Electronic Circuit Examples

Jim Emery

3/2/2011

Contents

1 The LM317 Adjustable Voltage Regulator.

Let a resistor R_1 be connected from the output pin to the adjustable pin. Let a resistor R_2 be connected from the adustable pin to ground. The LM317 maintains a current I_q less than $100\mu\Omega$ out of the adjustible pin and a voltage of $v_{ref} = 1.25$ volt drop from the output pin to the adjustable pin. Therefor a current

$$i_1 = \frac{v_{ref}}{R_1}$$

flows into the adj junction. From Kirkoff's current law it follows that current

$$i_2 = i_1 + i_q$$

flows through resistor R_2 to ground. So the voltage drop across R_2 is

$$i_2 R_2 = \frac{v_{ref}}{R_1} R_2 + i_q R_2.$$

Hence the output voltage from the output pin to ground is

$$v_{out} = v_{ref} + \frac{v_{ref}}{R_1} R_2 + i_q R_2.$$

$$= v_{ref}(1 + \frac{R_2}{R_1}) + i_q R_2.$$

Usually the voltage

$$I_q R_2$$

may be neglicted because I_q is small. In a typical application the resistor R_1 might be 240 ohms, with R_2 a 5k potentiometer. For $R_2 = 0$ we get the 1.25 volt reference voltage. For $R_2 = 5k$ we get

$$v_{out} = v_{ref}(1 + R_2/R_1) = 1.25(1 + 5000/240) = 26.$$

```
Reference: The National Semiconductor Data sheet lm117.pdf,
and the Fairchild data sheet lm317fairchild.pdf both located in
c:\je\pdf
```

2 The LM7805 Voltage Regulator.

The LM7805 5 volt regulator, has three pins. Pin 1 takes an input voltage of from +5 to +18 volts. Pin 2, the middle pin is grounded and connected to the negative terminal of the battery. A capacitor C_1 can also be connected between pin 1 and pin 2, $C_1 = 47\mu F$. The output, pin 3, will be at +5 Volts.

For example we can power an LED from the output (See notebook 9-8-2009, p30). When the LED is forward biased (the long lead is positive), it drops about 2 volts. The current through the LED needs to be limited. If we place a 330Ω resister R_1 from the regulator to the LED in series, the current will be

$$i = \frac{5-2}{330} = 9.09 \times 10^{-3} A,$$

about 9 milliamps. One can also place a capacitor $C_2 = 47\mu F$ from the junction between the resistor R_1 and the capacitor C_2 to ground.

This regulator may be used to regulate supply voltages for those ICs that require a 5V input voltage.

Datasheets:

`http://www.st.com/stonline/books/pdf/docs/2143.pdf`

`c:\je\pdf\fairchild7805.pdf`

3 Using the LM7805 Voltage Regulator as an Adjustable Regulator

The LM7805 is used mostly as a 5 volt regulator, but it can be made adustable like the LM317. The difference is that the current I_q out of the adjustment pin is The LM7805 can be adjusted like the LM317, but the reference voltage is 5 volts, and the adjustment current is 5.3 mA, so can not be neglected.

Because this regulator behaves somewhat like the adjustable LM117, we can get an adjusted output voltage V_O using two resistors R_1 and R_2 with the same hookup as with the LM317. Again we have

$$V_O = V_{ref}(1 + R_2/R_1) + I_Q R_2.$$

But now $V_{ref} = 5$ volts, and $I_Q = 5.2mA$ is the current coming out of the middle pin. is an error term. See the Fairchild data sheet about increasing the output voltage.

4 Using the LM7805 to Make a 15 Volt Positive Supply.

Because this regulator behaves somewhat like the adjustable LM117, we can get an adjusted output voltage V_O using two resistors R_1 and R_2. The values for this 15 volt power supply are

$$R_1 = 1k, R_2 = 1k, C_1 = 1000\mu F, 35volt.$$

P is a 100k potentiometer.

