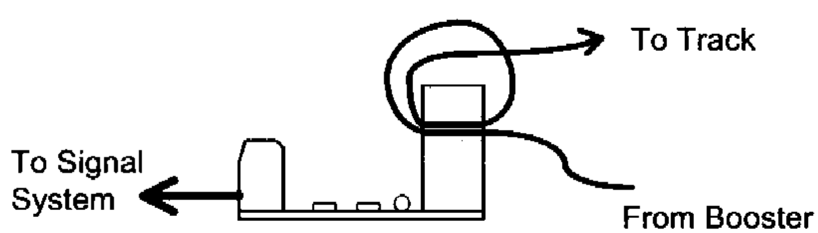

Fig. 2-6. Wiring a NCE BD-20 detector to the track (drawing provided courtesy NCE Corp.)

The sensitivity of the BD20 is controlled by the number of passes the track feed wire makes though the transformer. In addition, the instructions caution that you are limited in the number of turns permitted, without damage to the detector, as a function of the rated booster current. I have summarized this information for you in Table 2-2 where the shaded areas are Non-Permitted Operation (NPO).

Table 2-2. Quoted NCE BD-20 detector current sensitivity

Number of Passes Through Transformer	Quoted Current Sensitivity (mA)	Maximum Resistance (Ω)	Rated Booster Current 4 Amp	5 Amp	10 Amp
1	8	1.78K	OK	OK	OK
2	4	3.55K	OK	OK	OK
3	2.5	5.68K	OK	OK	NPO
4	1.9	7.47K	OK	OK	NPO
5	1.5	9.47K	OK	NPO	NPO

For example, using a 5A booster with the BD-20, you are limited to a maximum of 4 passes through the transformer, which results in 1.9mA sensitivity. Using the relationship established in Table 2-1, this compares to a maximum allowable wheelset resistance of about 7.5kΩ. A 4.7kΩ is suggested by NCE to provide a 1.6 to 1 margin. My experience shows that reliable detection requires using a resistor value much less than the theoretically calculated value. Thus, in the BD-20 case you might want to go with a 3.6kΩ, providing slightly over a 2 to 1 margin.

In general, even higher margins are desirable. For example, the diode-type DetectTrain™ detector, designed by Rich Weyand of TracTronics is rated at a sensitivity level of 30kΩ. However Rich recommends using a wheelset resistance of 10kΩ to provide a 3 to 1 margin. By contrast the DCCOD displays a typical sensitivity up to around 80kΩ and with it, I use 20kΩ resistance wheelsets for a 4 to 1 margin. The higher the margin achieved the greater your detection reliability. For this reason, I am seriously considering adding a second 20kΩ resistor set per car that would increase my detection margin with the DCCOD up to 8 to 1!

However, independent of whatever brand of detector you may be using, do not fall into the trap of using too small a resistance value as this can result in resistor overheating which leads to resistor failure as well as possible car and truck damage. For example, using 14.2Vdc track power with DCC and a 1kΩ resistor gives you a power dissipation of V^2/R or $14.2^2/1000$ or .202W. This exceeds the rating of the 1/8W size resistor used in the Jay-Bee wheelsets and .1W surface mount resistors used in most other wheelsets. If used, this would likely result in resistor failure and possible damage to any plastic parts located near the resistor.

In summary, keeping your wheelset resistors at 10kΩ, or higher, is best, provided that this value of resistance will reliably trigger your brand of detector. Alternatively, where required to satisfy a given brand of detector with lower sensitivity, such as the BD-20, and many other brands of detectors, go to lower values of resistance such as 4.7kΩ, 3.6kΩ or 2.2kΩ. However, never go so low that you exceed the power rating of the resistor. Where your needs approach the power rating of the resistor you are better off keeping the resistance value higher and using two, or more, resistance wheelsets per car.

Another factor to consider when selecting resistance wheelsets is the extra load they place on the DCC booster, or in the case of DC, the throttle’s power source. Table 2-3 shows the total current drawn as a function of the wheelset’s resistance value and the total number of wheelsets on a DCC equipped layout.

Table 2-3. Current requirement as a function of resistance value and number of wheelsets

	Number of Wheelsets and Current Drain in Amps				
Wheelset Resistance (Ω)	**1**	**100**	**500**	**1000**	**2000**
1K	.0142	1.4	7.1	14.2	28.4
2K	.0071	.71	3.6	7.1	14.2
5K	.0028	.28	1.4	2.8	5.7
10K	.0014	.14	.71	1.4	2.8
15K	.0009	.09	.47	.9	1.9
20K	.0007	.07	.36	.7	1.4

It is easy to see from Table 2-3 that the total current drain becomes substantial when selecting low resistance values and a large number of wheelsets. For example, let us say you have selected a 2kΩ resistance and you have 500 cars with 2 resistance wheelsets installed per car. Entering Table 2-3 in the column for the 1000 wheelsets, the total current drain caused by the 2kΩ wheelsets is over 7A. At 1kΩ the current would be 14.2A. Staying at 10kΩ, or higher, the total current drain is not really of much concern even for the largest of layouts.

