Errata

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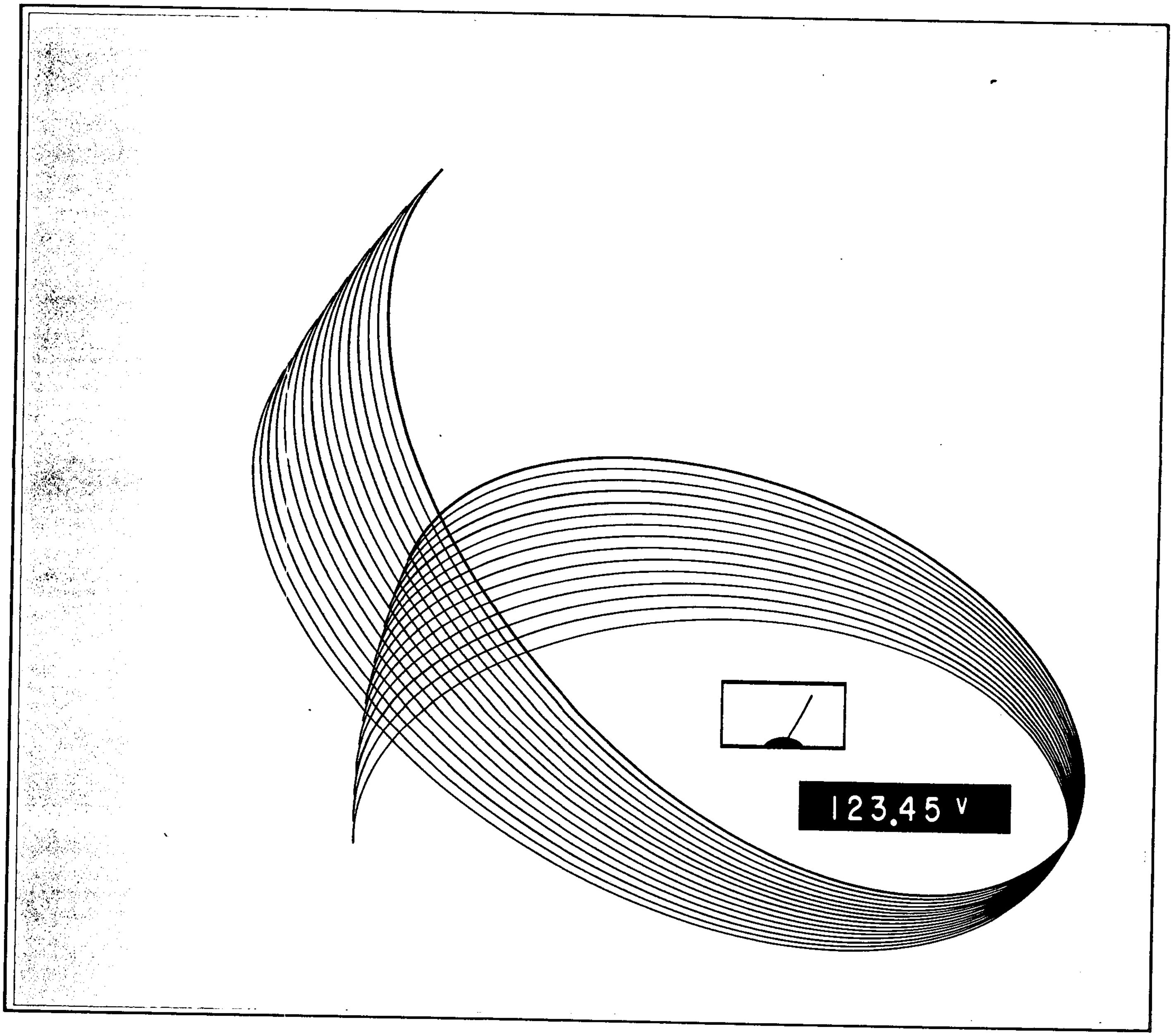
APPLICATION NOTE 123

Floating Measurements and Guarding



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Floating Measurements and Guarding

June 20, 1970

Guarding can effectively solve the common mode problem in floating measurements but has created a new kind of problem. Now there's a new terminal, the guard terminal. What's it for? Where should it be connected? When does an operator have to worry about it? Just what is guarding? . . . . . This Application Note explains what floating measurements are, where common mode voltages come from, how guarding can solve the problem, and most important, how to use the guard connections.

The best place to start is with a brief discussion of floating measurements and what they are. First, look at the simple grounded measurement in Figure 1. E_{in} represents the source being measured together with any noise associated with it and is generally called the "normal mode source". R_a represents both the source resistance of the normal mode source and the lead resistance of the high lead; R_a is called the "high source resistance". R_b is the lead resistance of the ground lead. Current from E_{in}, normal mode current, flows through R_a and Z_1 and the instrument responds to the drop across Z_1. As long as both grounds are alike both sides of R_b will be at the same voltage and no current will flow through it.

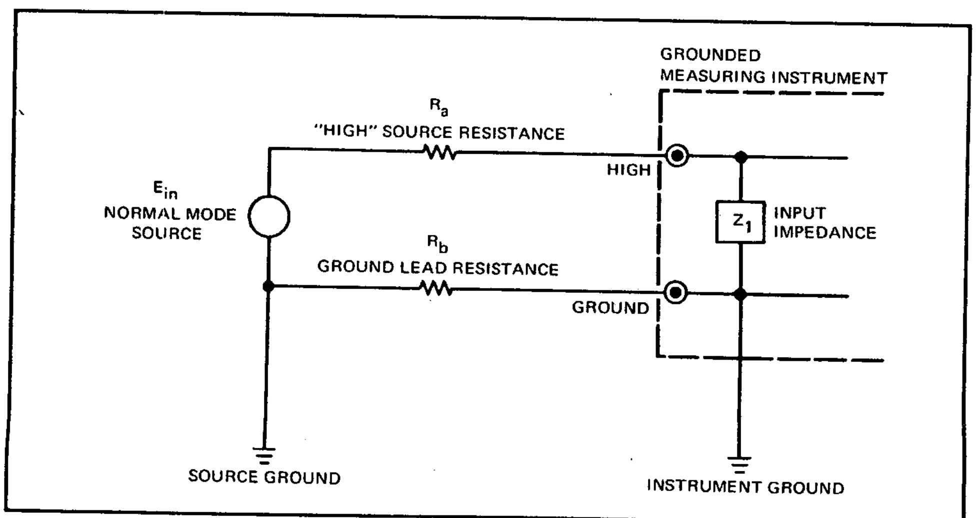

FIGURE 1. Simple Grounded Measurement

Now, suppose that the ground at the measuring instrument and the ground at the source being measured are different, maybe because of voltage drops in the ground lines or currents induced into them. Then the measurement looks like the one in Figure 2. There is a new source, E_{cm}, the difference between grounds; it's called the "common mode source", because it's "common" to both the high and the ground lines. Common mode current can go either through R_b or through R_a and Z_1. Since Z_1 is usually much larger than R_a, and since they are both in parallel with R_b, most of the voltage across R_b will also appear across Z_1. All of the common mode voltage will be dropped across R_b, so the instrument will respond to most of it, causing a change in the reading — an error.

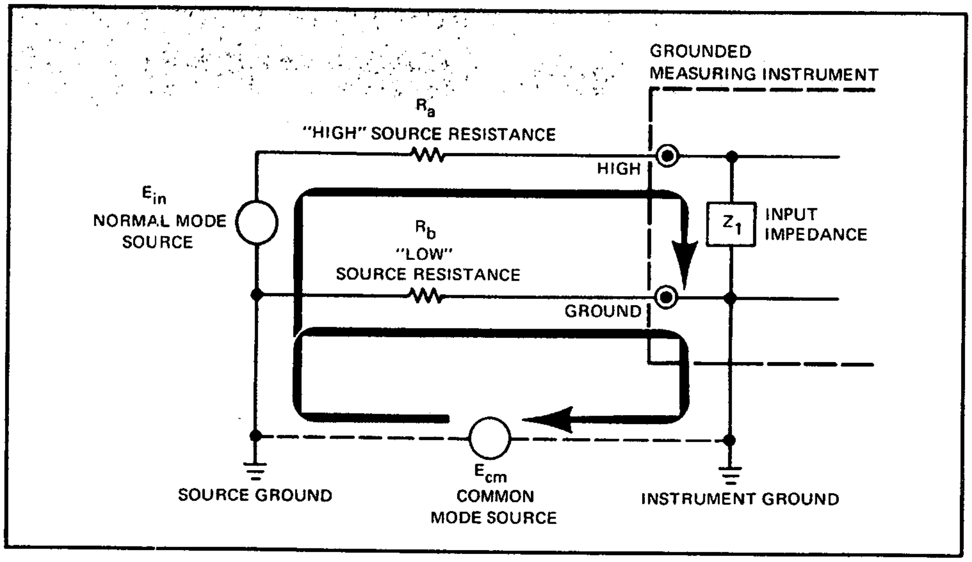

FIGURE 2. Grounded Measurement with a Common Mode Voltage

FLOATING MEASUREMENTS

Measurements with differences between grounds, or common mode voltages, are called floating measurements and are said to "float" by the amount of common mode voltage. An ideal floating measurement would be insensitive to the common mode signals; it would measure only the normal mode input, no matter how much common mode it had.

