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Trimming Paralleled Modules

General Description

While output voltage trimming of a single module is a simple process of adding a fixed or adjustable resistor network to get the desired voltage (see AP-5); trimming a paralleled system of converters is a little more difficult. With the RO approach to paralleling modules each module has the potential to control the output voltage. While this leads to a simple, robust paralleling method; it can lead to some difficulties when trimming. The best approach to resolve these difficulties is determined by the application.

Implementation

Fixed Trimming

Fixed trimming of a paralleled system is by far the simplest trimming method and is preferred over all other trimming methods. *Figure 9a* shows the basic approach with a trim resistor for each module. The voltage can be trimmed up or down as discussed in Application Note 5. Because the trim signal remains local to each module this approach is the least sensitive to noise pickup on the trim pin. And since each module is trimmed to the same voltage there will be no effect on the output if one of the modules fails in a redundant system.

Adjustable Trimming

Adjustable trimming of a paralleled system is a little more complicated. Which module is in control of the system? With each module capable of being in control of the system how do you trim the overall voltage up if another module assumes control from the one that you are trimming? There are three basic approaches to address these questions: 1) force one or more modules to be in control of the system and trim them, 2) trim all of the modules using the same voltage trim reference, or 3) trim each module in the system using a specific setup or procedure to keep the module being trimmed in control of the output. The best approach and implementation are determined by the level of redundancy desired. For purposes of discussion we will define three levels of redundancy:

- No redundancy - a single component failure can result in an altered output voltage or a catastrophic failure of the output.
- Limited redundancy - a single component failure can result in an altered output voltage
- Full redundancy - the system will be unaffected by a single component failure

Adjustable Trimming with No Redundancy

When redundancy is not required the simplest method to trim paralleled modules is to force control of the system to a particular module. In the RO paralleling scheme the system is controlled by the module with the lowest output voltage setting. To force control of the system to a particular module, all other modules must be trimmed to a higher output setting. This is done by trimming all but one of the modules to the maximum voltage of the adjustment range, and using an adjustable trim network on the remaining module to trim the output over the desired range.

This approach is shown in *Figure 9b* and has several advantages. First, it is very simple and requires few components. Second, the trim signal for each module is local to the module. This minimizes the possibility of noise pickup on the trim line, as well as simplifying the interconnect. This is especially important for systems that use multiple PCB cards to handle the entire paralleled system.

Adjustable Trimming with Limited Redundancy

The implementation shown in *Figure 9b* can be made to have limited redundancy by adding or'ing diodes, PDMs, and startup assist resistors (see AP-13). With these additions; the system, shown in *Figure 9c*, will always provide power to the load. However the output of the system will shift to a different voltage if the controlling module or the adjustable trim network should fail. The advantages of this approach are the same as listed above. The disadvantage is that this system is vulnerable to a single point module failure which may cause the output voltage to change.

One way around this disadvantage is to make all of the modules adjustable, as shown in *Figure 9d*. This approach has one trim pot to generate a trim signal which is then fed to each module via a series resistor. The series resistor has three functions. First, it limits the range of adjustment of the system output voltage. Second, it limits the effects of a failed module on the system output voltage. And third, it helps to isolate each module from noise pickup on the common trim line. This approach is simple, like the previous approach, but it is not as vulnerable to a single point module failure. It does, however, have the disadvantage of exposing the trim pin to noise pickup as well as increasing the complexity of the module interconnects.

A compromise between the previous two implementations is shown in *Figure 9e*. This approach trims some of the modules to a fixed voltage and makes the rest adjustable via a single pot. This approach is not as vulnerable to a single point failure as the approach in *Figure 9c*, and does not have the noise pickup potential or the interconnect complexity of the approach in *Figure 9d*.

