# LDO Voltage Regulator Uses Regenerative Amplifier

If an integrated circuit low-dropout (LDO) voltage regulator that exactly meets your needs is not available, you can make your own discreet version with this simple high performing circuit. This circuit employs what I call a regenerative amplifier, which uses positive feedback to create a huge amount of gain from just two transistors. This technique was cleverly used by Philips of Holland in the late sixties to precisely control the speed of a cassette tape recorder motor with just two cheap, low-beta transistors. A knock-off of this motor governor circuit can be seen at the following website.
http://members.shaw.ca/novotill/SmallDcMotorSpeedReg/index.htm

While trying to understand the operation of this type of motor governor many years ago, I became intrigued with the idea of using this regenerative circuit to produce an awesome voltage regulator. The extremely high gain is produced by the fact that the output of Q1 is amplified by Q2, which is again amplified by Q1, which is again amplified by Q2 and so forth in a continuous loop. The circuit would latch up like an SCR if something didn't intervene, such as D1 in this case. When the desired output voltage is reached D1 begins conducting, stopping further positive feedback. This is because the voltage at the emitter of Q2 rises faster than the voltage at its base, backing down its conduction.

I abandoned this concept for a voltage regulator years ago due to disappointing performance. I recently revisited the circuit and found a solution to the problem. First of all, the circuit needs to be started up. The simplest way to start the circuit up is to place a resistor across the pass transistor Q1. This technique was used in the motor governor, but only works for a limited range of load and input voltage. Q5 solves this problem, while compensating for most (70% for current values of R7 and R8) of the temperature-related Vbe variation of Q4.

The reason for the poor voltage regulation of the simple version of the circuit in spite of the extremely high available gain is the current-related variation in the Vbe of Q2. This causes the output voltage to drop with increased load, which then lowers the voltage on the base of Q2 effectively shifting the output voltage set-point. This magnifies the drop in the output voltage. Using an LM431 in place of a zener diode provides a much more stable voltage reference and allows electronic adjustment of the output voltage set-point.

Q6 senses the current-related variation in the Vbe of Q4 and adjusts the output voltage set-point in compensation. Since Q6 follows the same temperature curve as Q4, Q6's output is not affected by temperature. Now we can get the performance that the regenerative amplifier is capable of delivering. The regenerative amplifier has such tight control that, unlike many IC regulators, no capacitors are needed to keep it stable.

Only R11 can be used to change the output voltage without having to change R9 to maintain perfect compensation of Q4's Vbe. If R9 is too low in value, the output voltage of the regulator will actually go up with increasing load. This could be used to improve regulation at a distant load, but the effect will not be perfect because the compensation is not linear. The temperature coefficient of the enhanced version of this circuit with the component values shown was calculated at +0.60mv/degC . R6 sets the maximum base current of Q3 plus the minimum quiescent current of U1, which is 1ma according to the LM431 datasheet. I used 5% resistors to breadboard and test this circuit.

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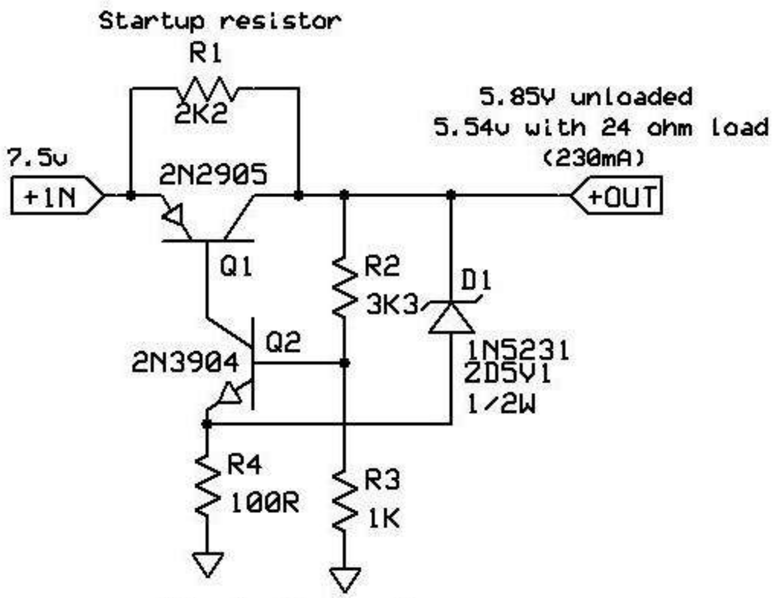
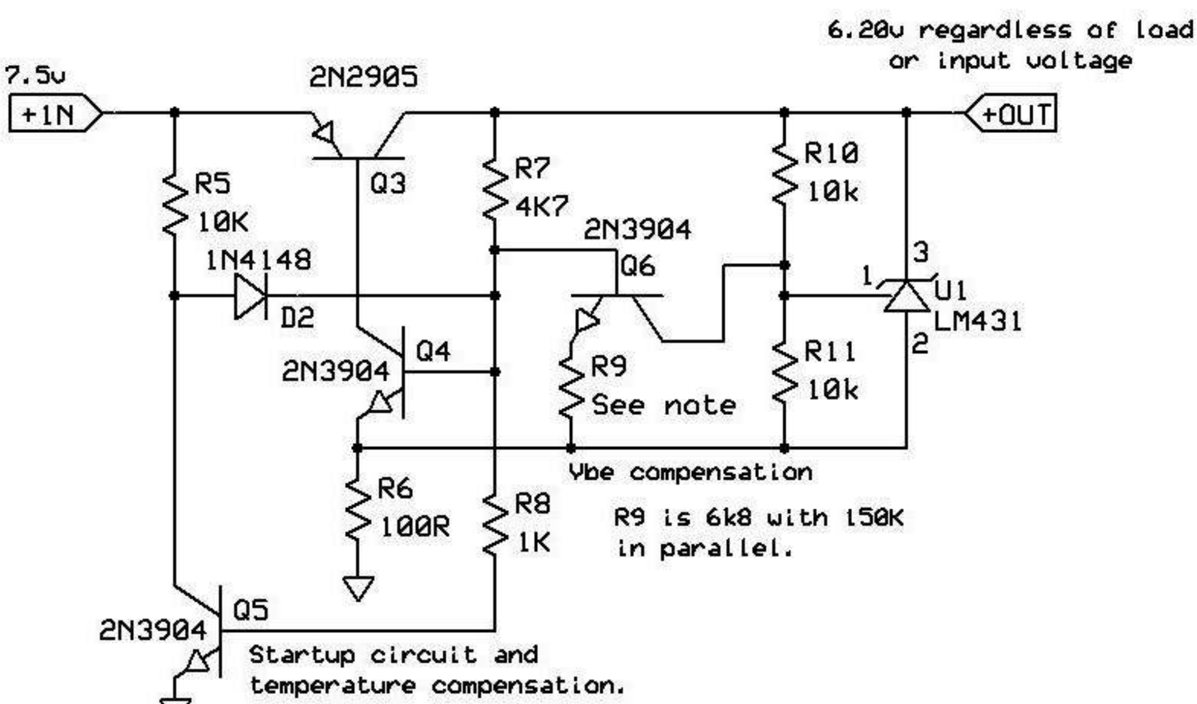



Simplest version




Enhanced version