Figure 3 shows three common floating measurements and shows how the common mode signals develop. The top one is the simplest. There the voltmeter and the circuit being measured have the same ground, but the voltmeter measures a voltage that isn't directly referenced to that ground. It measures the voltage across the top resistor (R_1) and is referenced to the top of the other resistor (R_2). So in this measurement the top of R_2 is the source ground and the voltage across R_2 is the difference between grounds — the common mode voltage. If the voltmeter can reject the effects of the common mode it can measure the 2 V across R_1 accurately, but if it's like the one in Figure 2 it will short out R_2, large currents will flow in the ground circuits, and then all of the 4 V supply voltage will be dropped across R_1. The voltmeter will read twice the value it should.

The middle example in Figure 3 occurs often in systems containing a large number of instruments. Although both the instrument ground and the source ground are on the same line, the ground voltage is different at each point along the line. The differences are due mainly to induced currents and ground currents. The voltmeter is eventually grounded (dotted line) back to the same ground as the rest of the system, so the voltmeter input contains a common mode whenever it's referenced to any point but the one where it's actually grounded. It's especially important that instruments used in measurements like this one be able to reject common mode voltages well, because the common mode sources can easily amount to several hundred volts.

The bridge circuit at the bottom of Figure 3 appears in transducer measurements where high resolution is needed. Both sides of the bridge are above ground, so no matter how the voltmeter is connected there will be a common mode voltage, and the measurement will be floating. If the voltmeter has poor common mode rejection (CMR) capabilities it can upset the bridge and make the measurement virtually impossible. A bridge measurement requires complete isolation from common mode effects.

None of the measurements in Figure 3 can be made with the grounded voltmeter shown in Figure 2. They all require some voltmeter that rejects the effects of common mode voltages in order to be floating. They require a floating voltmeter.

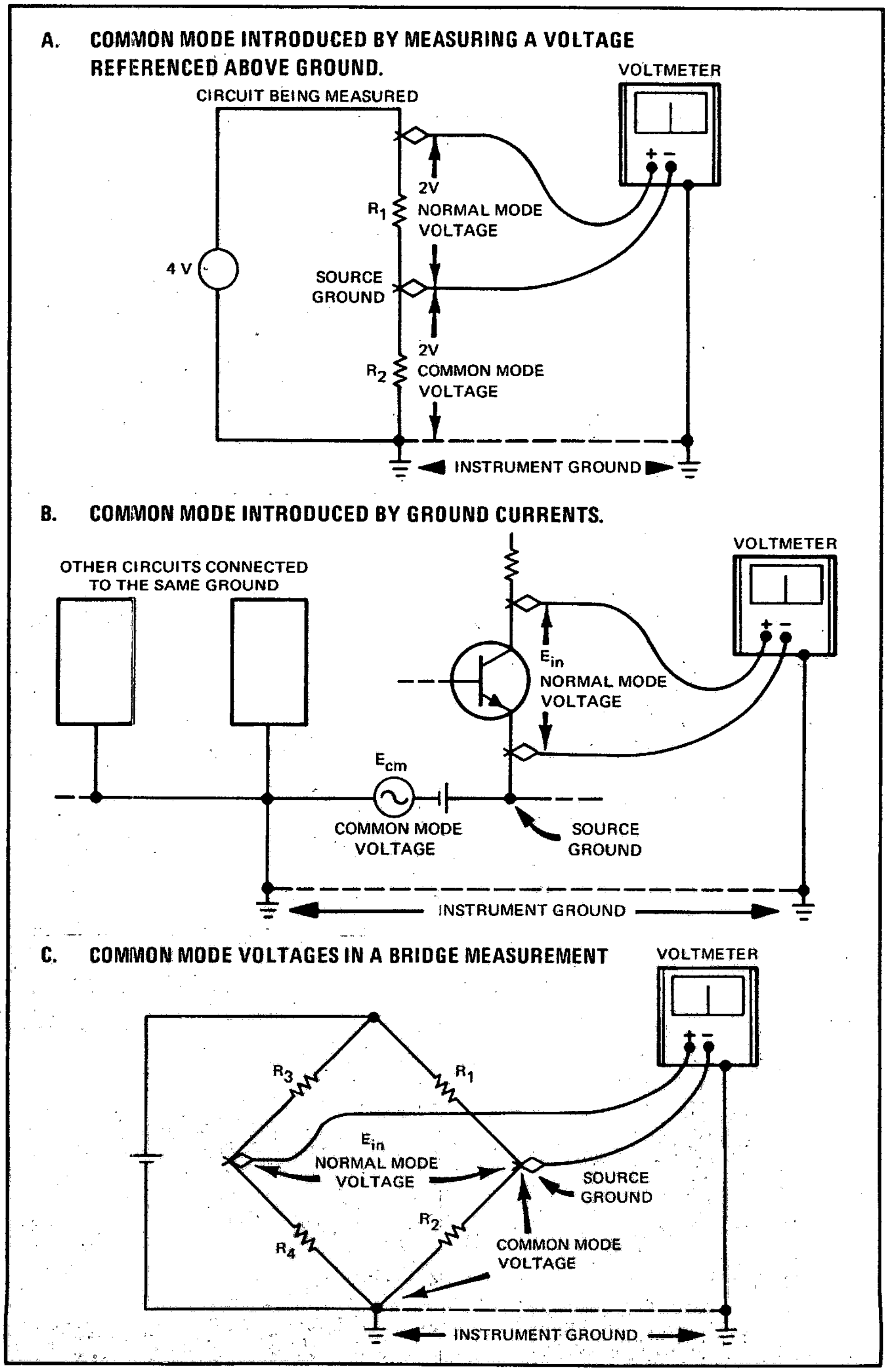

FIGURE 3. Some Examples of Floating Measurements

The Floating Voltmeter

The grounded voltmeter in Figure 2 can be made into a floating voltmeter by adding a shield between the inner circuits and the outer chassis or cabinet. The resulting instrument is shown in Figure 4. It has three input connections, called "high", "low", and "ground". "High" is the same as the high terminal in Figure 2; "low" is the inner chassis; and "ground" is the same as the ground in Figure 2. It also has two important internal impedances, Z_2, the isolation impedance between low and ground, and Z_3, the isolation impedance between high and ground.

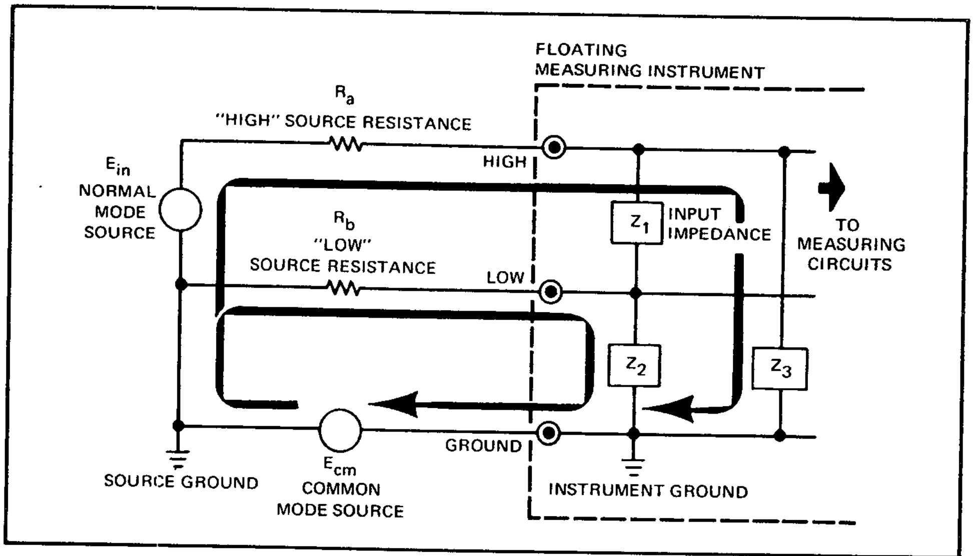

FIGURE 4. Inside an Ideal Floating Voltmeter

If Z_3 and Z_2 were equal and much larger than R_a and R_b, the common mode current would divide between the two loops shown in Figure 4 in about equal amounts. If R_a and R_b were also equal the voltage drop across Z_3, applied at the top of Z_1, would equal the drop across Z_2, applied at the bottom of Z_1. There would be no difference of potential across Z_1, and therefore no normal mode offset due to common mode voltages — no common mode error. Such a floating voltmeter is called a "balanced" floating voltmeter. If R_a and R_b weren't equal the voltages at the top and bottom of Z_1 would no longer be equal, and there would be a net difference of potential across Z_1. The result would be a normal mode offset proportional to the difference between R_a and R_b.

