ELECTRONOTES

WEBNOTE 10/15/2012

ENWN7

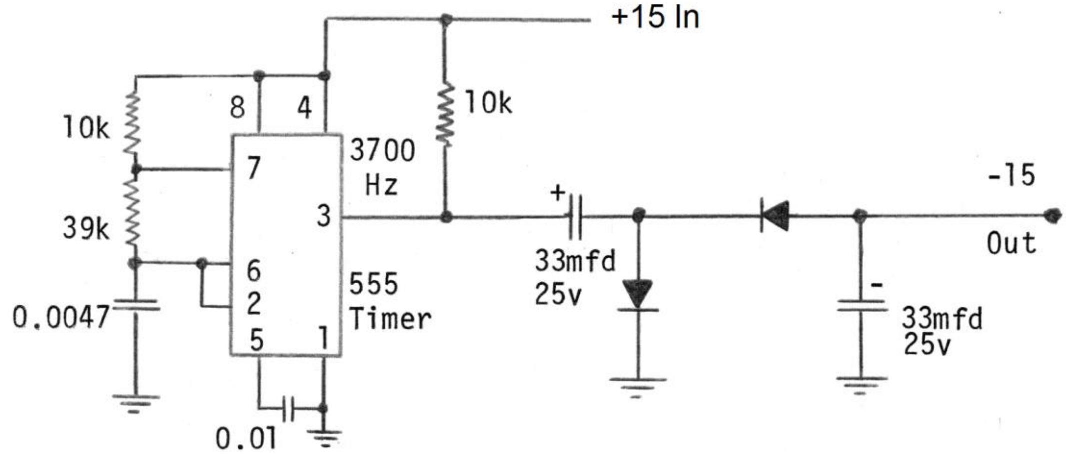
NOTES ON A "DERIVED" NEGATIVE SUPPLY

Recently my attention came back to an old app note: "An Op-Amp Supply Based on a 12.6V Filament Transformer", AN-136, June 15, 1979. The goal then was to make available a usable op-amp bipolar supply from a readily available and inexpensive transformer. This we thought of as a ±15V supply, which was the standard we were using at the time. As stated in the original AN, getting +15 was a stretch, but possible, as long as we did not need a lot of current. Thus we thought of this as a means of powering an individual unit, not a large studio setup. In this view, obtaining the -15 without an additional transformer was also an attractive option.

Here are a number of points to address about this at the present time.

(1) There is an error on the schematic in Fig. 3. Pins 1 and 5 of the 555 timer are reversed. Thanks to Kelly Heaton for noticing this. The correct connections are shown below. This is the standard 555 "square wave" generator. So it is pin 1 that is grounded and pin 5 that is connected to ground through a 0.01 mfd capacitor. (Recall that this capacitor stabilizes an internal connection of the 555 and is strictly not essential – but always used.)

Fig. 3



(2) It also bothers me that the provenance of the original circuit is not clearly at hand. From the AN, there is the reference to the ***Wireless World*** item of A. Pongsupaht of April 1978, so this is certainly where I got it from. I do not however have a copy of the article. I wonder if they still have WW in the library (do they still have libraries even!). So I don't know if there were prior references given there. It is clear from the internet that the circuit (with different component values) is widely posted there, without acknowledgment to Pongsupaht, <u>or to anyone</u> for that matter. Admittedly, the idea is simple (just the steps of Fig. 2 from AN-136 reprinted here below)