Making Your Own Resistance Wheelsets

It is difficult to beat the simplicity of slipping in commercial wheelsets with built-in resistance, but if you would like to make up your own resistance wheelsets, it is really very easy. Also, because adding resistors to wheelsets that one already owns offers good savings, this is a procedure that many users follow.

What I find extremely interesting, is that each user seems to develop his own unique approach to selecting the type of resistor and its mounting method. For example, some users make use of “regular” 1/8W resistors with wire leads while others use different sizes of the more modern surface-mount resistors. Some attached the resistor using regular epoxy and then use “conductive paint” to connect the ends of the resistor to each wheel. Others make use of “conductive epoxy” while others simply use conductive paint to hold the resistor in place. One significant difference between approaches depends upon whether your axle is metal or plastic.

There is no way I can cover all the different techniques in this handbook, partly because of space restrictions. I am sure there are many techniques that are used of which I am not aware. Fig. 2-7, however, does provide examples of 5 popular methods.

Fig. 2-7a illustrates using a 1/8W wire lead resistor with a metal axle. By placing the resistor near the end with the insulator you avoid the possibility of the second lead touching the axle which would cause a short against the insulated wheel. Conductive epoxy, an epoxy with a dominant silver content as listed in Table 2-4, is used to secure the ends of the wire leads to the inside wheel faces making sure everything stays well clear of the flange area. A drop of regular epoxy, or CA, can be used to secure the resistor to the axle if required although once the conductive epoxy sets, everything is well secured.

Fig. 2-7b illustrates about the same situation except that with a plastic axle the resistor can be mounted anywhere along the axle. Typically near the center point is the most convenient.

