Switching Power Supply

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1 A Square Wave Oscillator Using the 555 Timer

The National Semiconductor data sheet for the 555 is LM555.pdf

`http://www.national.com/ds/LM/LM555.pdf`

Link to the circuit diagram for the square wave oscillator:

`http://www.stem2.org/je/swo.pdf`

The component values we used were

$$C_1 = 10\mu F, 16V$$

$$C_2 = .1\mu F, ceramic 104J$$

$$C_3 = 100pF, ceramic 101J$$

$$C_4 = 10\mu F, 16V$$

$$R_1 = 1k$$

$$R_2 = 1k$$

Resistor R_3 is to be computed to give a period of

$$T = 20\mu s.$$

The power supply is a laptop supply giving about 19 volts. The voltage from pin 1 to pin 8 should be about +10 volts. The charge time is

$$T_1 = (R_3 + R_2)(.69)C_3$$

The discharge time is

$$T_2 = R_2(.69)C.$$

So the period is

$$T = T_1 + T_2 = (R_3 + 2R_2)(.69)C_3.$$

$$R_3 + 2R_2 = \frac{T}{.69C}$$

$$R_3 = \frac{T}{.69C_3} - 2R_2$$

If we want the period to be $T = 20\mu s$ then using Matlab we have

```
oscres.m
t=20.e-6
r2=1000.
c3=100.0e-12
r3 = t/(.69* c) - 2*r2
```

We find

$$R_3 = 287.86K\Omega.$$

But for testing we used

$$R_3 = 100K\Omega.$$

So the period should be

$$\begin{aligned} T &= (R_3 + 2R_2)(.69)C_3 \\ &= (100 \times 10^3 + 2(1000))(.69) * 100 \times 10^{-12} \\ &= 7.038\mu s. \end{aligned}$$

2 Creating a Pulse Width Modulator (PWM) Using a Second 555 Timer

For the schematic for the PWM refer to figure 1, or to the following link for a second version:

`http://www.stem2.org/je/swopwm.pdf`

We choose our rectangular wave with a duty cycle close to 100 per cent so that it maintains a constant value until near the end of the period where it dips to zero. This output from the first 555 timer, pin 3 is fed to the input pin, pin 2 of the second 555 timer running in a one shot astable mode. So at the end of the cycle the voltage dips to zero triggering the second 555. The resistor R_4 and C_5 control the length of the resulting pulse to be a portion of the cycle time T. The result is that R_4 and C_5 control the duty cycle of the rectangular wave output from the second 555 timer. This wave becomes a constant voltage when run through a low pass filter. The new PWM circuit is

$$C_5 = 100pF,$$

$$C_6 = 10\mu F.$$

We used

$$R_4 = 50K$$

for testing, but ultimately we will adjust R_4 to give a duty cycle so that we get a 15 volt output of our switching power supply.