Adjustable Trimming with Full Redundancy

All of the previous examples had the disadvantage of being vulnerable to a single point failure of the adjustment pot. A failure of the pot network would result in a change in the output voltage. One approach to reduce the vulnerability is to make each module adjustable as shown in *Figure 9f*. This circuit has several disadvantages in that it requires a large number of parts, and it is logistically difficult to adjust. The adjustment difficulty stems from the control algorithm used -the module with the lowest voltage wins. One way to simplify the adjustment procedure would be to use a "ganged" pot, where all of the pots are connected to a single adjustment shaft. Ganged pots are commonly used in audio amplifiers to simultaneously adjust the volume of the left and right channels from a single knob.

Some of the disadvantage of the previous example can be minimized by only using as many pots as required to reach the desired level of redundancy. In an n+m system, m+1 pots are needed for a fully redundant system. *Figure 9g* shows an example of this approach. As in the previous example, if the pots are ganged the logistics problem of adjusting the system is somewhat reduced.

Trimming Examples

Here is an example of how to calculate the resistor values for a trimmed system. These calculations assume that the adjustment range surrounds the nominal output voltage. The pertinent requirements for our example are as follows:

Vnom = 5.0V
Vmax = 5.5V
Vmin = 4.5V
Load = 1200W
n = 6 (number of modules required)
m = 2 (number of redundant modules)

For this example we decided to use the circuit shown in *Figure 9d*. First calculate the fixed trim resistor values to achieve the max and min voltages of the desired range. These calculations start with the trim equations from Application Note 5.

Trim-up:

$$R_{Vmax} = \frac{5.677k\Omega \times (1.5V)}{5.5V - 5.0V}$$

$$R_{Vmax} = 17.03k\Omega$$

Trim-down

$$R_{Vmin} = \frac{5.677k\Omega \times (1.5V - 5.0V)}{4.5V - 5.0V}$$

$$R_{Vmin} = 39.74k\Omega$$

Since we want **RS** to be as big as possible, and the above two resistor values represent the maximum limits for the trim up and trim down configurations; we pick the smallest of the two resistors above and set **RS** equal to it.

RS = RVmax = 17.03k

We want the resistor **RS** to be directly connected to the corresponding sense line when the pot is adjusted to its limit. Therefore, we have to delete one of the range limiting resistors in line with the adjustment pot. If **RS** = **RVmax**, then short out **Rbot**. Otherwise, short out **Rtop**. For our example we will short out **Rbot**.

Next, we need to determine the remaining range limiting resistor. To do this we need to determine the voltage at the pot wiper when the pot is adjusted to the limit nearest the remaining limiting resistor.

This is done by returning to the fixed trim resistors that we calculated at the beginning of the example. We take the larger of the two values and split it into two parts as shown in *Figure 9h*. The piece closest to the module is equal to **RS** and the other piece is equal to the remainder. We now analyze the trim circuit for the intermediate node voltage and force the corresponding node voltage in the adjustment network to be the same. *Figure 9h* shows the fixed trim network for our example. The intermediate node voltage is calculated as follows:

$$V_n = \frac{V_{min} - 1.5}{R_{Vmin}} * R_{Vmax} + 1.5$$

$$V_n = \frac{4.5 - 1.5}{33.66} * 17.32 + 1.5 = 3.044$$

Now we sum the currents in the wiper node of our adjustment network and then solve for the desired resistor value.

$$\frac{V_{min} - V_n}{R_{top}} - \frac{V_n}{R_{pot}} - \frac{V_n - 1.5}{R_s/(N+M)} = 0$$

Solving for Rtop we get:

$$R_{top} = \frac{(V_{min} - Vn) * R_{pot} * R_s/(n+m)}{Vn * R_s/(n+m) + (Vn - 1.5) * R_{pot}}$$

$$R_{top} = \frac{(4.5 - 3.044) * 50k * 17.32k/(6+2)}{3.044 * 17.32k/(6+2) + (3.044 - 1.5) * 50k}$$

$$R_{top} = 1.88k\Omega$$

Figure 9i shows the final trim network.