In most floating instruments Z_2 and Z_3 are far from equal. Usually Z_3 is much larger than Z_2, so much larger that its effects on common mode are negligible . . . Z_3 practically amounts to an open circuit; then the instrument looks more like the one in Figure 5.

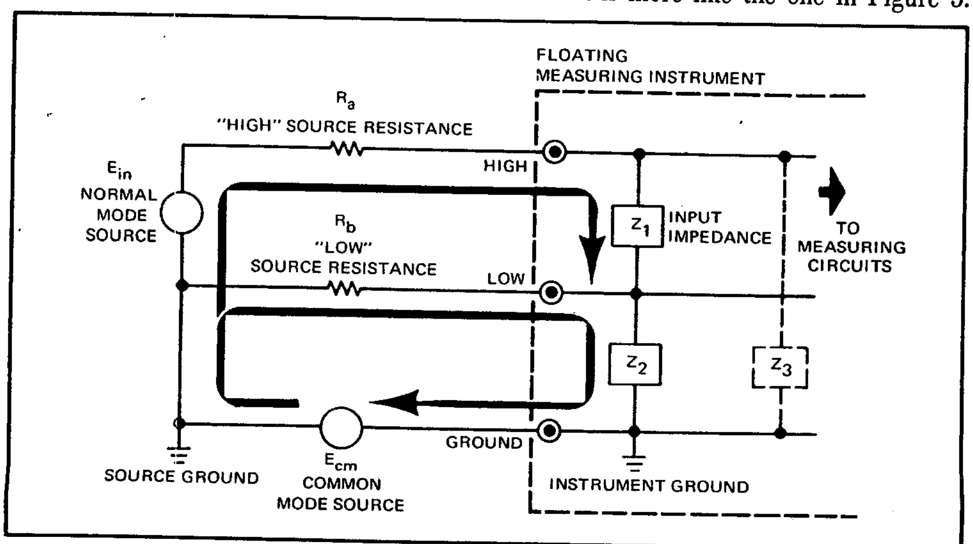

FIGURE 5. A More Realistic View of a Floating Voltmeter

Common mode current flows through the two parallel paths indicated by the heavy lines in Figure 5 and develops a voltage across R_b. The same voltage will be dropped across R_a and Z_1, with the largest part of it dropped across Z_1, and the meter will respond to the drop across Z_1. Most of the common mode voltage dropped across R_b will become a normal mode offset; so the common mode errors depend almost entirely on the relationship between Z_2 and R_b. If R_b is much smaller than Z_2 the errors will be small. R_b is just lead resistance in most measurements and Z_2 is an isolation impedance between two metallic chassis, amounting to 10^8 — $10^{10}\Omega$ shunted by anywhere from a few thousand pF to a few tenths of a μF. At dc, Z_2 is much higher than R_b, but it falls off gradually with frequency, resulting in poorer immunity to common mode signals at higher frequencies. Also, Z_2 is very dependent on environment. High humidity and just a slight amount of dust or other contamination on the chassis can cause Z_2 to drop by a factor of several thousand or more, which will increase common mode effects by a factor of several thousand.

A floating meter like the one in Figure 5 can reduce the effects of common mode voltages by anywhere from 80 dB to 120 dB at dc or from 60 dB to 100 dB at line frequency, if the resistance in the low lead can be kept low and the environment can be kept both clean and dry. Such an instrument has enough common mode immunity for analog measurements or measurements made on a three digit or perhaps four-digit digital voltmeter. For measurements requiring higher resolution or sensitivity it may not be adequate. As an example, consider measuring the output of a circuit like a precise strain gage or thermocouple bridge circuit with a full scale output of less than 100 mV. A bridge circuit inherently has a high value for R_b, as much as several kΩ (more on bridge circuits later), and also has more than one common mode source. Suppose the circuit to be measured has a 25 millivolt full scale output and an R_b value of 1 kΩ, and also suppose that the measuring instrument is a four-digit digital voltmeter with a 100 mV range and common mode rejection (CMR) of 100 dB for an R_b value of 1 kΩ. And finally suppose that you need at least 1% resolution—you have to resolve at least 250 μV, with a common mode voltage of 120 V.

If the common mode voltage is 120 V and the rejection is 100 dB—a factor of 10^5—the resulting normal mode offset is 1.2 mV. The DVM just described won't make the measurement even for full scale outputs; for small outputs like 10th scale outputs, the signal is practically buried in common mode. The floating voltmeter has good CMR, but not quite good enough for this measurement; and this is a fairly common type of measurement. High resolution or high sensitivity measurements require a great deal more CMR than the floating voltmeter can offer. The only kind of instrument with sufficient rejection is the guarded instrument.

The Guarded Voltmeter

A guarded instrument has an additional shield between the low and ground, effectively increasing the low to ground leakage impedance; the extra shield is called the guard and may be connected to the circuit being measured through a "guard" terminal. The extra shield divides the low-to-ground impedance into series impedances, Z_2 and Z_3, (See Figure 6.) increasing the resistance and decreasing the total capacitance. The resulting higher impedance improves the leakage resistance and the CMR somewhat, but the real strength of the guarded instrument comes from what the guard can do when it's properly connected to the circuit being measured.

