

# A New Production Technique for Trimming Voltage Regulators

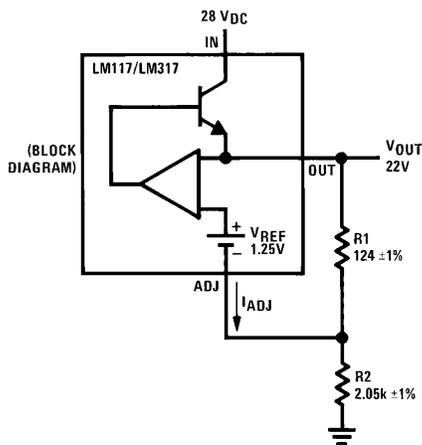
National Semiconductor  
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A New Production Technique for Trimming Voltage Regulators

Three-terminal adjustable voltage regulators such as the LM317 and LM337 are becoming popular for making regulated supplies in instruments and various other OEM applications. Because the regulated output voltage is easily programmed by two resistors, the designer can choose any voltage in a wide range such as 1.2V to 37V. In a typical example (Figure 1) the output voltage will be:

$$V_{OUT} = V_{REF} \left( \frac{R_2}{R_1} + 1 \right) + R_2 \cdot I_{ADJ}$$



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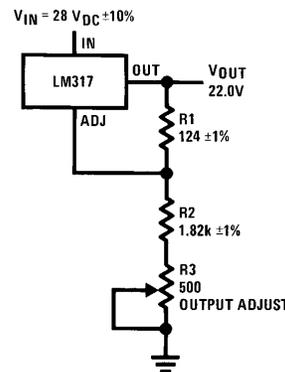
FIGURE 1. Basic Regulator

In many applications, when R1 and R2 are inexpensive  $\pm 1\%$  film resistors, and the room temperature accuracy of the LM117 is better than  $\pm 3\%$ , the overall accuracy of  $\pm 5\%$  will be acceptable. In other cases, a tighter tolerance such as  $\pm 1\%$  is required. Then a standard technique is to make up part of R2 with a small trim pot, as in Figure 2. The effective range of R2 is  $2.07k \pm 10\%$ , which is adequate to bring  $V_{OUT}$  to exactly 22.0V. (Note that a 200 $\Omega$  rheostat in series with 1.96 k $\Omega \pm 1\%$  would not necessarily give a  $\pm 5\%$  trim range, because the end resistance and wiper resistance could be as high as 10 $\Omega$  or 20 $\Omega$ ; and the maximum value of an inexpensive 10% or 20% tolerance trimmer might be as low as 180 $\Omega$  or 160 $\Omega$ .)

In some designs, the engineering policy may frown on the use of such trim pots, for one or more of the following reasons:

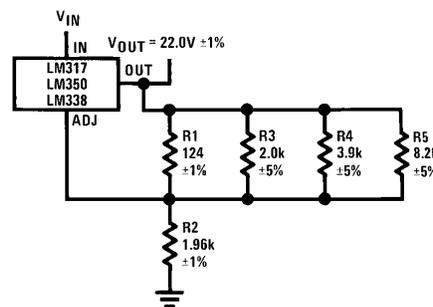
- Good trim pots are more expensive.
- Inexpensive trim pots may be drift or unreliable.
- Any trim pot which can be adjusted can be misadjusted, sooner or later.

To get a tighter accuracy on a regulated supply, while avoiding these disadvantages of trim pots, consider the scheme in Figure 3.



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FIGURE 2. Regulator with Small Adjustment Range



TL/H/8495-3

FIGURE 3. Regulator with Trimmable Output Voltage

When first tested,  $V_{OUT}$  will tend to be 4% to 6% higher than the 22.0V target. Then, while monitoring  $V_{OUT}$ , snip out R3, R4, and/or R5 as appropriate to bring  $V_{OUT}$  closer to 22.0V. This procedure will bring the tolerance inside  $\pm 1\%$ :

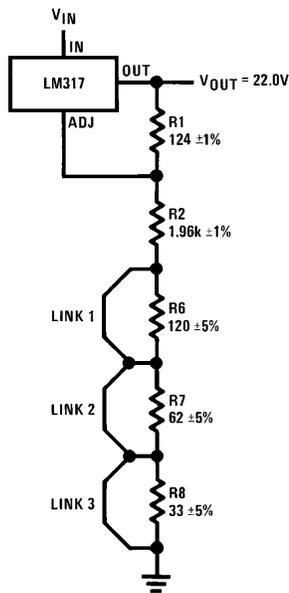
- If  $V_{OUT}$  is 23.08V or higher, cut out R3 (if lower, don't cut it out).
- Then if  $V_{OUT}$  is 22.47V or higher, cut out R4 (if lower, don't).
- Then if  $V_{OUT}$  is 22.16V or higher, cut out R5 (if lower, don't).