Possible Applications

Eliminating the need for remote sense - Output trimming can be used instead of remote sense when the load current change is limited and the voltage drop between converter and load is relatively constant.

System testing (margining) -Often, it’s helpful to test system operation with the supply voltage -usually the +5V logic -set first at one extreme, then at the other. Any circuitry that fails to perform properly under these manufacturer’s test conditions might also fail under conditions found in the user's environment. Margin testing helps insure trouble-free system operation.

Obtaining non-standard output voltages - When a nonstandard output voltage is necessary, it may be available simply by trimming the output voltage of a module with an output voltage that's close to the desired voltage. Although the published data sheet limits are valid over the guaranteed adjustment range, lower output voltages are commonly available by using the trim function. Contact the factory for details.

Reducing the number of stocked models - When two output voltages are necessary, such as 24V and 28V, one model may be able to supply both, using the trim function to set the lower voltage.

Precautions

Connect trim resistor to sense, not to output -The trim resistor(s) should be connected to the sense leads, not to the output leads or to the load. Otherwise, load current changes could cause the converter's trimmed output voltage to vary.

Noise sensitivity -The TRIM pin is noise sensitive. External resistors (either fixed or variable) should be located within one cm of the converter. If wires are necessary, use twisted or shielded wires. **Do not bypass the TRIM pin with a capacitor. It could cause module instability.**

Output power, output current -If the output voltage is increased, output current must be derated to avoid exceeding module maximum output power. If the output voltage is decreased, output current is limited to its maximum rating.

Adjustability range limits -In some cases, the output voltage can be trimmed outside the guaranteed adjustment range. However, data sheet specifications are only valid for Vout within the guaranteed range.

Related Topics

AP-5 Output Voltage Trimming
AP-13 Paralleling with Current Sharing, n+m Redundancy, and Hot Plug-in