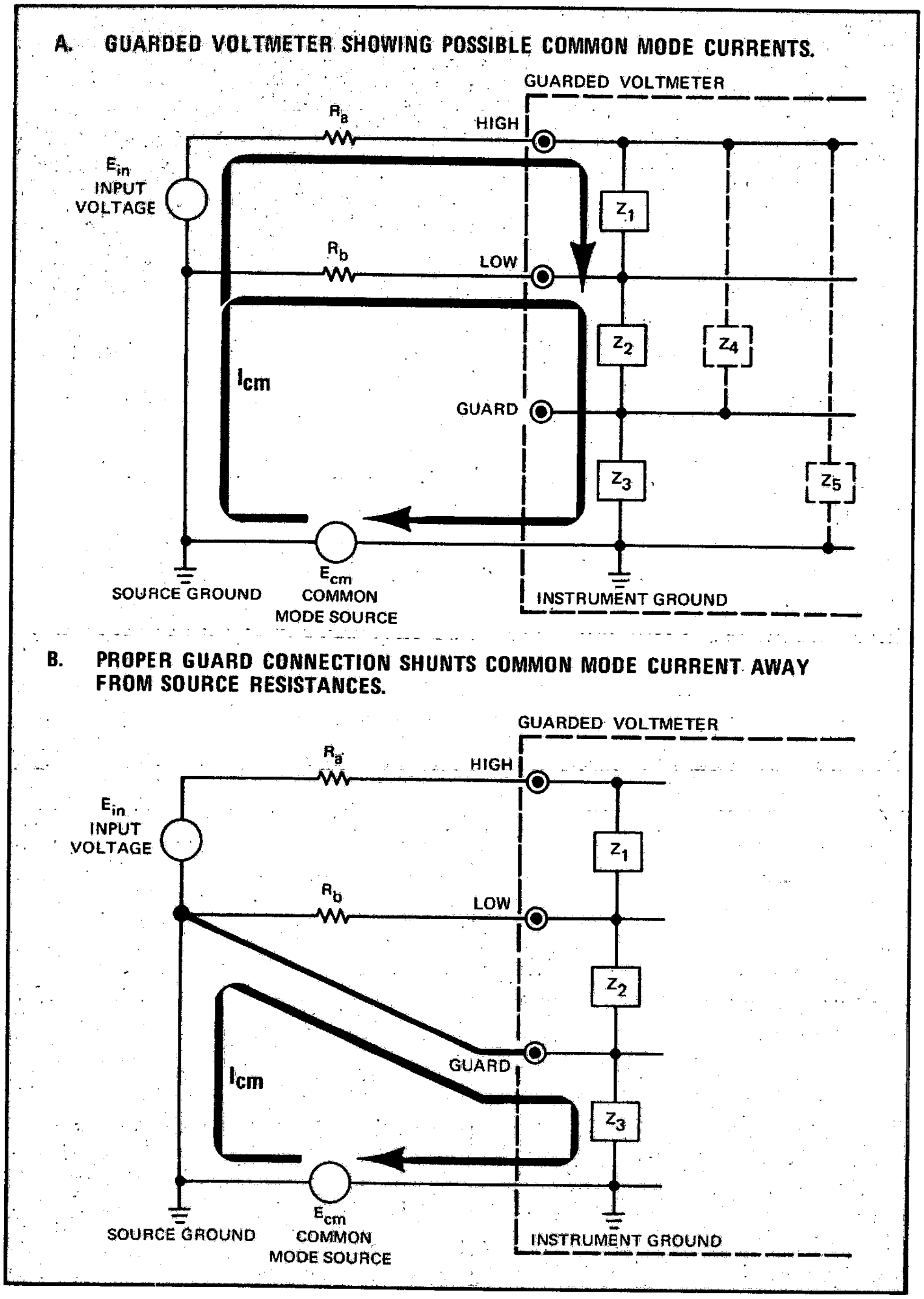

FIGURE 6. Guarded Voltmeter

Figure 6 shows how the guard works. The situation with the guard terminal disconnected (top of figure) is very similar to that of a floating voltmeter except that the low-to-ground isolation impedance is larger. Common mode current from E_{cm} could pass through the two parallel paths shown in the figure, and again the drop across R_b results in a voltage difference across Z_1, the common mode error. As in the case of the unguarded voltmeter, the error is very small if the isolation impedance (Z_2+Z_3) is large and R_b is small. At dc the added guard shield increases the leakage impedance dramatically, especially in a dry environment. But at line frequency the added shield only increases leakage impedance slightly. The result is a marked improvement in CMR at dc and only a slight improvement at higher frequencies.

When the guard is properly connected, as shown in the bottom of Figure 6, it shunts the common mode current around the two current paths shown at the top of the Figure and just about eliminates R_b and R_a from the common mode circuit; virtually no common mode current goes through R_b, so it can't cause much error. Also since low and guard are at nearly the same voltage, the voltages at the top and bottom of Z_2 are nearly equal. And as long as the voltage difference across Z_2 is held very small, very little current can flow through it. The guard connection improves the common mode rejection significantly over a wider range of common mode frequencies, so that rejection doesn't fall off nearly as rapidly. A good guarded voltmeter will reject common mode signals by more than 160 dB at dc and more than 140 dB at line frequency. There are two relatively simple rules to follow to connect the guard like it's connected in Figure 6.

THE GUARD CONNECTION

1. Connect guard so that it and the low terminal are at the same voltage, or as close to the same voltage as possible.
2. Connect guard so that no common mode current, or guard current, flows through any of the low source resistance, or more generally, so that no common mode current flows through any resistance that determines the input voltage.

And that's all there is to it. So it appears that our discussion of guard and how to use it might just end here. We've defined common mode and normal mode and floating measurements and guard and shown how they work and how the guard should be connected . . . That's only the beginning. There are very few measurements, if any at all, where the guard can be connected as we've shown. Usually one or the other of the two rules will be violated, sometimes both of them will. Sometimes you won't know for sure. Now we have to look at the tradeoffs and approximations one makes to minimize common mode effects in a real measurement.

CONNECTING THE GUARD
A Simple Example

The Best Connection

First we'll take a very simple but real measurement where the two rules just about fit and then show what happens when the rules are violated. For example, consider a guarded digital voltmeter measuring the output of a floating electronic power supply (Figure 7). The power supply has high internal gain and good regulation, making R_a and R_b in this measurement almost entirely due to lead resistance. According to the two rules the best way to connect the guard is as shown in the top example in Figure 8; guard is at practically the same potential as low, and no common mode current passes through any of the high or low source impedances.

Some Alternative Connections

Figure 7 also shows the alternative guard connections. In the second example guard is connected to low right at the voltmeter's front panel using the guard-low shorting bar provided on most instruments. This is a good approximation to the first connection and appears to be easier. Low and guard are at almost exactly the same voltage, so Z_2 is kept very high; but all of the common mode current goes through R_b, and any drop across R_b will cause a normal mode offset and an error. In systems measurements where the leads can be extra long R_b becomes more significant and connecting guard to low at the instrument can cause significant errors. Use this connection only when the leads are short and when the leads are the only resistance included in R_b.

The third example shows what happens when guard is connected to ground. If guard is connected to "instrument ground" at the voltmeter (dotted connection) the guard connection shorts out Z_3 and puts guard and ground at the same potential and eliminates the shunt path for common mode current. All the common mode current goes through R_b and the common mode current that goes through R_b is higher than it might be because Z_3 is shorted. But more important . . . . most guarded instruments have lower breakdown voltage ratings between low and guard than they have between low and ground, and most of the common mode is applied between low and guard. Common mode voltages often amount to several hundred volts and the common mode could easily be greater than the low to guard breakdown rating. *So don't connect guard to ground at the instrument . . . . doing so may damage your instrument.*

Connecting guard to ground can be a good connection if the connection is made *at the source* and if most of the common mode exists between the point where the source is grounded and the point where the meter is grounded. Then the guard connection shunts most of the common mode around R_b and low and guard are at nearly the same voltage. But any common mode voltages generated within the source won't be affected by the guard and their currents will go through R_b.

Don't Leave The Guard Open

Just about any connection is better than leaving the guard open. Any connection that diverts any of the common mode current from R_b or brings low and guard closer to the same voltage will improve your CMR. Leaving the guard open may damage your instrument. The breakdown rating between low and guard is lower than the one between low and ground, less than 300 V for most instruments and sometimes as low as 50 V. If the guard is left open the common mode voltage will divide between the low to guard impedance (Z_2) and the guard to ground impedance (Z_3), and since they are about the same size about half the common mode will drop between low and guard. Large common mode voltages could easily drop enough between low and ground to exceed the breakdown rating.