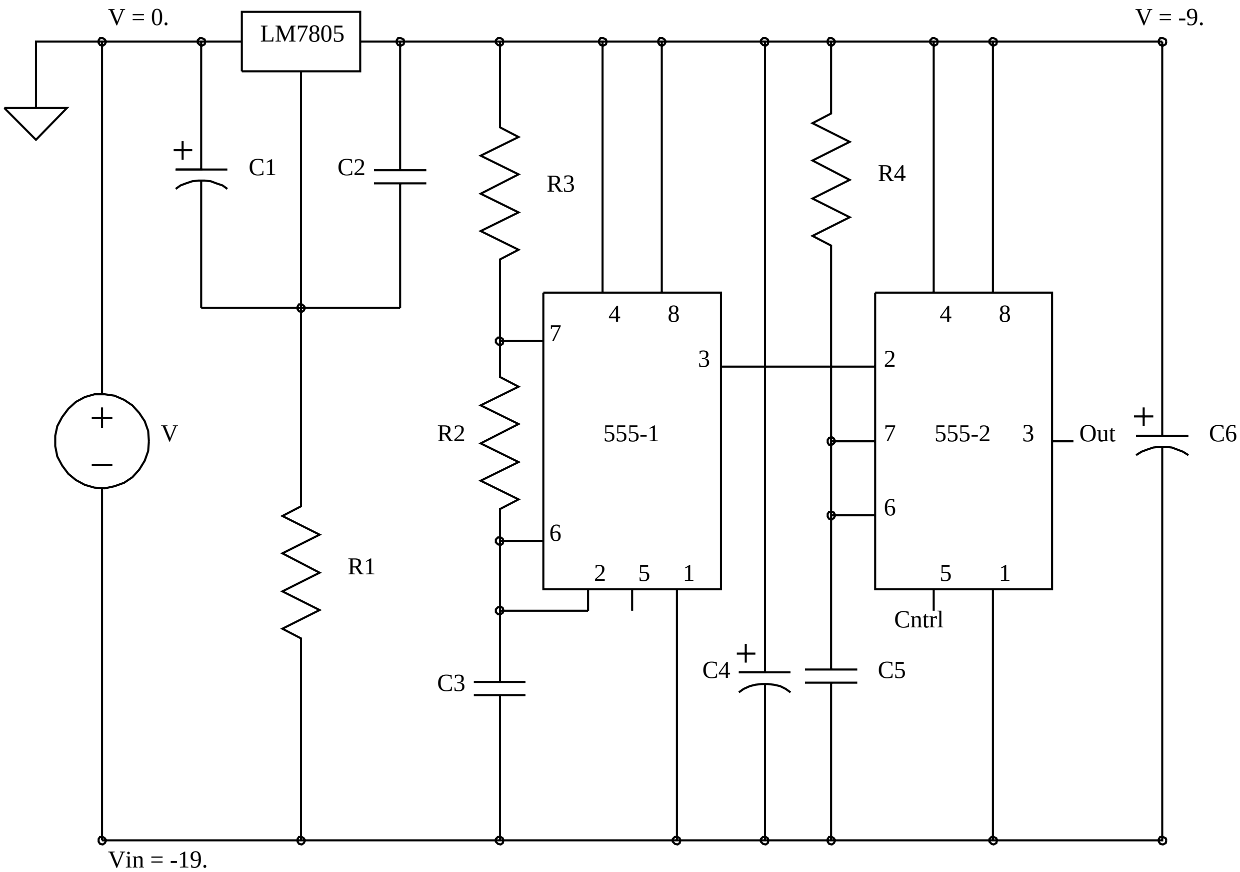

Figure 1: The Pulse Width Modulator. The 7805 five volt regulator is functioning here as a ten volt regulator. This occurs because a constant current of 5ma flows out of the middle pin of the 7805, and produces a constant voltage drop of 5 volts across resistor $R_1 = 1k$. The first 555 timer, 555-1, produces a square wave of period about $15\mu s$. The output is fed to the second 555, to trigger it for one pulse. A control signal is fed to pin 5 of 555-2 which starts a single pulse with duty cycle depending on the signal voltage. The result is a square wave at pin 3 of variable duty cycle. The component values are: $C_1, C_4, C_6 = 10\mu F, 16V$, $C_2 = .1\mu F, 104J$, $C_3, C_5 = 100pF, 101J$, $R_1, R_2 = 1k, R_3 = 100k, R_4 = 56k$. V_{in} comes from a laptop power supply