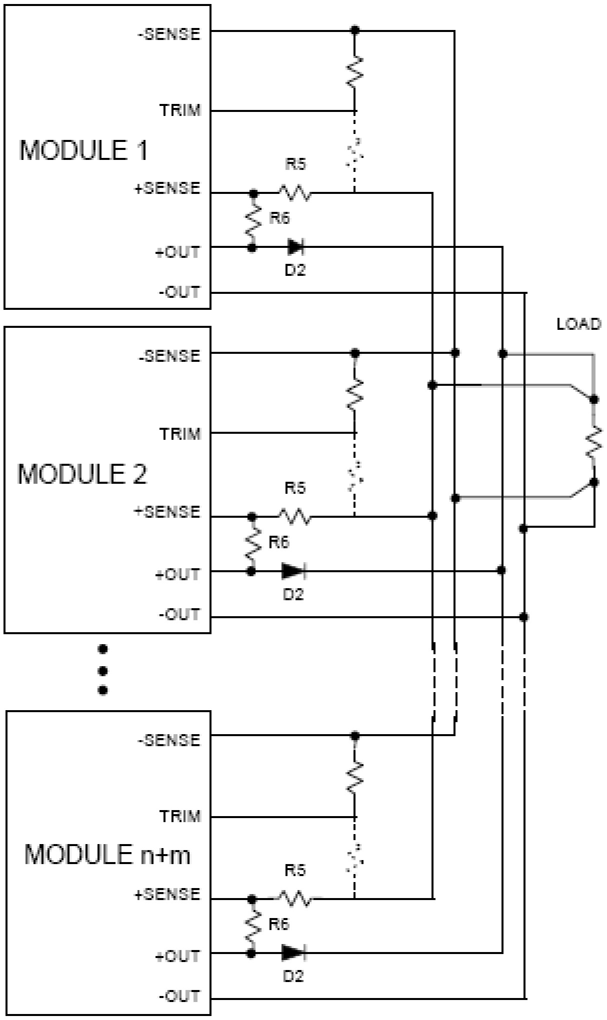

Figure 9a Fixed voltage trimming of a paralleled system

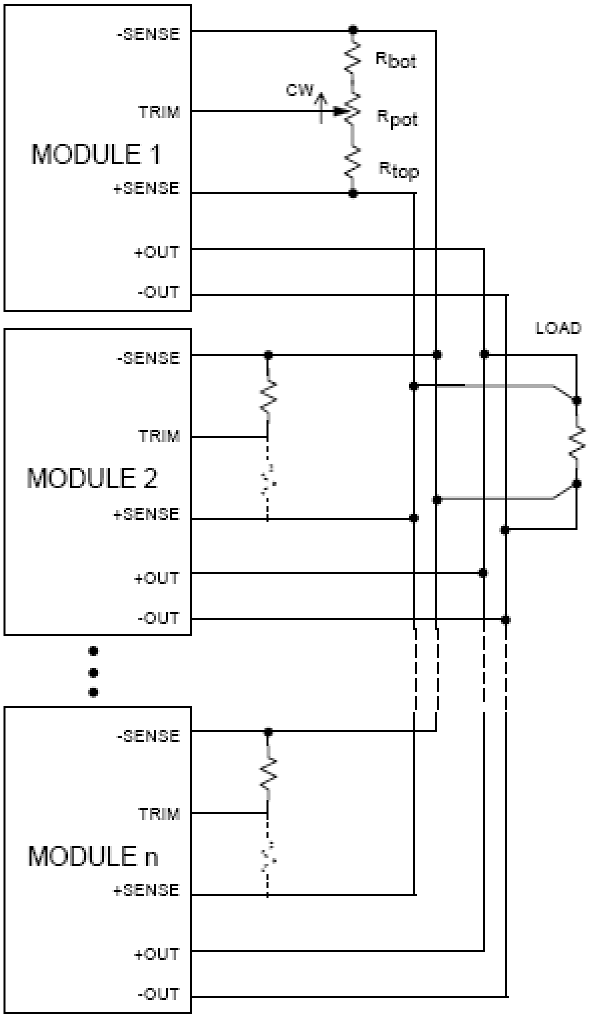

Figure 9b Adjustable trimming of paralleled modules with no redundancy