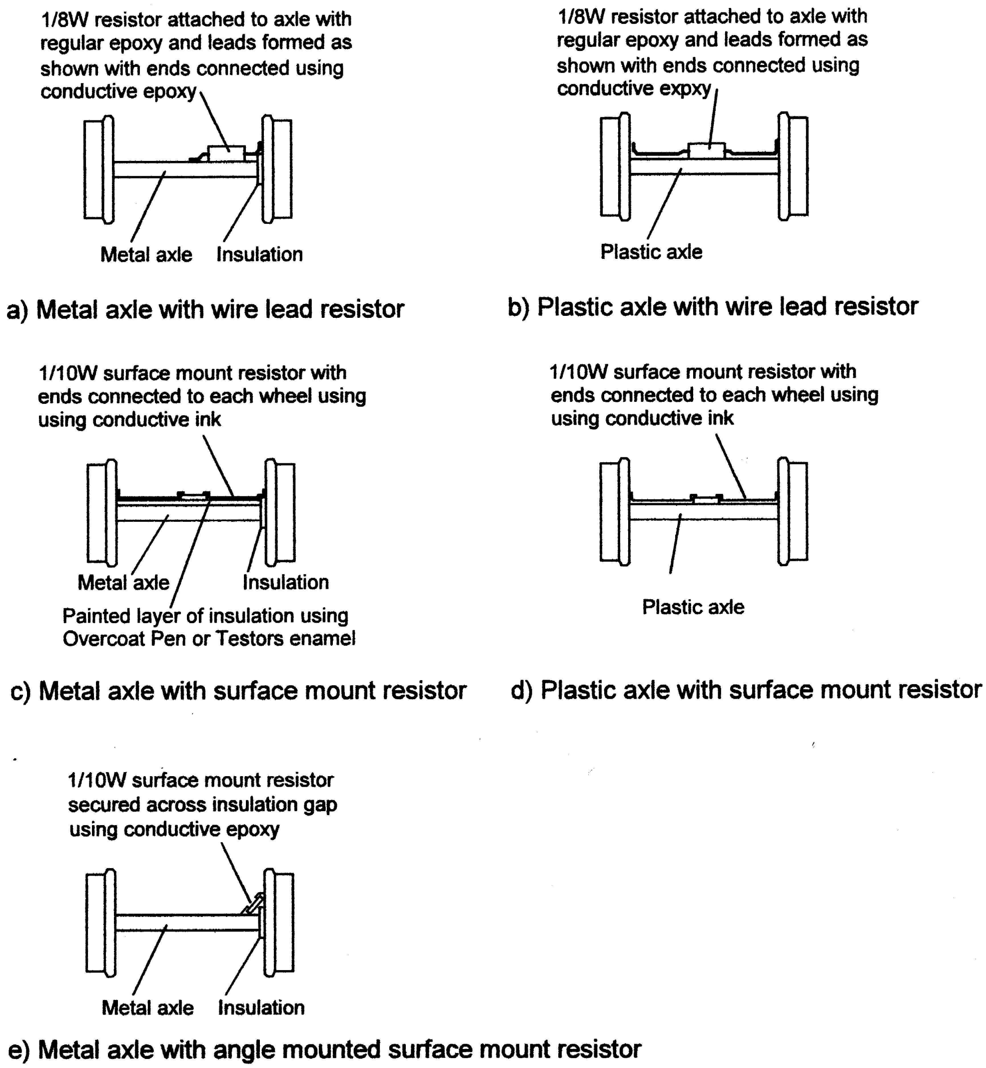

Fig. 2-7. Different approaches to making your own resistance wheelsets

Fig. 2-7c illustrates using a 1/10W surface mount resistor with a metal axle. An insulating stripe is painted along the axle using an “Overcoat Pen”, see Table 2-4, or a thick coat of Testors enamel found at most hobby shops. The enamel costs less but can take 2 days or so to dry. Use a small drop of CA to secure the resistor taking special care to keep the glue off the very small metal ends of the resistor. Once the CA is cured, use the Conductive Ink Pen or Wire Glue to connect each of the two resistor ends to its corresponding wheel. Alternatively, if you are really good and with a little practice you can simply lay the first track of the conductive paint and use the paint to stick on one end of the resistor. Then once this dries, lay the second track of conductive paint.

Fig. 2-7d illustrates about the same situation except with the plastic axle you eliminate the step concerned with laying the insulation strip along the axle. Fig. 2-7e illustrates a method in which you can eliminate laying down the insulation strip even with the metal axle by mounting the surface mount resistor on an angle to transition across the insulated ring. This approach can be a bit tricky and how successful it is depends upon your dexterity and the manner it which the insulation is installed in the wheelset.

No matter which technique you use, once your wheelsets are cured, be sure to use your VOM to check the resistance between the two wheels to make sure it matches the value of resistor that you are using. A reading close to zero means that you goofed and somehow created a short circuit between the two ends of the resistor. Sometimes you can use a No. 11 Xacto blade to cut away the offending short but the best approach if this happen is to break away the resistor and start over.

A very high, or open circuit reading, means that you failed to complete one, or both, circuits between the resistor and its corresponding wheel. Close visual inspection, typically using a bright light and a magnifying glass, will reveal the culprit or you can track down and correct the problem using your VOM.

The materials required can be purchased from Mouser with the part numbers and approximate cost data, as of October 2014, listed in Table 2-4.

Table 2-4. Items usable for creating your resistance wheelsets

Mouser Part No.	Item Description	Approx. Cost
5168-2400	Silver Epoxy Kit – 2-part quick cure - .25 ounces	$111.66
5168-2200ST	Conductive Pen – standard tip – dries 2-3 minutes	$45.33
5168-3300G	Overcoat Pen – green – optional	$21.03
260-Value-RC	1/10W surface mount resistors – case size 805	$1.50 per 100
299-Value-RC	1/8W 5% carbon film wire lead resistors	$2.80 per 200

Note: For the resistor part numbers insert the actual value of resistance desired in place of "Value" such as 2.2K, 4.7K, 10K, 20K, etc.

The resistors themselves are very inexpensive, but the items for their application are not cheap. However, you use very little application material per wheelset so one purchase will likely do your whole railroad and probably those of your friends as well. The biggest challenge is the Conductive Pen, which because everything is premixed within the pen, it has a rated shelf life of 12 months. Many modelers use Conductive Glue, available e.g. at www.allelectronics.com and frequently called Wire Glue by other suppliers. Because it is a graphite-filled product it is much less expensive than the silver-based products listed in Table 2-4. I find the secret to its application is to keep it well stirred and wait until it is thoroughly dry, e.g. overnight, before checking the resistance of each wheelset. Once checked OK, I find it desirable to apply an overcoat of CA to help insure a long-lasting reliable connection.

Because all the above noted processes appear to be quite tedious, many modelers shy away from doing their own resistance wheelsets. However, once you get the hang of it the process can move along quite speedily. For example, C/MRI User Bruce Carpenter, the owner of the BNSF layout featured numerous times in the modeling press and in Allen Keller's **Great Model Railroads** Video collection, reports that he can easily complete 200 wheelsets while watching a football game on TV.

As another example where a large number of resistance wheel sets are being assembled, John Morrison, the General Manager of the Golden State Model Railroad Museum, www.gsmrm.org and a C/MRI user reports that, *"We glue a surface mount resistor (size 1206 - the largest they make) to the axle with a drop of CA. We butt the resistor against the nylon insulated bushing so that one contact is against the wheel. Then, we apply "Wire Glue" with a toothpick to one end (connecting to the axle) and the other end (connecting to the wheel). You can use cheap black paint (e.g. Testors) to cover the assembly, if desired. Once the assembly is dry, we test each wheelset for the correct resistance."*

John reports that they find that Wire Glue works better than anything else they tried. Additionally, it is cheap! Available at Electronic Goldmine (www.goldmine-elec.com), part number G16133; and when they bought theirs it was "on sale" for $2.75. It must work great, because John says that they are already on their second reel of 5000 resistors.

As a last example, Lee Nicholas, a prominent C/MRI supporter and contributor to the C/MRI User's Group, is quite famous for his technique of directly soldering resistors to Intermountain Wheelsets. He has done over a thousand for his Utah Colorado Western and has been known to do them for a nominal fee for others. Lee can be reached via his popular railroad website www.ucw.com.