The regulator maintains a 5 volt difference between the cntrl pin and the output pin. Also it always maintains a current of $5mA$ into the cntrl pin. So the current through R_1. We have

$$V_O = V_{ref}(1 + R_2/R_1) + I_Q R_2,$$

where $V_{ref} = 5$ volts, and $I_Q = 5mA$ is the current coming out of the middle pin, and so can not be neglected. We find

$$v_O = 5(1 + 1) + 5mA \cdot 1k\Omega = 15v.$$

```
To:
jdemery@member.ams.org
Hi Jim,

This circuit works exactly like the LM317.  The difference is that Vout = 1.25V and
IQ = 100uA for the LM317 whereas the LM7805 has Vout = 5V and IQ = 5mA.
You're probably neglecting the ~5mA difference in IQ.

Please take a look at the enclosed and let me know if that helps.
If you find this useful, feel free to add it to the resources page.

I haven't looked at everything on the stem2 page yet. I spent today tackling this document.

--- On Wed, 1/19/11, jim emery <jdemery1@yahoo.com> wrote:

> From: jim emery <jdemery1@yahoo.com>
> Subject: Power Supply
> To: "chris wilkson" <cwilkson@yahoo.com>
> Date: Wednesday, January 19, 2011, 10:56 PM
> Chris, I have put up a bit more stuff
> on the electronics page of stem2.
> The positive 15 volt power supply using the 7805 works
> great, but I
> must confess that I don't understand how it works. If it
> worked like
> the LM317 variable supply, it would put out about 10 volts.
> So
> I would appreciate an explanation sometime.
>
>
>
```

5 Using the LM7805 to make a 10 Volt Supply to Power a 555 Timer

Uses a 1k resistor from the control pin of the 7805 to the negative supply to give a 5 volt drop across the resistor because the control pin has approximately 5ma flowwing out. This plus the regulated 5 volts by the 7805 gives a sum of 10 volts. A .33μ farad capacitor from input pin to control, and a .1μ farad capacitor from control to output pin.

See electronics class notes, or notebook 2/14/2011 p. 147

6 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`

A resistor $R_1 = 1k$ is connected between pins 6 and 7. A resistor R is connected between pins 7 and 4. Pin 4 is connected to pin 8. Pin 2 connects pin 2 to a ceramic capacitor $C = 100pF$, the other end of the capacitor is connected to ground. Pins 2 and 6 are connected together. The voltage from pin 1 to pin 8 is +10 volts. The charge time is

$$T_1 = (R + R_1)(.69)C$$

The discharge time is

$$T_2 = R_1(.69)C.$$

So the period is

$$T = T_1 + T_2 = (R + 2R_1)(.69)C.$$

$$R + 2R_1 = \frac{T}{.69C}$$

$$R = \frac{T}{.69C} - 2R_1$$

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

```
oscres.m
t=20.e-6
r1=1000.
c=100.0e-12
R = t/(.69* c) - 2*r1
```

We compute

$$R = 287.86K\Omega.$$

If $C = .01\mu F$ then

$$R = 898.5507.$$

7 Using a Positive LM7805 and a Negative LM7905 to Make a Bipolar Power Supply

See Electronics Now, April 1995, page 8. Notebook 2/14/2011 p. 148

8 Operational Amplifiers

An operational amplifier has two inputs called the inverting input and the noninverting input and one output. It has a very high amplification factor α. The ideal operational amplifier has infinite amplification. A practical operational amplifyer has an amplification factor of 200,000 or so. The output voltage is the product of α and the difference ΔE of the two input voltages. This difference is very small. The ideal op amp has infinite input resistance and 0 output resistance. The inverting input is labeled with a $-$ sign and the noninverting input is labeled with a $+$ sign. If the voltage at $+$ is above the voltage at $-$ the output voltage is positive, on the other hand if the voltage at $-$ is above the voltage at $+$ the output is negative, that is, it is inverted. The op amp is powered by a split supply, usually a ± 15 volts with the center of the supply grounded. α is called the open loop gain. The closed loop gain is controlled by external resistors.

8.1 Inverting Amplifier

Suppose the noninverting input is grounded and the inverting input is connected to a resistor R_1 with the signal voltage at the other end of the input resistor R_1. The noninverting input is connected to ground. Let a second resistor R_2 be connected from the inverting input to the output. Because the voltage difference between the noninverting input and the inverting input is approximately zero, the voltage at the inverting input is zero. if V_i is the input signal voltage applied at the left end of R_1, then the current through the resistor R_1 is

$$I = \frac{V_i}{R_1}.$$

Now the current into the inverting input is approximately zero, so the current I also passes through the second resistor R_2. It follows that the voltage drop across R_2 is IR_2 and this is the magnitude of the output voltage V_o. Now the voltage at $-$ the inverting input is above the voltage at $+$ the noninverting input so V_o is negative. Thus

$$V_o = -IR_2 = -V_i \frac{R_2}{R_1}.$$

So the closed loop gain is

$$-\frac{R_2}{R_1}.$$

So the output voltage is negative if the input voltage is positive.