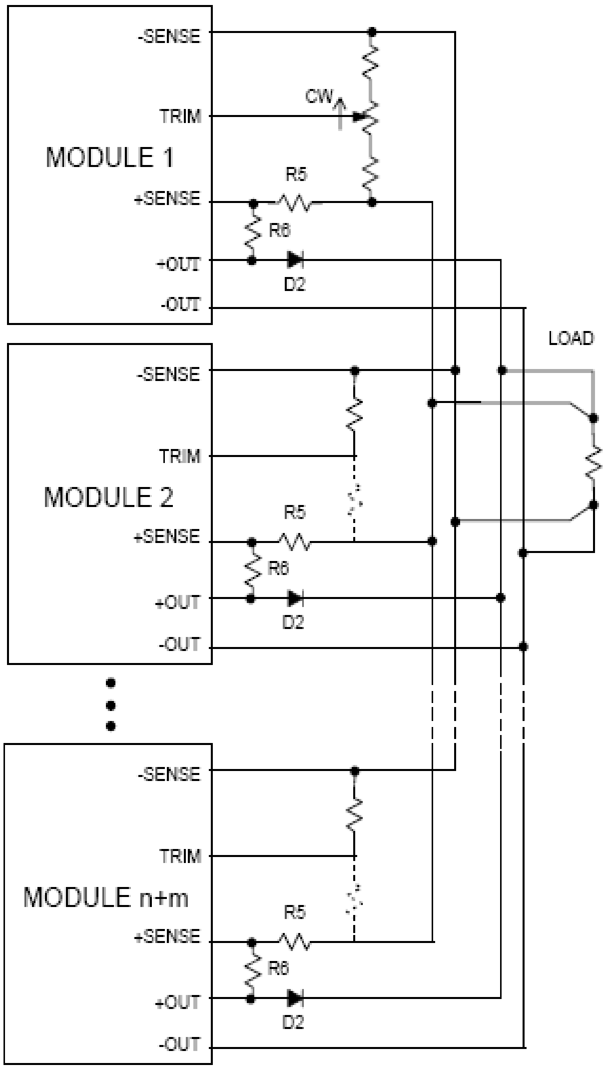

Figure 9c Adjustable trimming - all modules but 1 fixed, 1 module adjustable

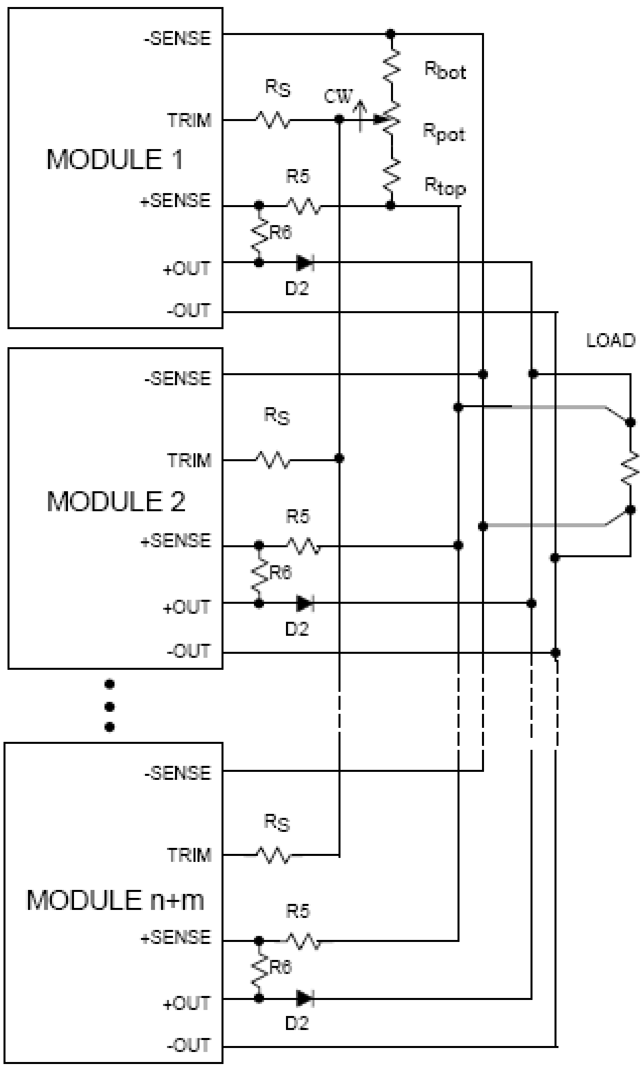

Figure 9d Adjustable Trimming with limited redundancy - all modules adjustable, one pot