IMPORTANCE OF HIGH DETECTOR SENSITIVITY & BUILT-IN ADJUSTMENT

Probably the best way to demonstrate the importance of high sensitivity detection is to take a typical piece of rolling stock equipped with a resistance wheelset and lightly push it along a piece of flextrack, separate from your layout, while you measure the resistance between the two rails using your VOM. Typically, as you roll the car, your meter reading will be very erratic, covering the range from the value of the wheelset resistance all the way up to near infinity, an open circuit. Fundamentally, you are measuring a point contact between wheel and rail and even with relatively clean track and wheels you encounter minute particles of dust, etc. resulting in the measured resistance frequently varying to levels much higher than the wheelset's resistance. The smaller the scale and the lighter the car, the more erratic are the readings.

Perform the above test with average, or worse, rail and wheel cleanliness conditions, and you might wonder how quality detection of a single car is ever achieved. This is where the detection time delays and the very high sensitivity built into the DCCOD and OD become so very important.

****Important Points****

1. If you seek quality detection of a single car, as might well be all that is occupying a short OS section in CTC territory, then absolutely you need high sensitivity detectors.

2. If you are going to operate with maximized sensitivity, then you need detectors with an easy to perform sensitivity adjustment. This is the only way that you can tweak the detector for each particular track section for best detection, while avoiding false detection.

MEASURING DETECTOR SENSITIVITY

A handy, but not very precise test to evaluate a detector's sensitivity is to place a finger across the track. If that causes the block to show up as occupied then the detector has the potential to be a good detector. A more quantitative test is to use the potentiometer and resistor clip lead assembly illustrated in Fig. 2-8.

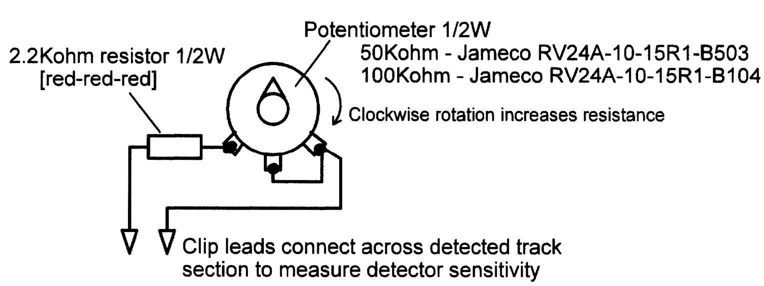

Fig. 2-8. Clip lead assembly for measuring detector sensitivity

To perform sensitivity testing, use the clip lead assembly in Fig. 2-8 and with your track power turned on (set to 12Vdc if using conventional DC), execute the following steps:

1. On the detector to be tested, turn its sensitivity adjustment (assuming that it has one) all the way up as far as it will go until a clear block indicates as occupied. Then back off the sensitivity adjustment just a little until the block indicates as clear.

2. With the test potentiometer resistance set to its maximum, clip the assembly across the track and the block should still show up as clear. If not then you will need to use higher resistance values in your test circuit.

3. With the block showing clear, rotate the test potentiometer counterclockwise, to reduce its resistance, to the point where the detector shows the block to be occupied.

4. Remove the clip leads and connect them to your volt-ohm meter (VOM) to measure the combined resistance of the test resistor and potentiometer. This reading is the sensitivity of your detector.

The separate resistor is required in series with the potentiometer to prevent burning out the potentiometer if it is rotated too close to its minimum resistance setting.

Typically, you will be able to set detectors at OS sections to higher values than longer blocks because OS sections have less leakage resistance and capacitance coupling between the rails. Fortunately, it is the short OS sections where you need the highest sensitivity.

******Key Points******

- By using detectors with an easy to use built-in sensitivity adjustment, you can quickly adjust each detector's sensitivity to its maximum value, taking into account the unique characteristics of each track section.

- In this way, shorter detected track sections, such as OS sections, will typically be able to be set to greater sensitivity which is exactly what is needed for reliable operation.

- By contrast, longer blocks, with higher inherent leakage resistance and capacitance coupling between the rails, will tend to be set to a lower sensitivity.

- The net result is that with each and every detector adjusted to its maximum sensitivity setting, you achieve the best possible occupancy detection for your entire railroad.

Fortunately, with the DCCOD and OD, you will seldom if ever experience lack of detection problems. However, even with the OD, when used with conventional DC powered trains, there are a few special situations where it is possible to obtain false indications and I will cover these in detail in Chapter 3. I will also show you additional steps you can take to minimize loss of detection problems.

TESTING DETECTOR OPERATION

The above test is an effective way to accurately measure detector sensitivity. However by itself, if you are using the OD or the DCCOD, it does not guarantee that your detector is totally functional. This is because the primary purpose of the LED built into the detector is to aide in setting each detector to its maximum possible sensitivity without indicating that a block is occupied if it is in fact clear. To make this adjustment easy and quick to accomplish, it is necessary to position this LED, electrically speaking, ahead of the detector's built-in turn-on and turn-off delay circuitry. For example, if the LED was placed after the built-in delays, then you would need to wait up to 3.5s each time you rotated the potentiometer a small fraction, to see if the LED came on or off. This would make setting detector sensitivity a very long and impractical process.