8.2 The 741 Operational Amplifier

The eight pin 741 has the following pins numbered from the upper left corner counterclockwise:
1 offset null
2 inverting input
3 noninverting input
4 power negative
5 offset null
6 output
7 power positive
8 not connected

9 A Relay Oscillator

Book Make:Electronics p60

10 Stepper Motor

Stepper motor driver chip for ten dollars in paper cup. Rob Giseburg

11 Servo

Operated it with the Arduino.

12 Micro Controller: Arduino

13 Make: The Laser Light Show Variable Power Supply

Data sheet for LM117 (LM317 similar to LM117) link:

`http://www.national.com/ds/LM/LM117.pdf`

```
Saved file:
c:\je\pdf\lm117.pdf
```

See Notebook p137 10/23/2010.

14 The 555 Timer

I'm running late. Way, way late. I won't make it to class until 8pm tonight. Sorry. But anyone who wants to can start the lab without me. We will be building/discussing square wave generators using the 555 timer chip. (NE555, LM555, etc)

First, confirm that your 10V supply is operating correctly. Power it using your 19V laptop supply. And remember that we are using it as a MINUS 19V input....so System GND is the positive lead of the laptop supply. You can use a multimeter to measure the output voltage, but you should also use the 'scope to verify that it is a "clean" 10V supply, no oscillations, etc. You should get somewhere between 9V and 11V....the exact value isn't critical this time.

If your laptop supply has a 3-wire power cord then the output COULD be Earth referenced. Be careful connecting the scope probes' GND lead. But if it's got a 2-wire power cord then it is not earth referenced. So it is ok to connect the scope GND lead directly to System GND.

Next, please read the ASTABLE OPERATION section of the 555 datasheet (starts on page 7) and construct the astable oscillator shown in Figure 4. You should use the following values: RB=1k, C=100pF. You can use the formulas given or you can use the graph in Figure 6 to obtain a value of RA that gives you a 20us period (50kHz frequency). Power the circuit with your 10V supply and measure the period and the duty cycle of the output (Pin 3) using the 'scope.

The 555 datasheet is here:

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

I'll be there ASAP. Looking like 8:15-ish after typing this up.

15 Chris Wilkson's Analog Electronics Class

Oscilloscope probe:

`http://www.stem2.com/je/probe.pdf`

Audio Amplifier:

`http://www./stem2.org/je/opamp_audio_amplifier.html`

Power Supply:

16 Experiments From "Make: Electronics"

See notes with sketched circuit diagrams.

17 Buck Converter

Wikipedia:
"buck converter"

```
Saved pdf print files (c: \je\pdf):
12/02/2010  03:39 PM          341,681 buckconverterecircuitcenter.pdf
12/02/2010  03:29 PM          560,879 buckconverter.pdf
```

18 Types of Capacitors and Labeling

`http://www.dsaprojects.110mb.com/electronics/data_book/capacitors.html`
`Stored as the pdf document: c:\je\pdf\typesofcapacitors.pdf`

A ceramic capacitor labeled 104J. Means 10×10^4 pF, with a J tolerance. This is

$$10 \times 10^4 \times 10^{-12} F$$

$$= 10^{-7} F = .1 \mu F = 100 nF,$$

with a tolerance of 5 percent.

A capacitor labeled 101J is

$$10 \times 10^1 \times 10^{-12} F = 100 pF = .1 nF$$

Tolerances:
J tolerance ±5 percent.
K tolerance ±10 percent.
M tolerance ±20 percent.

Little orange capacitors labeled $2700K \times 5F$ measured 2.3 nF. Explanation:

$$2700 pF = 2.7 nF$$

19 A Negative Power Supply Using the 15 volt LM7915 Negative Voltage Regulator

Looking at the LM7915 from the front (the back is the metal plate that bolts to a heat sink), the pins are from left to right, ground, input, and output. So the middle pin is the input pin. The voltages at the input and the output will be negative with respect to ground. The power supply consists of a transformer supplying on the order of 25 to 35 AC volts. The AC voltage is connected to a bridge rectifier. The plus DC output of the bridge rectifier becomes our ground connected to the ground pin of the LM7915, and the negative DC output of the rectifier is the input to the LM7915 ground pin. A 1000 μ farad, 50 volt electrolytic capacitor C_1 is connected across the output of the bridge rectifier. A 1.0 μ farad 35 volt tantalum capacitor C_2 is connected from the LM7915 output pin to ground (both C_1 and C_2 are electrolytic capacitors, C_2 has metal plates made of tantalum). So the plus side of the capacitor C_2 is connected to the plus side of the bridge rectifier, and to the plus side of the capacitor C_1. The output voltage of the LM7915 will be -15 volts with respect to ground, that is to the plus side of the bridge rectifier.