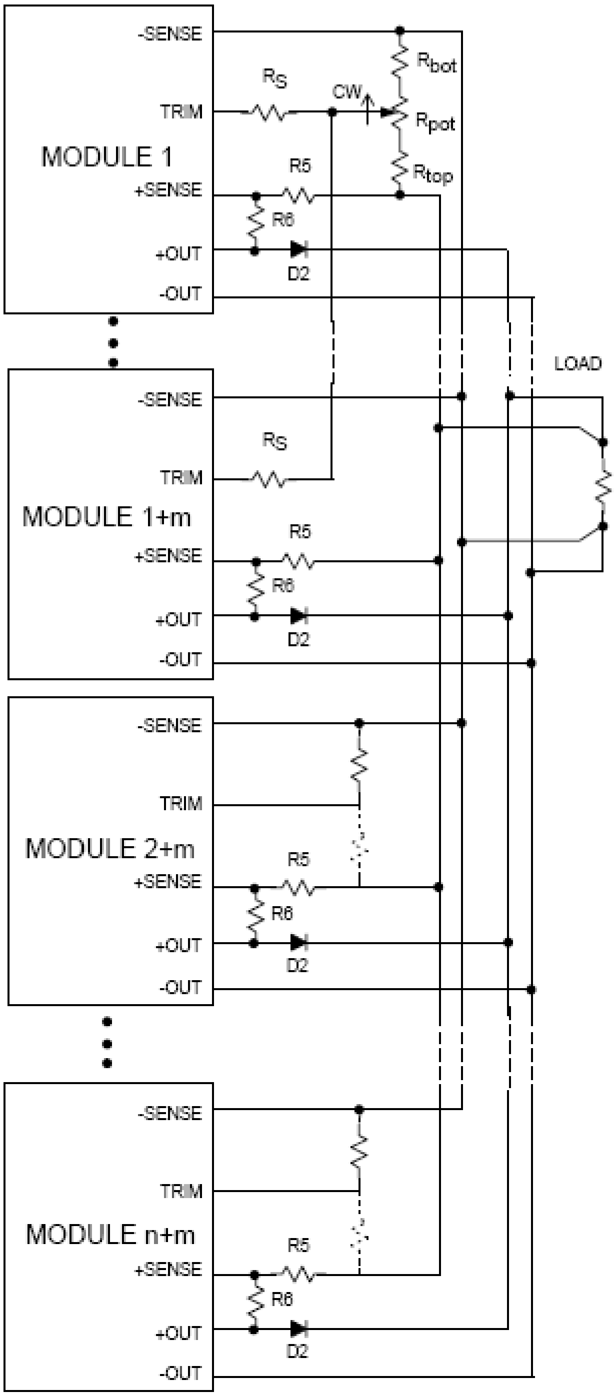

Figure 9e Adjustable Trimming with limited redundancy - some modules fixed, some modules adjustable, one pot