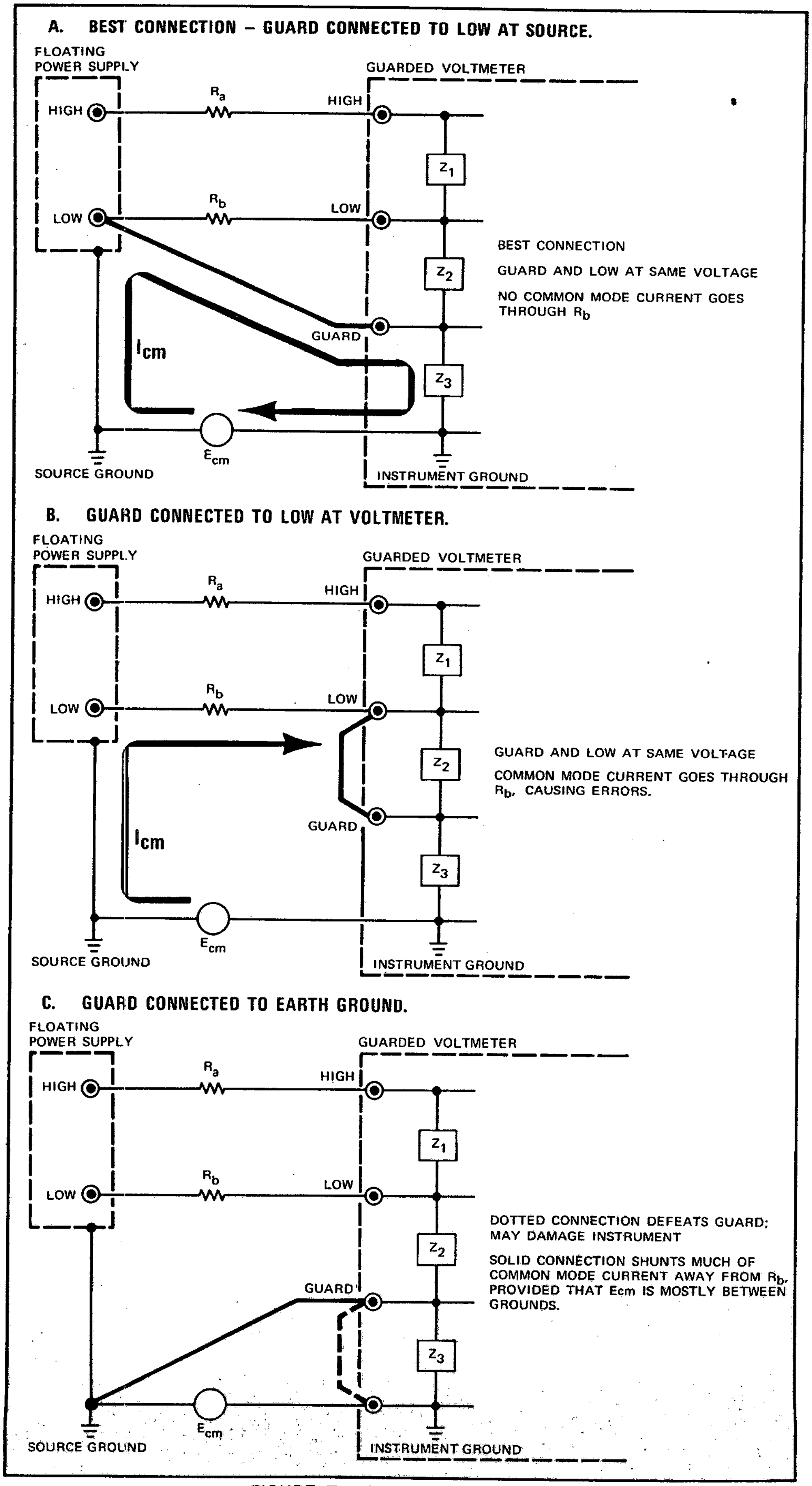

FIGURE 7. Connecting the Guard

THE BRIDGE MEASUREMENT
A More Complicated Example

The bridge measurement shown in Figure 8 is especially important in instrumentation and is a good example because it contains about every kind of common mode complication a measurement can have. It gives high resolution and sensitivity for small voltages and frees the measurement from the need of precise voltage references. But a bridge is also especially susceptible to common mode effects. Both sides of the bridge are operated above ground, so no matter how the voltmeter or detector is connected it's floating. Also, a great many bridge measurements are made with the bridge and the voltmeter separated by large distances, resulting in common mode signals induced from ground currents and ground differences. And some of these ground-related common mode signals can amount to several hundred volts.

. . . . then a bridge measurement should be made with a guarded voltmeter. But where should the guard be connected? The equivalent circuit (also in Figure 8) shows that R_b, the low source resistance, is the parallel combination of R_2 and R_4 and that there are two common mode sources. One is the E_{cm}, the ground-related common mode source, and the other is E_{R_4}, the voltage across R_4. If guard is to be connected according to the rules, it must go to the source side of R_b as shown the equivalent circuit. Then guard and low are at the same potential and no guard current passes through any source resistances.

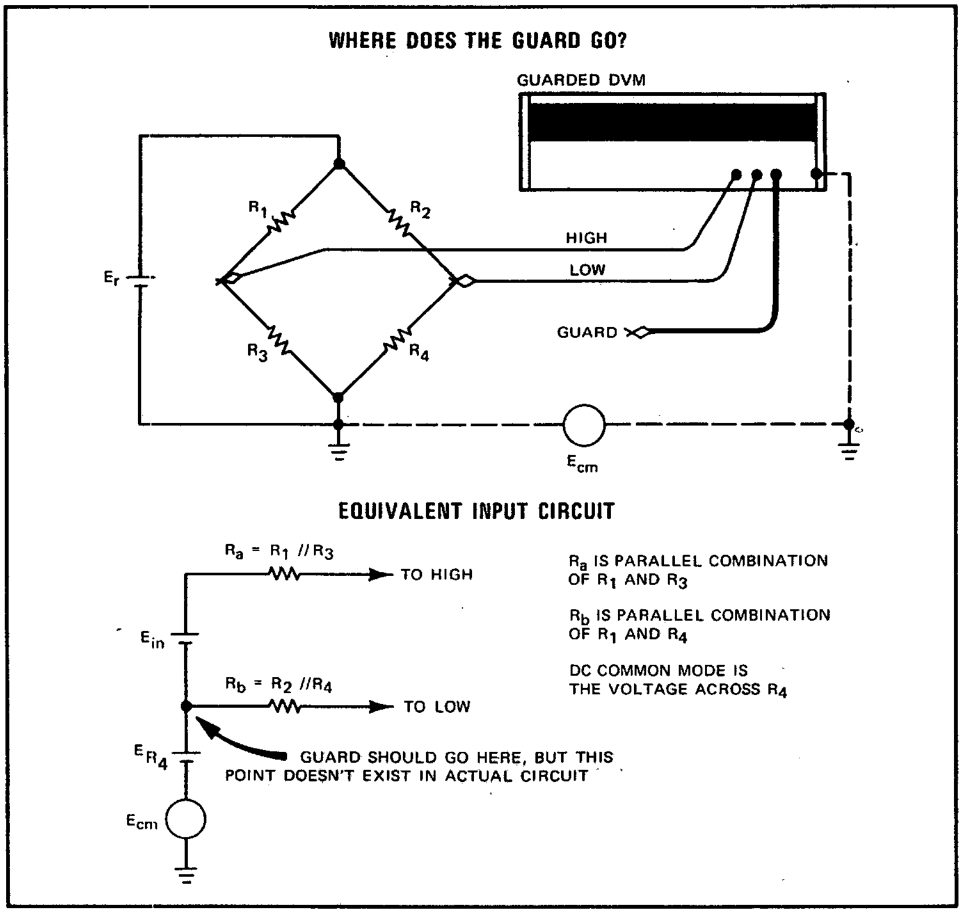

FIGURE 8. The Bridge Measurement

But the point where guard is connected in the equivalent circuit doesn't exist in the actual circuit. Guard must be connected somewhere else. There are three possible choices, shown in Figure 9. First, it can be connected to low, right at the voltmeter front panel, using the shorting bar. This puts low and guard at the same potential, but lets all the common mode current from both sources flow through all the source resistances and through the lead resistances, possibly causing some large offsets.