20 Switching Power Supplies

21 Measuring Transistor Parameters

Consider the circuit

which uses the 2N3904 NPN transistor. Looking at the flat side of the transister the pins from left to right are E (emitter), B (base), and C (collector). The transistor is powered by about -15 volts. Resister R_C connects the collector to the positive side of the power supply, which is called v_+. Resistor R_E connects the negative side of the power supply, which is called v_-, to the emitter. A pair of resistors in series, R_{B2} and R_{B1}, connect v_+ to v_-. The center point of the pair is connected to the base of the 2N3904. These resistors form a voltage divider.

Measured resistances for a specific circuit are

$$R_{B2} = 19.95K, R_{B1} = 9.88K$$

$$R_E = 9.92K, R_C = 9.90K.$$

Measured voltages are

$$\Delta v = v_+ - v_- = 15.11, v_{R_{B2}} = 10.06, v_{R_{B1}} = 4.95$$

$$v_{R_C} = 4.22, v_{R_E} = 4.30,$$

$$v_{BE} = 0.68$$

We calculate a positive voltage that we call

$$v_B = (v_+ - v_-) - v_{R_{B2}} = 5.05$$

$$I_C = \frac{v_{R_C}}{R_C} = 4.262626262626262 \times 10^{-4}$$

$$I_E = \frac{V_{R_E}}{R_E} = 4.334677419354839 \times 10^{-4}$$

$$I_B = I_E - I_C = 7.205115672857614 \times 10^{-6}.$$
$$\beta = \frac{I_C}{I_B} = 59.16110797060481$$

Matlab program transistor.m

```
% Transistor measurements
format long
rb2 = 19.95e3
rb1 = 9.88e3
re = 9.92e3
rc = 9.90e3
%\[v_+ - v_- = 15.11 ,
dv=15.11
vrb2 = 10.06
vrb1= 4.95
vrc= 4.22
vre= 4.30
vec=6.74
vbe=.68
%We calculate
vrb1= dv - vrb2
ic=  vrc/rc
ie= vre/re
ib=ie-ic
beta=ic/ib
%Thevinin method
rt=(rb1*rb2)/(rb1+rb2)
vt=dv*rb1/(rb1+rb2)
ib=abs(vt-vb)/rt
beta=ic/ib
```

Output of Matlab:

```
14-Jan-2011
>> transistor
rb2 = 19950
rb1 =  9880
re =9920
rc =9900
dv =15.11000000000000
vrb2 =10.06000000000000
vrb1 =4.95000000000000
vrc =4.22000000000000
vre =4.30000000000000
vec =6.74000000000000
vbe =0.68000000000000
vrb1 =5.05000000000000
ic =4.262626262626262e-004
ie =4.334677419354839e-004
ib =7.205115672857614e-006
beta =59.16110797060481
rt =6.607643312101911e+003
vt =5.00458598726115
ib =6.872951609793594e-006
beta =62.02031535551981
```

If we break the circuit at the connection to the base and at the supply voltage v_-, the circuit to the left consists of a power supply voltage source of $\Delta v = 15.11$ volts, and the two resistors R_{B1} and R_{B2} in series. Shorting the voltage source, we find a Thevenin equivalent resistence of the two resistors in parallel

$$R_T = \frac{R_{B1} R_{B2}}{R_{B1} + R_{B2}}$$

and an equivalent voltage source v_T consisting of the open circuit voltage seen at the two terminals. This is the voltage divider voltage

$$v_T = \Delta v \frac{R_{B1}}{R_{B1} + R_{B2}}.$$

Then the positive current flow I_B into the transistor is

$$I_B = \frac{|v_T - v_B|}{R_T}.$$

We have taken the absolute value because we know that the current flow into the base is positive, and we have taken all of our voltages as absolute values, and possibly disregarded some signs. Notice that this Thevinin method of computing I_B does not require I_C or I_E and its difference, which is good because these two numbers are nearly equal and computing this difference could lead to roundoff error. However v_T and v_B are also nearly equal, but probably not so nearly equal. So this method is probably better provided that the resistance and voltage values are measured quite acurately.