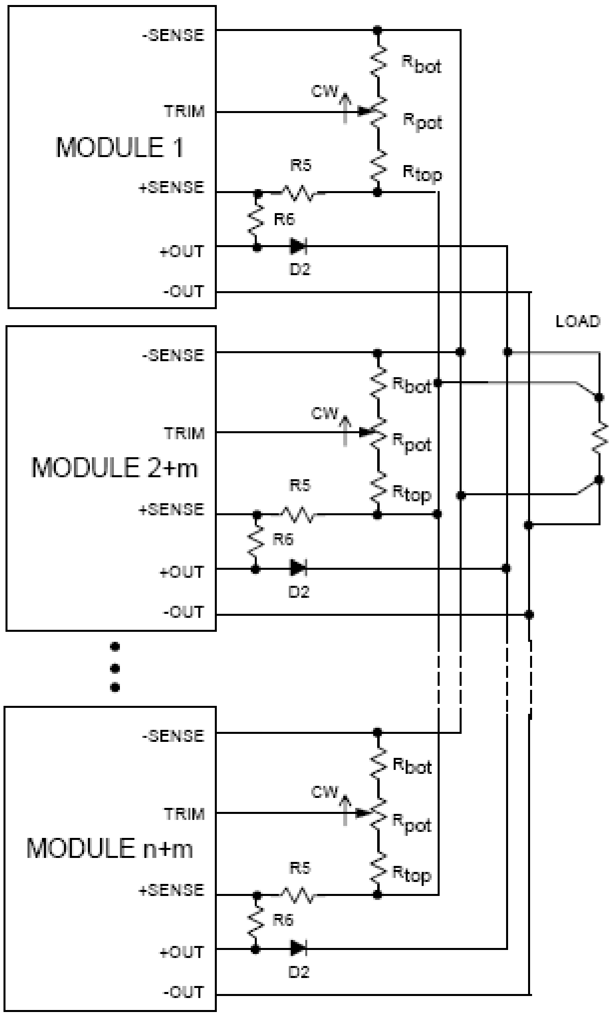

Figure 9f Adjustable trimming with full redundancy - one pot per module

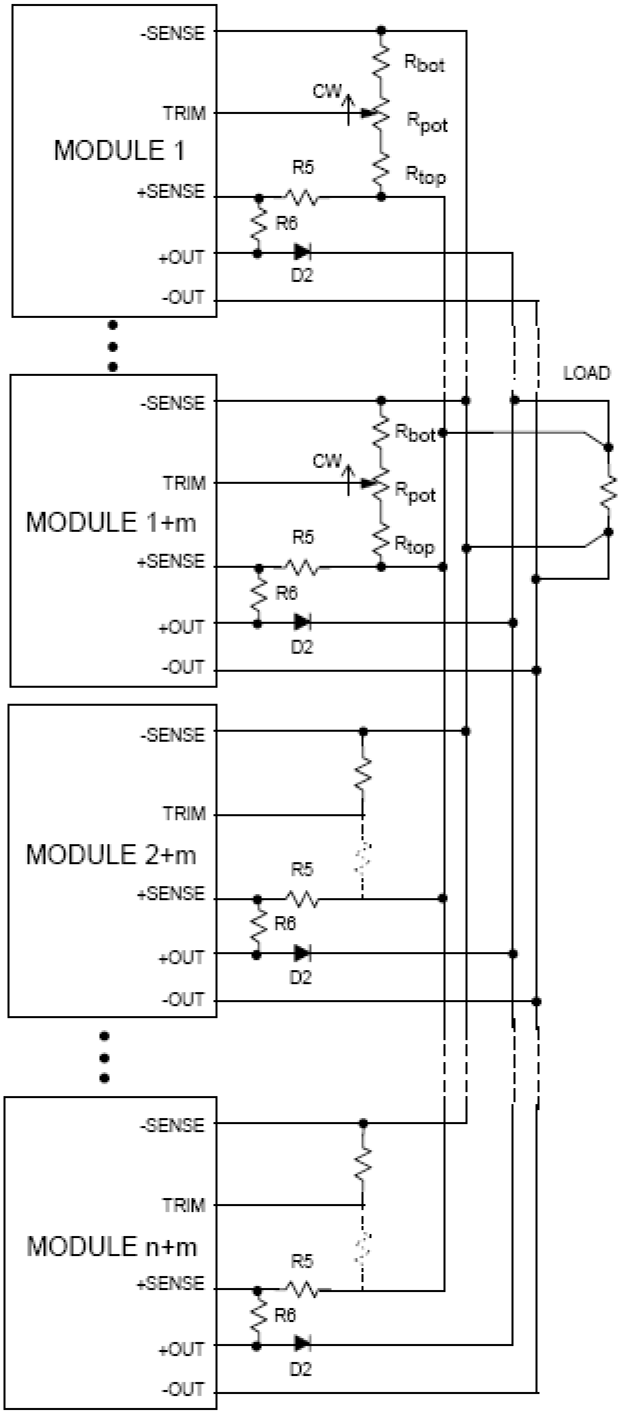

Figure 9g Adjustable Trimming with full redundancy - some modules fixed, some modules adjustable