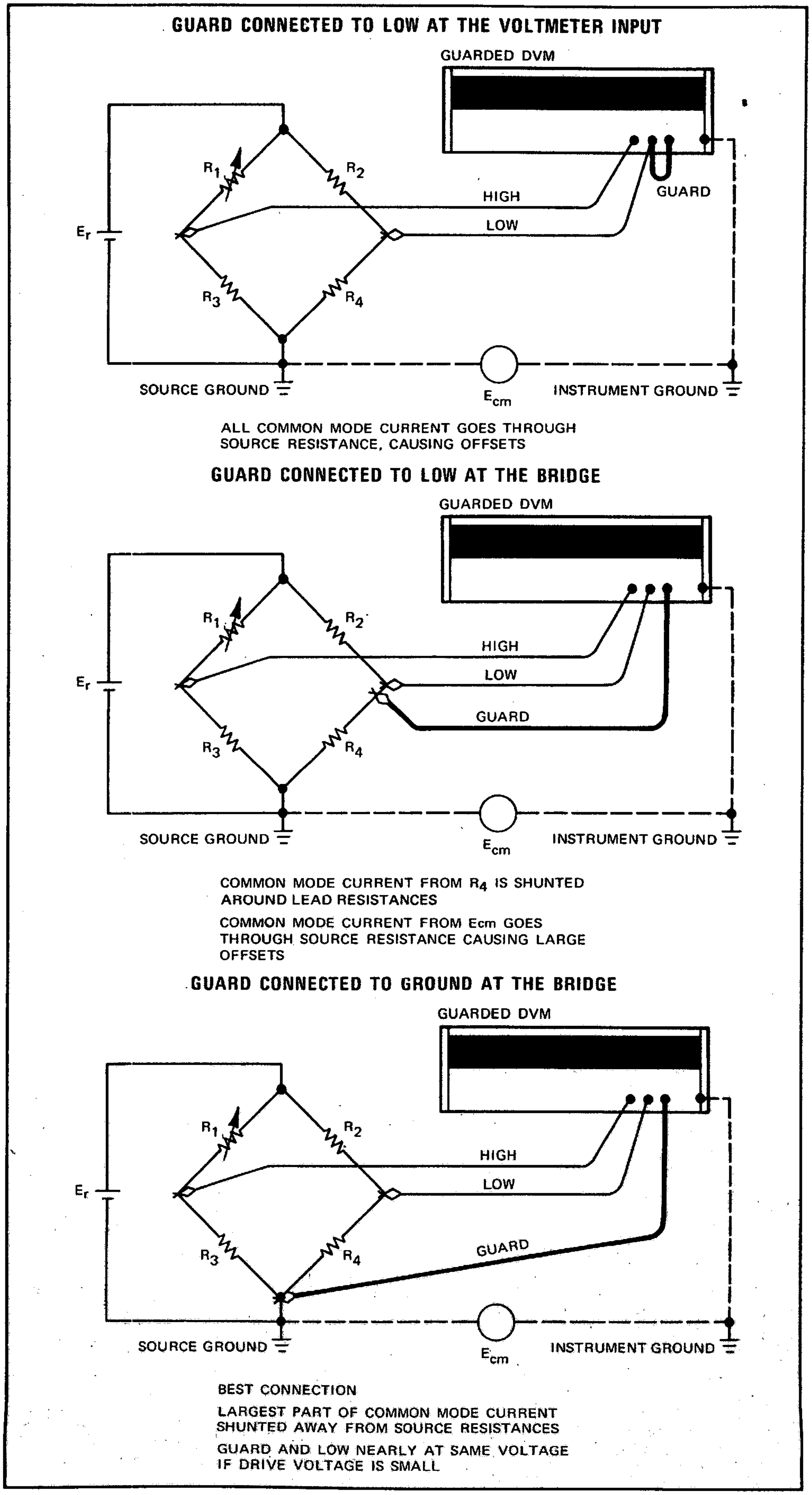

FIGURE 9. Alternative Guard Connections for the Bridge Circuit

The second possible connection is about the same as the first except that guard is connected to low at the bridge instead of at the voltmeter, removing the effects of common mode currents through the lead resistances. In the case where the bridge resistors were all small and the leads were very long this might be an acceptable solution, but common mode currents still flow through part of the source resistance.

The third connection keeps the ground-related part of the common mode current out of the source resistance but puts low and guard at different voltages. If the ground-related common mode source is much larger than the dc common mode source, and it usually is, this connection removes most of the common mode current from the source resistances. And precise instrumentation bridges, particularly strain gage bridges, are usually operated at low voltages, so the voltage across R_4 is small making the difference between low and guard small. For most cases, then, the third connection is the best of the three, particularly when the ground related common mode is high and the dc common mode is small.

There are some cases, though, where the bridge is operated at high voltage and the ground-related common mode voltages are not so large; then the third connection doesn't work as well. There is another approach to the bridge problem that can be particularly effective in situations where none of the other connections work too well. It's called driving the guard and is shown in Figure 10. It uses another circuit, a voltage divider, to provide the proper guard potential. R_5 and R_6 are connected across the same supply as the bridge supply and are mounted close to the bridge so that their ground is the same as the bridge ground. Their values are selected so that the voltage at the top of R_6 is equal to the voltage at the top of R_4 where low is connected, and so that the total resistance through R_5 and R_6 is less than a tenth of the resistance through the bridge. Then guard and low are at the same potential and most (more than 90%) of the common mode current flows through R_6 and the guard, around the source resistances. R_5 and R_6 could be selected so that only a very small percentage of the common mode current goes through R_5 and R_6; the only limitation is the amount of loading the E_r supply can stand.

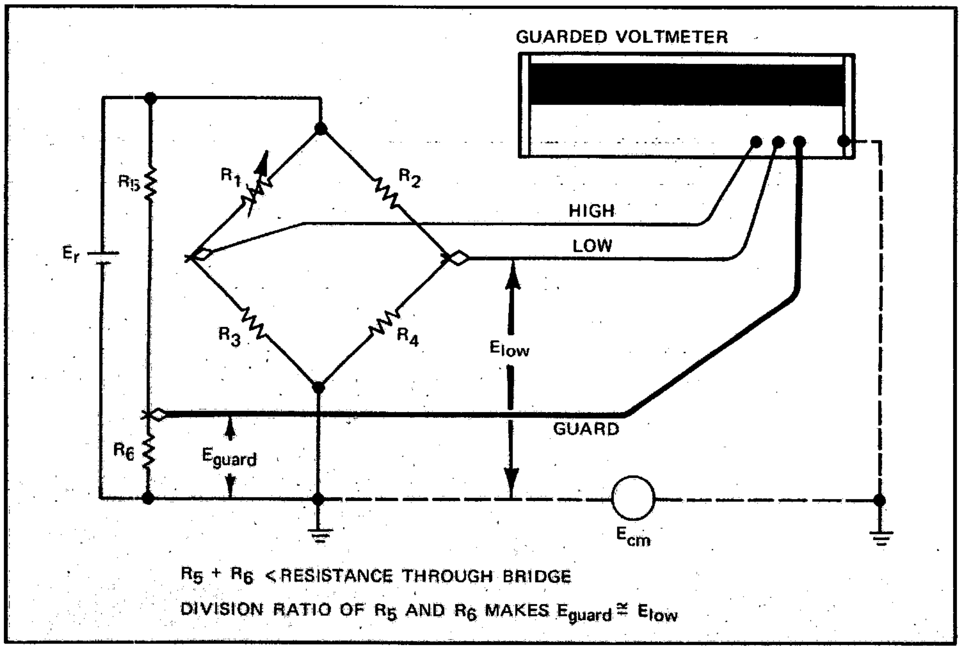

FIGURE 10. Driving the Guard in a Bridge Measurement

A SPECIAL CASE
The Balanced Guarded Voltmeter

Some guarded voltmeters are built so that the impedance from low to guard and the impedance from high to guard are just about equal. Then the guarded voltmeter is similar to the ideal balanced and floating voltmeter back in Figure 3. Its common mode errors are proportional to the difference between R_a and R_b rather than just on R_b. Making R_a and R_b equal will minimize common mode errors. The guard on a balanced guarded instrument is connected in exactly the same manner as the guard on an ordinary guarded voltmeter.

Such instruments are especially useful in systems where long leads are the largest part of the source resistance, because the two leads in a given measurement are often the same length and diameter and made of the same material, making R_a and R_b nearly equal. They are also helpful in bridge measurements because the high and low source resistances of a bridge, although high, are often nearly equal.

INJECTED CURRENTS
Another Complication

Not all common mode problems come from the circuit being measured. Some common mode sources are within the measuring instruments, caused by currents induced into the ground or guard shields by the power transformer windings. Internal common mode sources are generally constant current sources and force "injected currents" into the circuit being measured. They appear in virtually all line-operated floating instruments, between low and ground in the unguarded instruments and between low and guard in the guarded instrument. Figure 11 shows the results.