Because of the electrical location of the LED, if it functions properly you can be assured only that the front portion of the detector is working properly, i.e. the portion before the circuit delays. Therefore, to totally check that the overall detector is operating correctly, it is important to check its output. This is easily accomplished by using the clip lead assembly shown in Fig. 2-9.

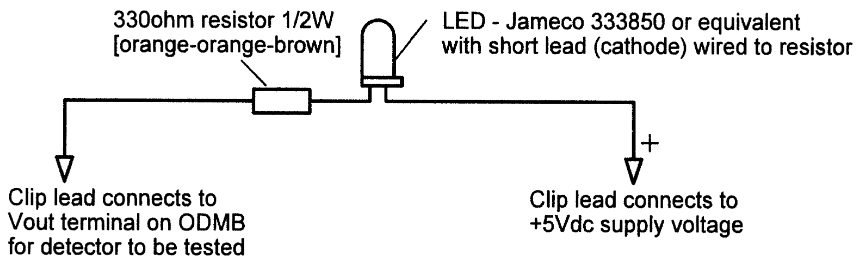

Fig. 2-9. Clip lead assembly for testing detector operation

To perform operational testing, use the clip lead assembly in Fig. 2-9 and with your track power turned on (and set to 12Vdc if using conventional DC), execute the following steps:

1. Attach the positive end of the clip lead assembly to the +5Vdc power and attached the remaining clip lead to the output terminal screw, Vout, corresponding to the detector to be tested.**[1]**

2. Assuming the detector is still adjusted to its maximum sensitivity setting, then occupying the block should light the clip lead's test LED, as well as the LED on the detector.

3. Conversely, when the block is clear, neither LED should be illuminated.

---

[1] Alternatively, for situations where you do not have your +5Vdc supply handy, you can change the resistor value in Fig. 2-9 to the 1KΩ value [brown-black-red] and attach the positive clip lead to the +12Vdc terminal on the ODMB rather than to +5Vdc. However, to avoid possible damage to any C/MRI inputs when using 12Vdc, it is important to make sure that the Vout terminal on the ODMB is not also connected to a C/MRI input pin. Anytime you apply more than +5Vdc to a C/MRI input you will very likely damage the input buffer IC which will need to be replaced. Also, if using the 5Vdc, its supply ground needs to be connected to the 12Vdc ground, which is the case when using a surplus computer power supply.

Successfully passing the last two steps indicates that your detector is functioning properly. While performing the above test, it is also very easy to verify that the two delays, as built into the OD and DCCOD, are functioning correctly.

For example, when you make a block occupied, you should see the LED on the detector light immediately and then about .75s later the output LED should light. Similarly, when you make the block clear, you should see the LED on the detector go dark immediately and then about 3.5s later the output LED should go dark.

ADVANTAGES OF USING A PLUG-IN MODULAR DETECTOR PER BLOCK

Some brands of detectors include multiple detectors on a single circuit board. Such an approach can be tempting at first with potential cost savings. However, the added card complexity, e.g. double sided versus single sided board construction, can easily cancel out any potential savings. Also the added complexity of multiple detectors per card introduces a significant loss in modularity and the ability for easy fault isolation and replacement, and complicates repair problems. Other detectors are sold to be hard-wired right into the railroad while others use edge tab connections to which you will need to add the cost of the edge card connector. Also the latter are not set up to handle the high amperage track currents associated with our railroads.

In my mind you cannot beat having a separate plug-in detector per signal block that uses a truly heavy duty Molex-style connector, like the DCCOD and the OD. Trying to locate a short circuit along the track, or within the track wiring itself, is greatly simplified by using separate plug-in replaceable detectors per block. This is especially true when each plug-in module contains a built-in indicator LED to show when blocks are drawing current, i.e. occupied.

For example, if you experience a track short and a detector LED is lit with a block unoccupied, you have almost instantly located the block with the short. If you experience a short during an important open house or operating session, simply pull each of the detectors that have their LED lit within the offending area. Doing so one at a time, quickly defines which block, or OS section has the short circuit. This approach works even with DCC and its fast acting circuit breakers because the detector's LED will repeatedly flash for an instant each time the circuit breaker tries to reset.

This separate plug-in replaceable feature is especially handy for Command Control layouts that otherwise tend to be wired together in one large block. Also, if you ever happen to have a detector failure, or you suspect a problem, it is a snap to unplug a detector and plug in a spare. Having only a few parts per card and having the single IC in a socket makes repair easy to accomplish.

In my opinion, the modular features achieved by plugging detectors into the ODMB are a very great advantage. Because both the OD and DCCOD can make use of the same motherboard, we will cover this next in this chapter.