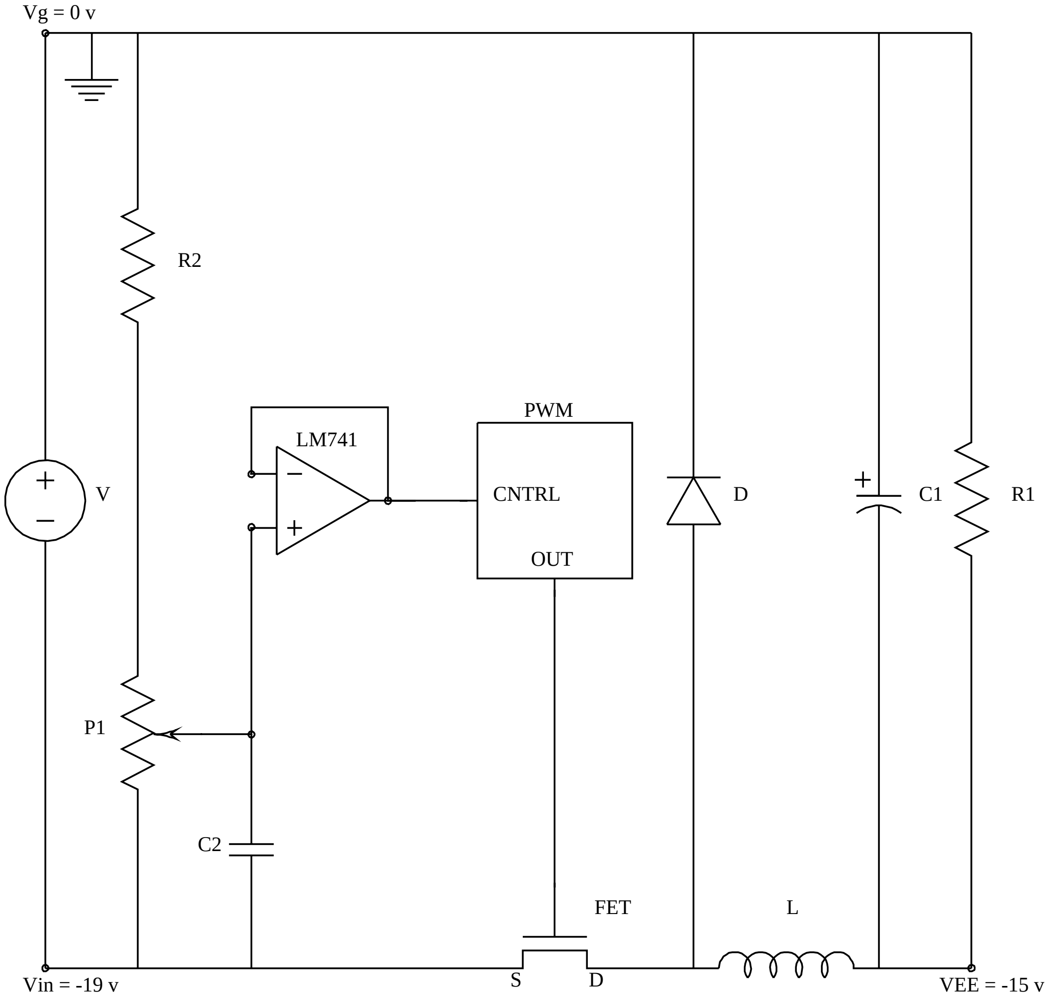

Figure 2: Manual Control.

3 Manual Control of the Output Voltage

Refer to the **Manual Control** schematic diagram. This control uses a potentiometer in a voltage divider and a voltage follower 741 op amp with output connected to the control pin, pin 5 of the one shot 555. So the output voltage is controlled by adjusting the potentiometer manually.

4 Automatic Control of the Output Voltage

Refer to the **Auto Control** schematic diagram. The automatic control contains an LM7805 to provide a constant 5 volt reference voltage, which is fed to the noninverting input of a 741 0pamp. The output of the voltage supply circuit using PWM is supposed to be 15 volts negative. This output voltage is applied to a voltage divider consisting of a 200k resistor in series

