LM2577,LM4040

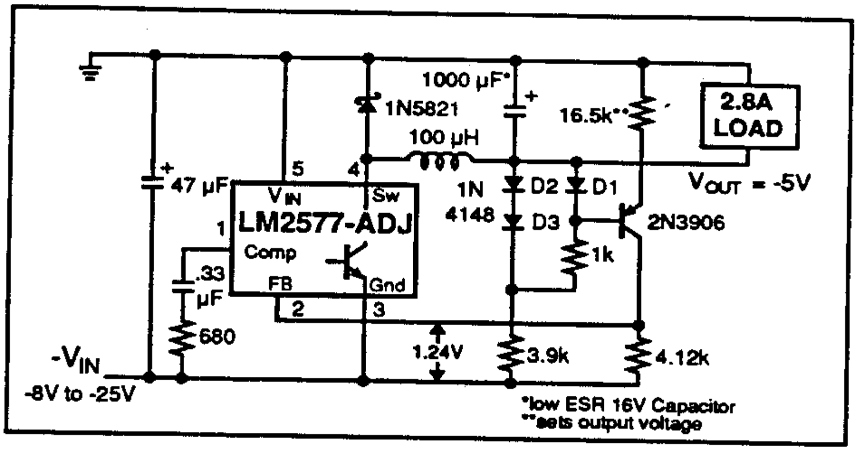
Negative Buck Switching Regulator (using LM258x)

Literature Number: SNVA536

Negative Buck Switching Regulator

High efficiency step-down switching regulators for positive voltages are very common, especially since National introduced the SIMPLE SWITCHER™ product line of IC switchers. But occasionally negative step-down switching regulators are needed in some systems.

The circuit shown here accepts a negative input voltage and efficiently converts it to a smaller negative voltage, at load currents up to approximately 2.8 Amps. (negative voltage in, negative voltage out, common ground)



Circuit description

The LM2577-ADJ step-up switching regulator IC is used in a non standard configuration to provide a negative buck regulator function. The 3 Amp IC switch current rating allows the regulator circuit to provide a guaranteed 2.8 Amps of load current when the circuit is operating in the continuous mode.

Since the 1.24V feedback sense voltage for the LM2577-ADJ is referenced to the IC's ground pin, (which is $-V_{IN}$ in this circuit) some feedback level shifting is needed. A PNP transistor is used to sense the output voltage and level shift the output voltage (which is referenced to the positive rail) down to the LM2577 feedback pin (which is referenced to the negative rail). With the values shown, the 5V output causes approximately 300 µA of emitter current to flow through the PNP, down through the 4.12k resistor, developing the needed feedback sense voltage of 1.24V to force the output to be -5V.

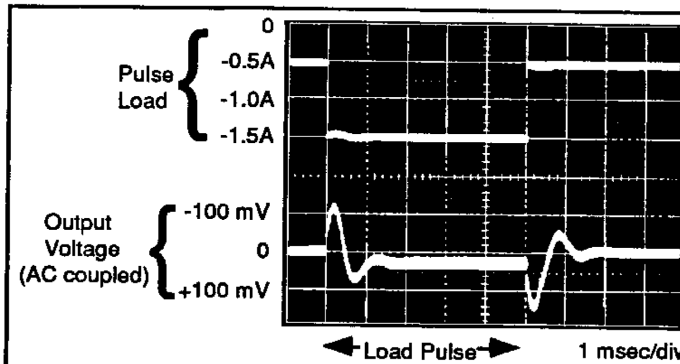
D1 provides output voltage temperature compensation by cancelling out the effects of the temperature drift of the PNP emitter-base voltage. D2 & D3 provide some pre-regulation for the biasing current needed for D1, thus improving both line regulation and 120 Hz ripple rejection by a factor of 2. Additional performance improvement is possible by replacing the two series connected diodes with a 1.2V reference diode such as the LM385-1.2 or the LM4040-2.5. To simplify the circuit, or if the input voltage is relatively constant and has very little 120 Hz ripple on it, D2 and D3 could be eliminated and the 1k & 3.9k resistors could be

Typical Specs for the above circuit are:

Line Regulation (V_{IN} from -10V to -20V)	35 mV (Output decreases with increasing input voltage)
Load Regulation (V_{IN} = 15V, ILOAD from 0.5A to 3A)	45 mV (Output increases with increasing load)
Ripple Rejection (V_{IN} = 15V, 120 Hz, 0.5A Load)	46 dB
Efficiency (depending on input voltage and output load current)	75% to 86%
52 kHZ Output Ripple Voltage (Output capacitor ESR = 20 mΩ)	20 mV p-p

placed with a 27k resistor. Also, eliminating D1 will provide a negative temperature coefficient of the output voltage.

Loop stability is determined by the compensation components (the R & C on pin 1) and also the Equivalent Series Resistance (ESR) of the output capacitor. Different types of output capacitors may need different values of compensation (R & C). Perhaps the easiest method to check compensation is to pulse load the output and look at how the output voltage responds. The capacitor used in this circuit had a very low ESR (20 mΩ) because it was a high frequency "switching type" capacitor. Input voltage may also affect overall stability, so if a different range of input voltages are to be used, the RC components may need some tweaking.



Pulsed Load Response Shows Loop Stability

Other output voltages are also obtainable by varying the 16.5 kΩ resistor. For a stable output voltage, use 1% resistors. Different voltages may need different values of compensation R & C.

The inductor used must be rated for 52 kHZ operation and of course its current rating must be approximately 10% greater than the maximum load current. The inductance value is not critical, and its value can range from 80 µH to 220 µH without any problem. For higher ambient temperatures and at the higher load currents, a small heat sink may be needed on the LM2577-ADJ to keep it at a safe temperature.

Always breadboard your circuit first, (and don't use one of the wireless breadboards because they have to much inductance and stray capacitance for a good switcher circuit), and follow good switcher layout techniques. Keep leads short, especially the schottky catch diode and input and output capacitors. Locate the input capacitor near the input and ground pins of the IC. Use a scope probe with a low inductance ground connection when looking at the switching spikes on the output voltage, otherwise you may be seeing transients that are larger than they actually are.

One additional item. Because of the level shifting circuitry, the minimum input voltage is approximately -8V, and if this voltage is ramped down slowly, (such as when the voltage adjust pot on a power supply is turned) the regulated output voltage will overshoot by approximately 2V before snapping into regulation. Because of the soft start feature built into the LM2577, this 2V overshoot doesn't occur when the input ramps down quickly.

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