22 Measuring the Inductance of a Coil Scavenged From A PC Powersupply

Used the function generator in the cave. Hooked up both the function generator and the Oscilloscope across the inductor (actually one side of a transformer wound on a torroid of unknown material. Had some trouble getting the triggering to work and the amplitude set so that I obtained a reasonal sin wave. Set triggering to vertical rather than automatic finally. Adjusted the function generator amplitude. So reducing the frequency to 550 Hz (5.5 Hz, with 100 multiplier button) got about half the amplitude of that amplitude for higher frequency. So see the formula in ee.tex. For f= 550 Hz got an inductance of about 8.353 mH. The winding appears to have about 25 turns. So Chris wanted an inductance of about 2mH. Thus the number of windings should be reduced to about

$$n_2 = \sqrt{2./8.353 n_1}.$$

which is about half of 25.

Chris measured his coil at an inductance of $1.84mh$.

$$L = \frac{R}{2\pi f\sqrt{3}},$$

where $R = 50\Omega$. So he must have measured a frequency of

$$f = \frac{R}{2\pi L\sqrt{3}} = 2.50 \times 10^3 Hz$$

Program frequency1.m

```
format long
R= 50.
L = 1.84e-3
f= R/(2.* pi * L * sqrt(3.))
```

Used octave, matlab, and Python for calculation, I think l.m, or inductor.m and l.py.

23 Digital Electronics

24 Chris Wilkson, Feb 23, 2011 email

```
Feb 23, 5:44 pm
From: Chris Wilkson cwilk...@gmail.com
Date: Wed, 23 Feb 2011 15:44:57 -0800 (PST)
Local: Wed, Feb 23 2011 5:44 pm
Subject: I can't make it to class tonight - but please continue without me!!

Chris Wilkson
```

Hi all, Through a comedy of errors, I got practically no sleep today. I'm dead tired and don't thinnk it would be safe for me to drive anywhere tonight. The good news is that you all can work without me this week. First, finish the 555 astable oscillator that is make the period close to 20 microseconds with a largish duty cycle. The exact numbers are not critical. And remember to add a 10uF capacitor across the 10V supply if you haven't already. You might also want to add a 0.01uF cap from pin 5 of the 555 to the negative supply, VIN. Note: upon further thought, I realized it is better to connect the negative lead of those capacitors to the negative supply, VIN in this case, instead of SYSTEMGND. Do that for all 3 of them. Then add a second 555 timer, in monostable mode, to complete your PWM generator. You can get the monostable circuit from the 555 datasheet. Use the 10V supply to power both 555's. The oscillator's output will be connected to the trigger input of the monostable and the PWM signal will come from the monostable's output. You should try to make the default duty cycle of the PWM output equal to the ratio of your measured Vin (about 19V) to the desired 15V, ballpark of 75. I hope that all makes sense. If you are feeling adventurous, use the 100k pot to form a voltage divider between v10v and vin. Connect the output of the voltage divider to pin 5 of the monostable 555. You should then be able to control (crudely) the duty cycle of the PWM output. A smaller value pot should give you a little better control. (Why is that?) I think everyone got the first 555 circuit working last week. So don't worry if you missed last week...there should be folks on hand to give group help. hack away! -Chris

25 Bibliography

[1]Platt Charles, **Make: Electronics**, O'Reilly, 2010.

[2]Coughlin Robert F, Driscoll Federick F **Operational Amplifiers and Linear Integrated Circuits**, Prentice-Hall, 1991, 4th edition (Linda Hall).

[3]Roberge James K, **Operational Amplifiers, Theory and Practice**, John Wiley, 1975, (Linda Hall).

[4]Wedlock Bruce D, Roberge James K, **Electronic Components and Measurements**, Prentice-Hall, 1969 (Linda Hall).

[5]Massobrio Giuseppi, Antognetti Paolo **Semiconductor Device Modeling with SPICE**, 2nd Edition, McGraw-Hill, 1993.

[6]Kaplan Daniel M and White Christopher G. **Hands-On Electronics: A Practicle Introduction to Analog and Digital Circuits**, Cambridge

University Press, 2003. This is a book for a laboratory course designed for physics and engineering students, written by two physicists. KCK Library.