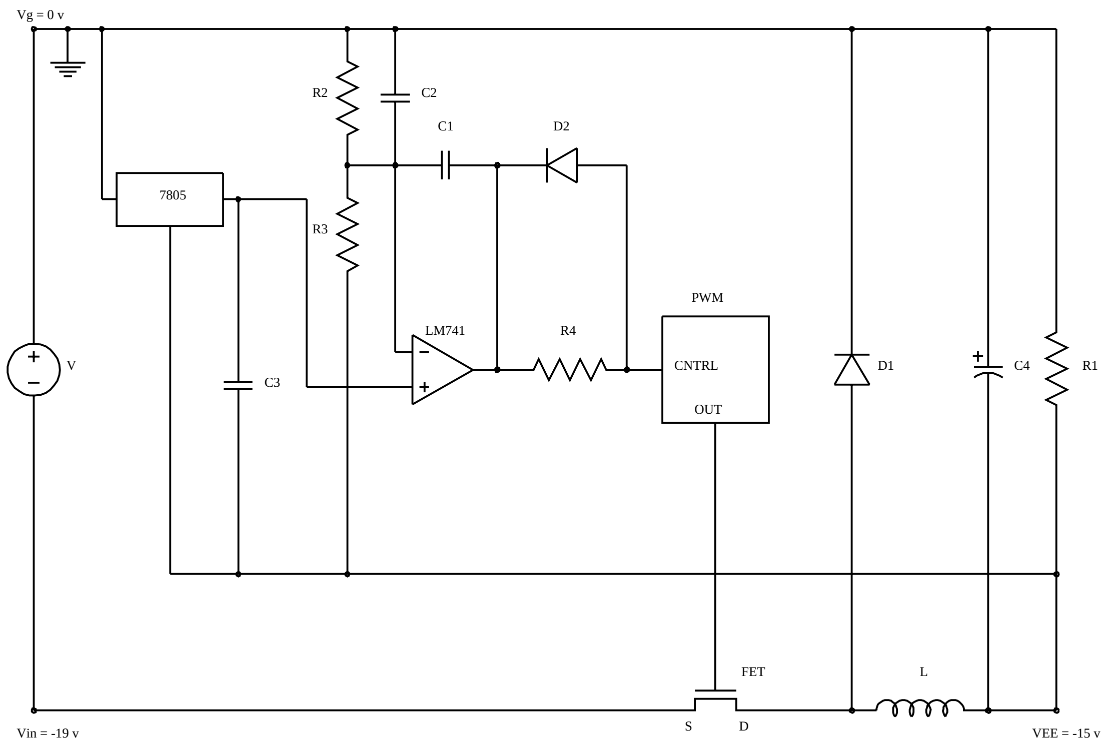

Figure 3: Auto Feedback Control. Values used were: $R1 = 1k, R2 = 200k, R3 = 100k, R4 = 22k$, $C1, C2, C3 = .1\mu F$, $C4 = 50\mu F$, $D1, D2 = 1N4148$, $L = 8mH$. FET is an N Channel MOSFET STP16NF06.

with a 100k resistor. The center tap of this divider is connected to the inverting input of the 741 and should be 10 volts. A feedback capacitor of .1 μ F is connected between the inverting input and the output, thus making the op amp function as an integrator. If the output voltage of the switching power supply rises above 15 volts, there will be different voltages at the inputs of the op amp. This difference is amplified and fed to pin 5 of the PWM. This changes the duty cycle and causes the output voltage to return -15 volts. Thus the output voltage of the supply ic controlled at -15 volts. There is a resistor between the output of the 741 and the cntl pin of the 555, with a diode in parallel. This controls certain problems and helps provide a stable voltage. There is a problem of overshoot on startup. To fix this , a "slow down" capacitor of value $.1\mu F$ is added across the 200k resistor.

Both of the op amp inputs are normally at $-10v$. V_+ is at $V_{EE} + 5v$ because of the 7805 5 volt regulator. V_- is at $2/3V_{EE}$ because of the voltage divider. So if $V_{EE} = -14v$, then $V_+ = -9v$ and $V_- = 2/3(-14) - 9.3333$. The difference is amplified and applied to control pin 5 of the 555_2 one shot to increase the pulse duty cycle, which increase V_{EE}. And so on.

5 Results

The original design goal was a period of $T = 20\mu$sec using an inductance of $L = 2mh$. My value of L is 8 mh. My measured period was 15 μsec. Chris measured his period at $T = 12.2\mu sec$, he used an inductor of $L = 2.2mh$. The output voltage of my negative supply is 15.18 volts. The operating duty cycle of the 555-2, the one shot, looks to be about 20 per cent.

6 The Complete ±15 Volt and $+5$ Volt Supply

Chris completed the entire supply on a small perf board and it works quite well. On 5/4/2011 he outlined the design of the +15 and +5 supplies. They are similar to the negative 15 volt supply, but with the positions of the inductor and diode in the buck converter interchanged.