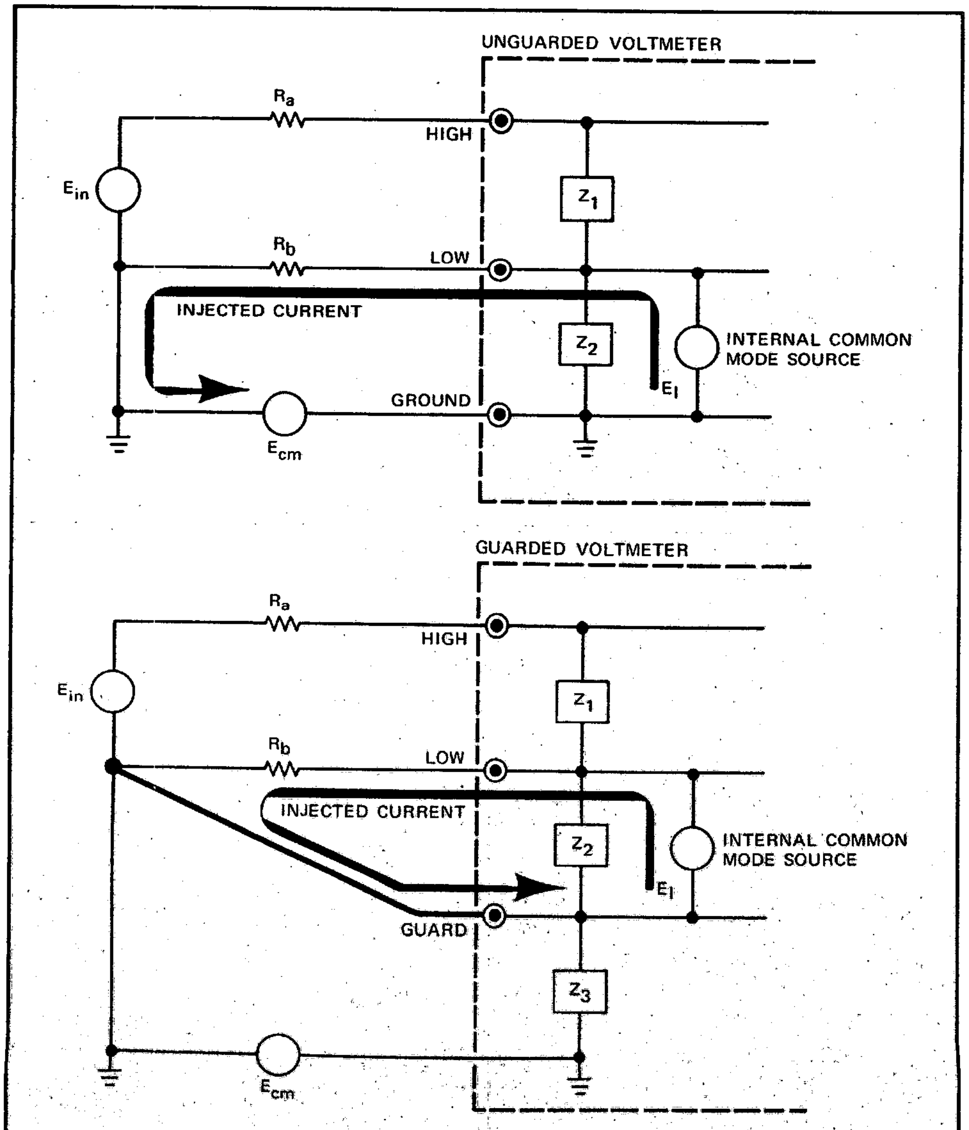

FIGURE 11. Internal Common Mode Sources in a Guarded and Unguarded Instrument

In the unguarded instrument (top of Figure 11) the injected current flows out of the low terminal, through the low source resistance, and back to ground, dropping a voltage across R_b. The result is an offset in the reading. The only thing that can be done to cut down the effect of injected current is to install a fairly large capacitor between low and ground in the instrument. Such a capacitor would shunt the injected current around the source resistance, but if it were too large it would degrade Z_2 seriously and ruin the instrument's ac CMR. Most unguarded floating voltmeters have a capacitor in the 0.01 μF range already installed. The value is selected to maximize ac CMR while minimizing the effects of injected current and results in a tradeoff between the two.

In the guarded instrument the injected current goes out the low terminal, through R_b, and back into the guard terminal, again causing an offset in the reading. But note that the injected current only goes through R_b if the guard is properly connected. If the guard were connected someplace else, to the low terminal right at the front panel, for example, the injected currents would not go through R_b. So connecting guard to maximize CMR also maximizes the effects of injected current. And connecting it to minimize injected current effects cuts down on the CMR.

The situation isn't as bad as it looks. First, guarded voltmeters have much less injected current than unguarded ones, usually only 50 to 100 pA. Then, injected currents are always at line frequency where most voltmeters have very good normal mode rejection. So the voltmeter's response to injected currents will be low, especially if the voltmeter is an integrating DVM with nearly infinite noise rejection at line frequency. Also, if R_b is small, the low and guard terminals can be connected right at the instrument without much loss in CMR. And then, if the input voltage can be set to zero or shorted out while the guard is connected properly, the offset due to injected currents can be read on the voltmeter's display and used as correction, or perhaps eliminated altogether with a zero adjustment. And finally, injected current can be measured directly by connecting a small-valued resistor between low and guard and measuring the voltage across it. The measured value can then be used to estimate the resulting offset if R_b can be estimated.

A FEW WORDS ABOUT SPECIFICATIONS

CMR specifications are figures of merit; they are useful for comparing the CMR capabilities of two instruments; but they won't predict how much common mode error a given measurement will have. And they won't tell if a given instrument meets the requirements of a given measurement unless a great deal is already known about the measurement, because common mode errors are so dependent upon the characteristics of the measurement and on how the instrument is connected. Fortunately there is some uniformity among manufacturers and there are only two basic ways of specifying CMR. One is to specify "true" common mode rejection, and the other is to specify "effective" common mode rejection.

Both methods have two things in common. First, CMR is specified with the guard connected properly, according to the two rules on page 7 ; and second, CMR is specified with a given value of either R_b or the difference between R_a and R_b, usually 1 kΩ. Most manufacturers do not explicitly state whether or not the voltmeter is balanced, and the CMR is specified "with a 1 kΩ unbalance in either lead". This expression means that if the instrument is balanced, the CMR is specified with 1 kΩ difference between R_a and R_b regardless of which is larger, and if the instrument is unbalanced the CMR is specified with 1 kΩ in the low lead since that's the worst case. Since the specifications don't tell if the instrument is balanced, the CMR should be checked with a 1 kΩ resistor in the low lead (more on checking CMR later).

True CMR, or "pure" CMR, is the ratio (in dB) of the common mode signal to the normal mode signal it produces with a 1 kΩ unbalance in either the high or low lead. It is an indication of the inherent rejection ability of the basic instrument and does not include the effects of any noise rejection capabilities of the measuring circuits. It is especially important when the input is to be connected to other instruments. For example, if the input must go to an amplifier in parallel, the true CMR gives an idea of how much common mode offset will appear on the amplifier input.

Effective CMR is the ratio (in dB) of the common mode signal to its resulting effect on the measured value or readout with a 1 kΩ unbalance. It combines the true CMR effects with the instrument's noise rejection capabilities, and is usually the most important specification, because it directly indicates how common mode signals affect the measured value. Figure 12 shows how true CMR and noise rejection combine to make an effective CMR specification. The instrument used is an integrating dc digital voltmeter so it has points of extremely high noise rejection whenever the noise period is the same as the integration period. Notice that at dc the true and effective CMR are the same; the instrument has no noise rejection at low frequencies, so effective CMR falls off the same as the true CMR until about 2 Hz when the voltmeter's noise rejection takes effect. After that the effective CMR is the sum of the two effects. If one CMR specification and the noise rejection specification are known, then the other CMR specification can be derived by addition or subtraction.