OPTIMIZED DETECTOR MOTHERBOARD (ODMB)

Because applications require one DCCOD or OD per detected track section or block, it is convenient, as with the general-purpose I/O cards, to have an OD motherboard (ODMB) into which the detectors are plugged.

Each ODMB accommodates 12 detectors; if more motherboards are needed they can be parallel connected with each of the three bus traces wired from one board to the next. If you need less than 12 detectors at a particular location, you can cut the ODMB into smaller pieces for easy decentralization around your layout. Ready-to-assemble cards are available from JLC Enterprises and assembled and tested cards, as well as complete kits, are available from SLIQ Electronics. The photo in Fig. 2-5 shows the parts layout for the ODMB and Table 2-5 contains the parts list.

Table 2-5 Detector Motherboard Parts List
(in order of recommended assembly)

Qty.	Symbol	Description
27	—	4-40 x ¼ Pan-head machine screws (Digi-Key H142)
27	—	4-40 Hex nuts (Digi-Key H216) (soldered to underside of board)
12	S1-S12	5-pin Waldom straight-headers (Mouser 538-26-60-2050 or use breakaway section of Mouser 538-26-48-1241 per text)

Author's recommendation for supplier given in parentheses above with part numbers where applicable. Equivalent parts may be substituted.

Regarding the header connectors, you can save considerable cost if you elect to use the Mouser 538-26-48-1241. These come with 24 pins and are designed so that you can easily snap them into smaller sections as desired, in the ODMB case a grouping of 5 pins each. By doing so you will need only 2.5 of the Mouser 538-26-48-1241 (2.5 x 24 = 60 pins) for each mother board you assemble.

The ODMB assembly steps are as follows:

□ **Terminal screws.** Insert 4-40 screws in the connection holes from the top (or component side of the board) for the 12 track connections, 12 detector outputs, +12Vdc, COMMON and the -12Vdc used for OD applications (which is the logic ground connection for DCC applications). Add 4-40 hex nuts on the trace side, tighten firmly, and solder the nuts to the circuit pads. Use spade lugs later on when you attach wiring to these screws and you will have yourself a nice heavy duty connection.

□ **S1-S12.** Hold each header firmly against the board and solder the two end pins first. Then examine each header to make sure it is flat against the board with the pins perpendicular to the board surface. If not then reheat the end pin joints until the header is firmly against the board. Once you have determined that each header is installed correctly, then solder the other three pins.

□ **Adjacent trace test.** Using a VOM set on R x 100, check the resistance between the COMMON terminal and the +12V and -12V (or logic ground for DCC applications) terminals. It should be infinite, an open circuit. Then clip one lead to the +12V terminal and touch the other lead to each of the track terminal screws for each card slot. Each should also read open circuit. Then, for each card slot, touch one lead to the track terminal and the other lead to the output terminal. Again, the test should read open circuit. Any reading close to 0Ω indicates a solder bridge between adjacent pads somewhere along the two bus lines under test. Locate it, remove it, and retest to be sure.

□ **Cleanup and inspection.**

For mounting, use six ¼"-long standoffs. The ODs need a ±12Vdc power supply while the DCCODs need only +12Vdc. Actually, any voltage between 5 and 15 will be satisfactory, but the nearer the high end the better. For OD applications, the positive and negative values must be of the same magnitude.

Each detector draws about 10mA (not counting external current on the open-collector output connection), so a 1.5A supply handles up to 150 detectors.

DISTRIBUTED OR CENTRAL MOUNTING DETECTORS

Because most wiring connections between ODs, or between DCCODs, are common, I group multiple cards together using a motherboard, the ODMB. Each ODMB mounts up to 12 detectors. The ODMBs can be distributed around your layout anyway you desire, with two or more boards piggybacked together for locations where you need more than 12 detectors. The ODMB cards also can be cut into separate pieces for wider distribution.

If you prefer, you can also forget the ODMB and connect the ODs, or DCCODs, directly to your layout wiring. There are at least four different ways this can be accomplished:

1. Substitute a 5-pin Waldom right angle header in place of the normally installed Waldom side entry connector (S2) and then attach a 5-pin Waldom terminal housing connector to your layout wiring. This way you retain the flexibility of being able to plug and unplug your detectors without the expense of the motherboard.

2. When assembling your detectors, solder a screw clamp-type terminal strip with the correct .156” spacing between pins in place of the recommended S2 connector. For example, Mouser part numbers 651-1727049 or 158-P02EK381V5, both with 3.81mm spacing (equivalent to .150” spacing), will do the job. With this approach you have screw terminals mounted right on each of your detectors.

3. Solder the layout wire directly to the pads provided on the OD and DCCOD instead of installing the Waldom side entry connector (S2). This is best accomplished by inserting the wire from the component side of the board and soldering on the trace side of the board. Once soldered, trim the excess length of the wire so it can not bend over and short against any nearby traces. Optionally, for the DCCOD you can simply loop the track wire through the transformer coil rather that making their respective solder connections.

4. For the case where you already have the Waldom side entry connector on the detector card you may elect to solder the layout wiring directly to the mating header connector that would have been used in the ODMB.