The entire production distribution will be brought inside  $22.0V \pm 1\%$ , with a cost of 3 inexpensive carbon resistors, much lower than the cost of any pot. After the circuit is properly trimmed, it is relatively immune to being misadjusted by a screwdriver. Of course, the resistors' carcasses must be properly removed and disposed of, for full reliability to be maintained.

An alternate scheme shown in Figure 4 has R6, R7, and R8 all shorted out initially with a stitch or jumper of wire. The

trim procedure is to open up a link to bring a resistor into effect. The advantage of this circuit is that  $V_{OUT}$  starts out lower than the target value, and never exceeds that voltage during trimming. In this scheme, note that a total "pot resistance" of  $215\Omega$  is plenty for a 10% trim span, because the minimum resistance is always below  $1\Omega$ , and the maximum resistance is always more than  $200\Omega$ —it can cover a much wider range than a  $200\Omega$  pot.

The circuit of Figure 5 shows a combination of these trims which provides a new advantage, if a  $\pm 2\%$  max tolerance is adequate. You may snip out R4, or link L1, or both, to accommodate the worst case tolerance, but in most cases, the output will be within spec without doing any trim work at



If  $V_{OUT}$  is lower than 20.90V, snip link 1 (if not, don't).  
 Then if  $V_{OUT}$  is lower than 21.55V, snip link 2 (if not, don't).  
 Then if  $V_{OUT}$  is lower than 21.82V, snip link 3 (if not, don't).

FIGURE 4. Alternate Trim Scheme

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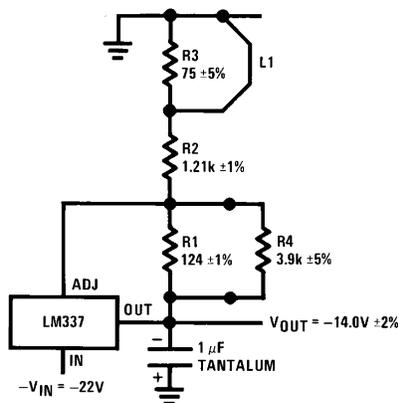
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all. This takes advantage of the fact that most  $\pm 1\%$  resistors are well within  $\pm 1/3\%$ , and most LM337's output voltage tolerances are between  $-1/2\%$  and  $+1 1/2\%$ , to cut the average trim labor to a minimum. Note that L1 could be made up of a  $2.7\Omega \pm 10\%$  resistor which may be easier to handle than a piece of wire.

In theory, a 10% total tolerance can be reduced by a factor of  $(2^n - 1)$  when n binary-weighted trims are used. In practice, the factor would be  $(1.8^n - 1)$  if  $\pm 10\%$  trim resistors are used, or  $(1.9^n - 1)$  if  $\pm 5\%$  resistors are used. For n = 2, a 10% tolerance can be cut to 3.8% p-p or  $\pm 1.9\%$ . For n = 3, the spread will be 1.7% p-p or  $\pm 0.85\%$ , and most units will be inside  $\pm 0.5\%$ , perfectly adequate for many regulator applications.

National Semiconductor manufactures several families of adjustable regulators including LM117, LM150, LM138, LM117HV, LM137, and LM137HV, with output capabilities from 0.5A to 5A and from 1.2V to 57V. For complete specifications and characteristics, refer to the appropriate data sheet or the 1982 Linear Databook.



If  $|V_{OUT}|$  is smaller than 13.75V, snip L1 and it will get bigger by 6%.  
 Then if  $|V_{OUT}|$  is bigger than 14.20V, snip R4 and it will get smaller by 3%.

FIGURE 5. Circuit Which Usually Needs No Trim to Get  $V_{OUT}$  Within  $\pm 2\%$  Tolerance

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