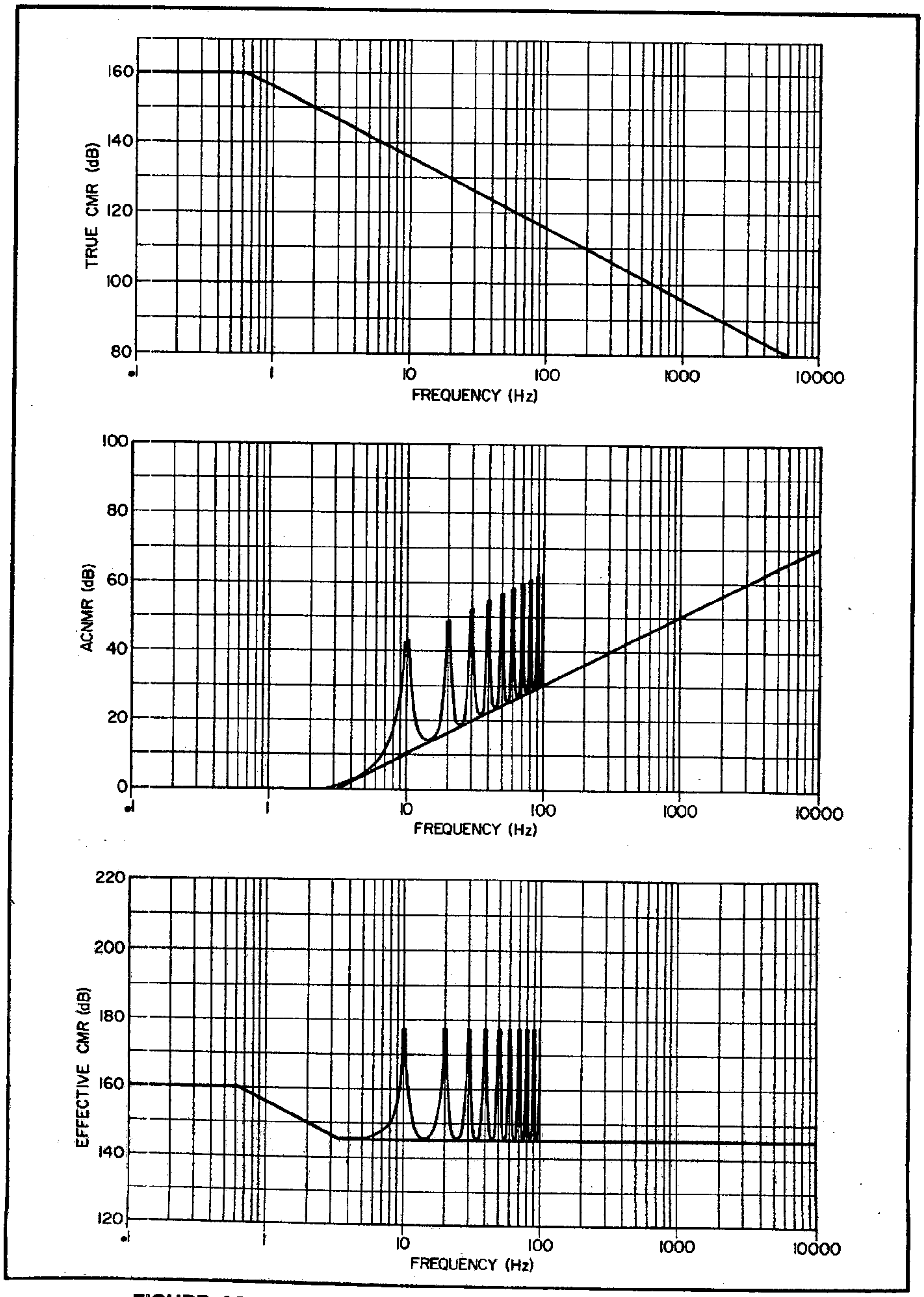

FIGURE 12. Relationship Between True CMR and Effective CMR

Both true and effective CMR are generally specified with a 1 kΩ unbalance; this is just an accepted convention . . . any value could have been used. But a different value of unbalance will result in a different value of CMR; the larger the unbalance the worse the CMR and vice versa. And the relationship is linear. So an instrument specified as having CMR of 180 dB with 100 Ω unbalance is the same as an instrument specified as 160 dB with 1 kΩ unbalance.

The amount of common mode voltage an instrument can accommodate is not often specified, but is very important, because exceeding recommended levels may damage the instrument. Most instruments can operate with 500 to 700 volts between guard and ground and with anywhere from 50 to 300 volts between low and guard. The low-to-guard voltage isn't as critical because the instrument, when connected properly, should have low and guard at the same potential.

MEASURING COMMON MODE REJECTION

Figure 13 shows effective CMR checks and true CMR checks for both a floating unguarded voltmeter and a guarded voltmeter. In each case the measurements are made

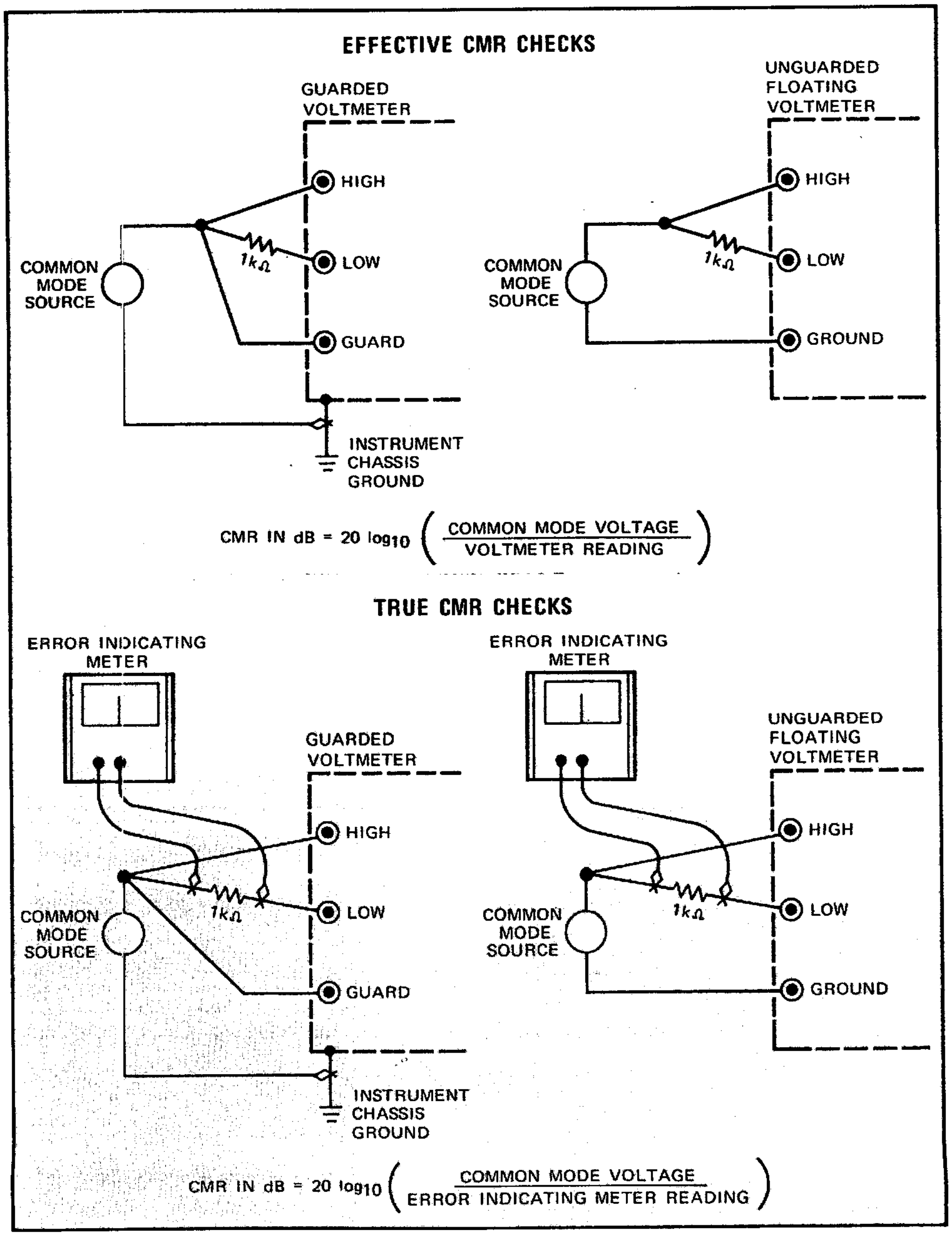

FIGURE 13. Common Mode Rejection Checks

with a 1 kΩ unbalance resistor and with the resistor placed in the low lead. These checks can be used to determine if the instrument is balanced by doing the check with the unbalance in the low lead and then with the unbalance in the high lead and noting any differences. If the two CMR values are equal the instrument is balanced.

The effective CMR check is the simplest and the most usable because it uses the instrument's readout to indicate CMR errors. The source is first a dc supply and then a variable frequency oscillator with a frequency range up to about 1 kHz. When checking instruments with very high CMR (~160 dB) it's hard to get an indication on the meter readout without using dangerously high voltages. Then it's a good idea to increase the value of the unbalance resistor in order to get greater CMR errors. Remember that CMR varies inversely with the value of the resistor.

The true CMR check is somewhat more difficult because an additional "error indicating meter" must be used to directly measure the normal mode offset generated by the common mode source. The meter used must be floating, preferably battery-operated, and should have enough sensitivity to read the normal mode offsets. If it hasn't enough sensitivity, the normal mode offset can be made larger by increasing the unbalance resistor. Try to make true CMR checks with the voltmeter turned off in order to completely eliminate any effects of its normal mode rejection. This isn't always possible, though, because some instruments have their inputs disconnected when they're turned off.

AND IN CONCLUSION

Guarded instruments will solve most common mode problems if they are connected according to the two basic rules . . . . . (1) always have guard and low at the same voltage, and (2), make sure that no common mode current passes through any source resistance. You'll find in many cases it's impractical or impossible to satisfy both rules. It's not as easy as it seems. But, look your measurement over and come as close as possible. Remember that the effectiveness of a guarded instrument depends on how it's connected . . . so use the guard . . . improve your common mode rejection.

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