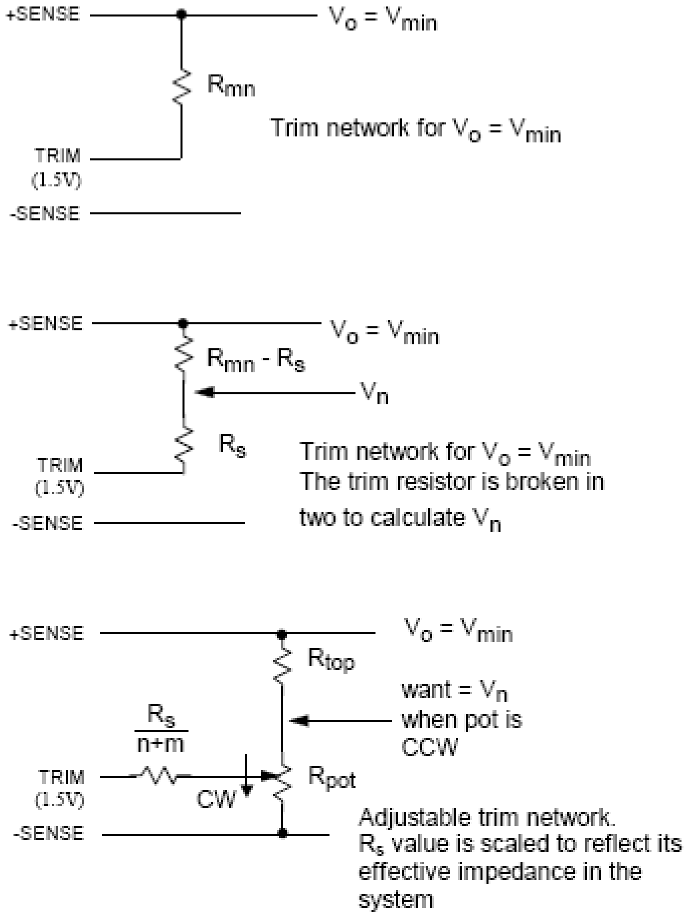

Figure 9h Schematics used to calculate the example trim network

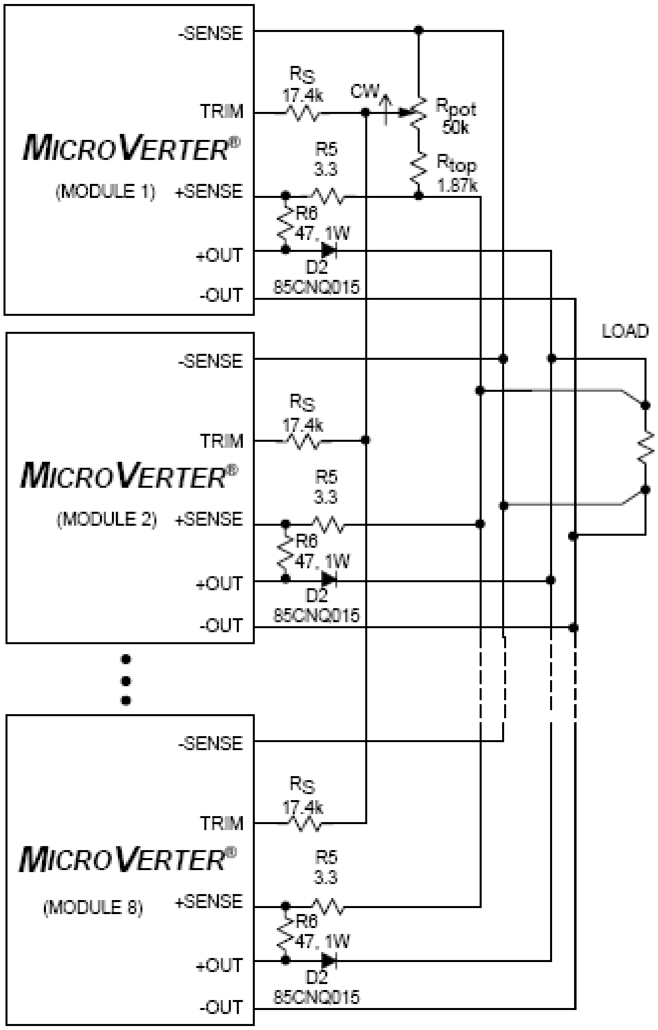

Figure 9i Final schematic for the trim network example