Methods 1 and 2 are the most popular approaches for those not wishing to use the ODMB.

CONNECTING DEVICES TO DETECTOR OUTPUTS

Because connecting devices, such as LEDs, lamps, C/MRI inputs and relays, to detector outputs is identical whether using the OD or the DCCOD, I will cover making the connections in this chapter rather than repeating it in the next two chapters. Fundamentally, the output line from the OD and the DCCOD, namely V_{out}, is provided via an open collector transistor. Therefore, you are free to attach any load to the detector provided that it does not exceed the rating of the transistor, namely 40V at .3A.

Fig. 2-10 shows examples of different devices attached to the detector’s output.

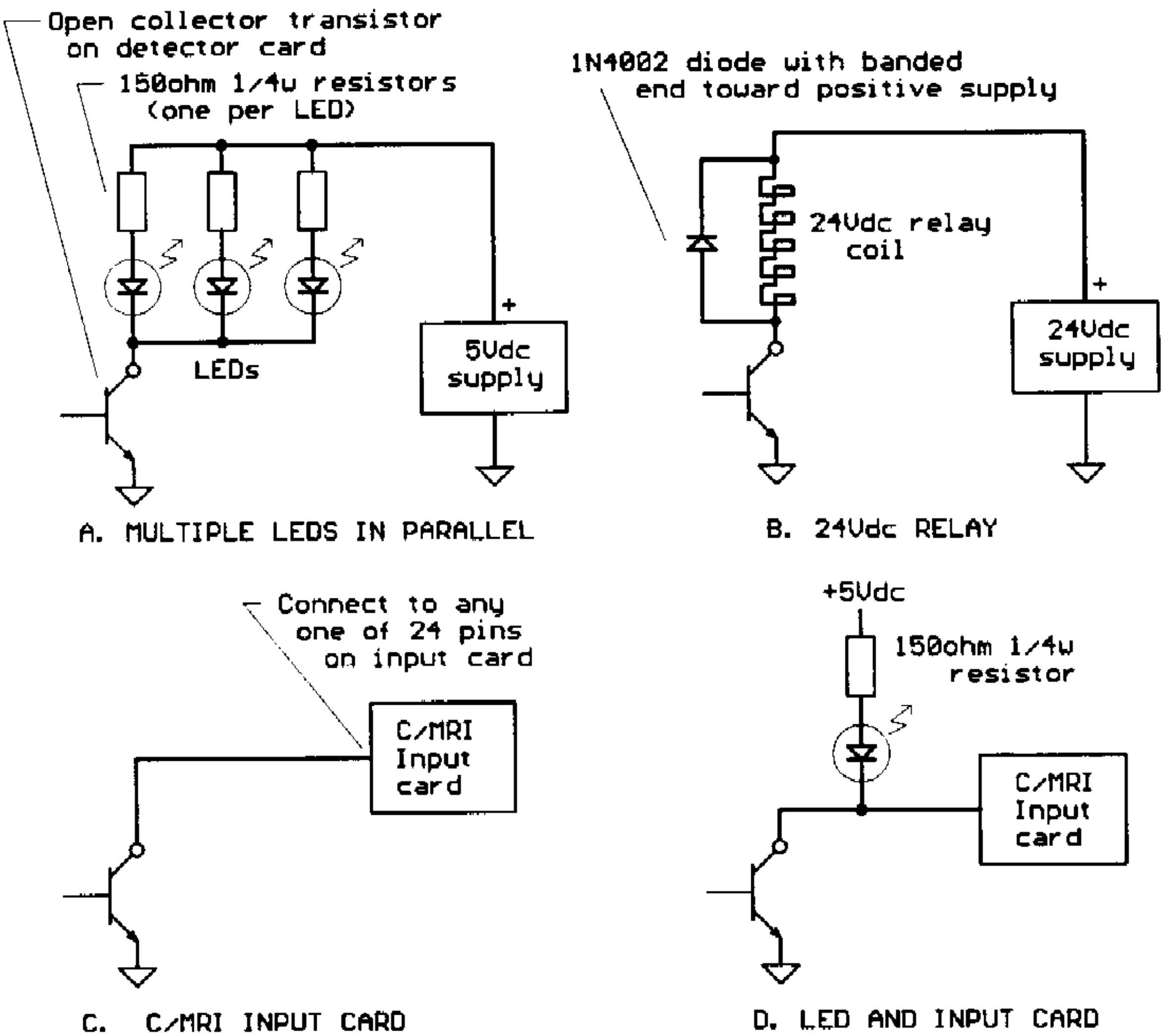

Fig. 2-10. Typical connections made to detector outputs

Summarizing the situation, connecting devices to a detector output, either with the DCCOD or the OD, is identical to connecting devices to any other C/MRI output pin located on SMINI, DOUT32, DOUT and COUT24 cards. Therefore, if you are interested in more detail on this subject, consult Chapter 9, where we will look deeper into driving all types of different devices with C/MRI outputs, including the outputs from detectors.

DETECTION SUMMARY: WHEN TO USE WHICH DETECTOR

Table 2-6 provides a list summarizing the characteristics of the OD compared to the DCCOD.

Table 2-6. Comparison characteristics between OD and DCCOD

Characteristic	OD	DCCOD
Layout applicability	Works on any layout, including all regular DC and all Command Control applications. Also works with AC applications such as Lionel and Marklin. With DCC applications wiring is a little more difficult than when using DCCODs and especially so if the DCC boosters are not optoisolated.	Works only on DCC-equipped railroads and railroads using other pulse-based CC systems such as CTC16, CTC16e, CTC80 and Railcommand. Wiring DCCODs into DCC-equipped layouts is easy and offers the best approach for layout owners using DCC without a prior investment in ODs.
Board size and modularity	1.87" x 3" with easy plug-in of one board per signal block. Test and repairability is easily accomplished with only 1 IC and 1 transistor per detector. Modularity makes locating and troubleshooting layout wiring problems and track shorts easier to correct.	1.75" x 2.85" with easy plug-in of one board per signal block. Test and repairability is easily accomplished with only one IC and one transistor per detector. Modularity makes locating and troubleshooting layout wiring problems and track shorts easier to correct.
Sensitivity	Potentiometer adjustable up to about 1MΩ with 16Vdc across the track as most Command Control systems such as CTC-16, 16e and Railcommand™. Sensitivity somewhat less with regular DC applications.	Potentiometer adjustable up to about 150kΩ with six primary turns on the current-sensing pulse-transformer and 14V DCC power on track.
Maximum track current	3A using standard diodes and higher, e.g. 10A or more, if substitute different diodes.	Up to 20A using recommended current-sensing pulse-type transformer.
Maximum output drive capability	.25A at 40Vdc using open collector transistor.	.25A at 40Vdc using open collector transistor.
Built-in time delays	Approximately .75s turn-on and 3.5s turn-off. Values can be altered by substituting different resistors.	Approximately .75s turn-on and 3.5s turn-off. Values can be altered by substituting different resistors.
Built-in monitor LED	Included before time delays for easier setting of the sensitivity level.	Included before time delays for easier setting of the sensitivity level.
Power supply voltage requirements	Detector supply must have 3 output wires: +12Vdc, -12Vdc and ground. The + and - voltages must be of the same magnitude and be regulated. Supply voltages may be increased to ±15Vdc, as on the original SV, but ±12Vdc is more commonly used.	Detector supply uses only +12Vdc and ground connections. The voltage must be regulated and +15Vdc may be substituted if desired.
Can be used with ODMB	Yes, but optional as detectors can be distributed around layout without using the ODMB. If using the ODMB the bottom connection on the ODMB is to the -12Vdc supply.	Yes, but optional as detectors can be distributed around layout without using the ODMB. If using the ODMB the bottom connection on the ODMB is to logic ground and not to -12Vdc as with ODs.
Interchangeable with each other	No. The power supply connections are different between the OD and the DCCOD. Once a given ODMB is configured for either ODs or DCCODs all detectors on that ODMB must be the same.	No. The power supply connections are different between the OD and the DCCOD. Once a given ODMB is configured for either ODs or DCCODs all detectors on that ODMB must be the same.
Wiring and ground connections	Detector logic ground is the same as track ground. Requires series diodes added to all undetected blocks to equalize voltage drop.	All track wiring is totally separate from detector and signal logic wiring. The detection circuit ground, and hence the logic ground for the complete C/MRI system is isolated from track ground.
Approximate cost of circuit board plus user obtained parts and assembly	$10.36. Cost drops to $7.91 assuming an average 24% quantity discount on board and parts.	$11.47. Cost drops to $9.26 assuming an average 20% quantity discount on board and parts.

Typically, choosing the right detector is an easy decision. In most cases it resolves to the following:

1. If you are using straight DC for train control, then choose the OD.

2. If you are using DCC, CTC16, CTC16e, CTC80 or Railcommand and you do not have a prior investment in ODs, then choose the DCCOD.

3. If you are using DCC, CTC16, CTC16e, CTC80 or Railcommand and you already have a significant investment in ODs, you can continue to use ODs. If your DCC boosters are optoisolated, as discussed in Chapter 6, then wiring with ODs is not much more involved than using the newer DCCODs.

4. If you wish to use ODs with non-optoisolated DCC boosters, then you will need to include a separate detector power supply per booster track section and provide an optoisolator at the output of each detector, as covered in the Chapter 5.

If your situation is number 4, then it is desirable to give serious consideration to selling your ODs and replacing them with DCCODs. There is still a good market for ODs and typically, via the C/MRI User's Group or via Ebay, you can sell your ODs for enough to cover most of the cost of building up the DCCODs you need.

In summary, starting from scratch on any DCC-equipped railroad, you are always better off using the DCCOD. If you are not using DCC, Railcommand, CTC80, CTC16e or CTC16 then you are better off using the OD. In the next two chapters we will examine each of these detectors and their application in detail. Feel free to skip the chapter that does not apply to your needs.