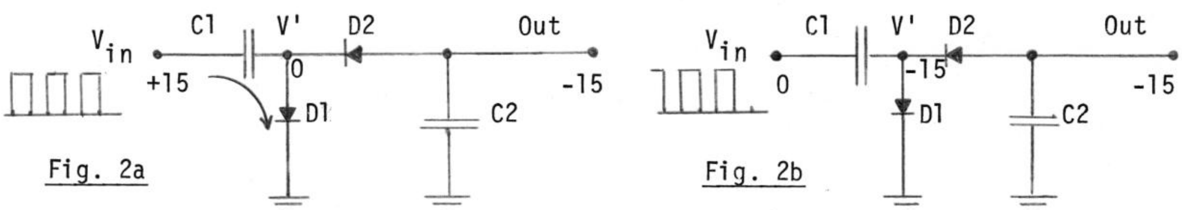


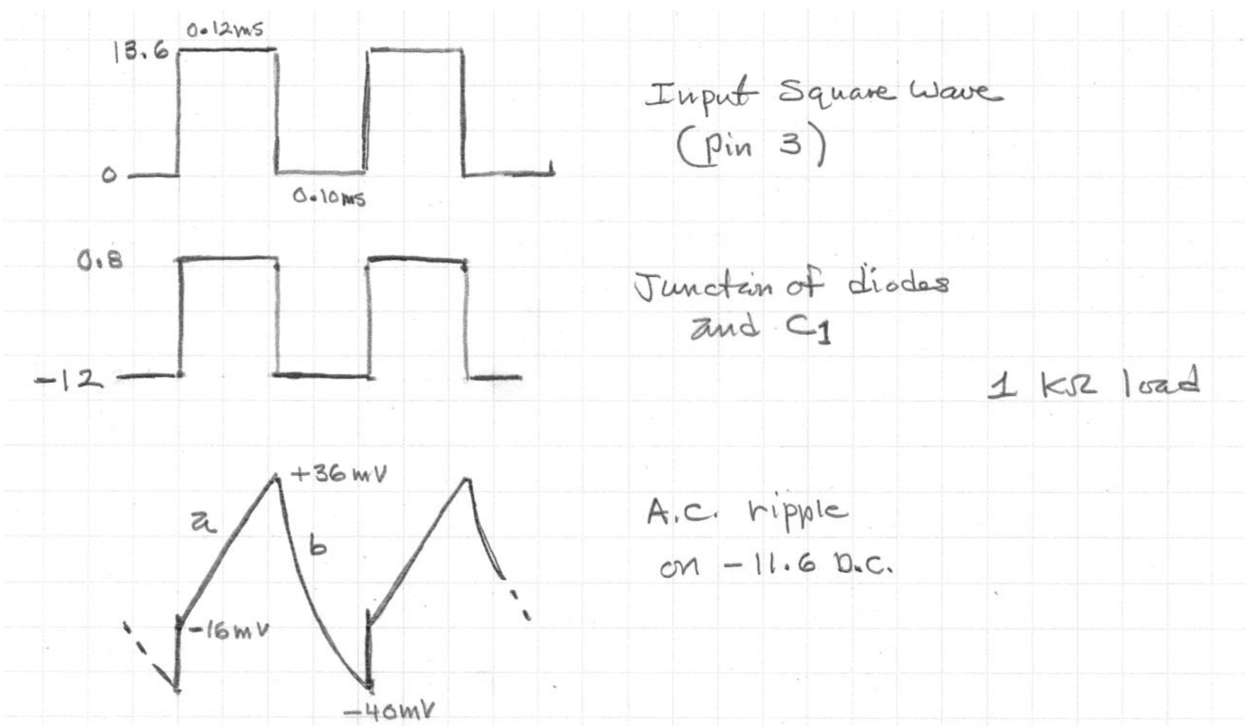
Fig. 2a Fig. 2b

and the rest is just a standard 555 oscillator. So perhaps the real thing I was looking for was more data relating to performance – which I did not find, except people saying that you couldn't expect more than 30 to 50 ma.

(3) So we build the thing and try it. I built it exactly as in Fig. 3 (the first figure in this webnote). Here is what I found.

(a) The square wave was indeed from 0 to about +14.6. The supply measured 14.6. The frequency was about 4540 Hz, and the symmetry was off a bit, about 0.12ms high and 0.10ms low. The output voltage was -13.6 (no load) with no AC ripple.

(b) Now I attached a lk load, and the output dropped to -11.6, so the current drawn by the load should have been 11.6 ma. This causes a measurable ripple on the DC output, as sketched in the figure below. Here we show three waveforms. The top is the square wave at pin 3. The middle is the junction of the two diodes with the capacitor C1. Basically this is the same as the square-wave input, except shifted by about -12 volts.



The bottom is the AC ripple, which has a total peak-to-peak amplitude of about 76 mV. Each full cycle of this ripple has three features, a segment "a", a segment "b", and a sudden glitch. We start with the segment we think we can understand well – segment "a". Here capacitor C2 is charged to a negative DC level (about -11.6 volts), and the voltage at the "junction" is near zero, so D2 is biased off.

This means that a current discharging C2 passes through the load resistor. Since the time intervals of the segments are short (about 0.1 ms) compared to the RC time constant (33 mfd x 1000 ohms or 33 ms) the discharge is small and can be considered near linear. [Don't be misled (as I was at first) into thinking that the discharge was segment "b". The segment "a" is aimed upward because it is discharging from a negative value toward zero.] Indeed, segment "a" appears quite straight. Further, the current is near constant at 11.6 ma. Thus using **i = dq/dt = Cdv/dt**, is it true that:

$$0.0116 = (33\times10^{-6})\times(0.052/0.00012) = 0.0143$$

No – but that is not bad at all, considering.

Segment "b" is more difficult. In general, we see that it is just the recharge – the diode D2 switches on to feed C2 (which continues to need to supply the output current). The charge curve is not linear, and in fact it appears exponential. But what is the resistance here – the resistance of the diode? All and all, it's complicated, and a more thorough analysis would seem necessary if warranted. The vertical-going "glitch" is unexplained, but not uncommonly seen, and often found in 555 circuits. The sharp edges of the square waves in the figure are by no means not perfectly sharp either.

(c) Does this square with the quoted performance of AN-136? Well – ballpark. Using a 3k load (should be about 3 ma) in the equation above we expect 9 mV (the note says 4 mV) and an AC meter says 6.6 mV RMS.

(d) But why the voltage drop? Why only 11.6 volts – lower with a smaller load resistance than 1k? Various discussions on the internet say this is because of the diode drops. Well, it's not – or at least only in part. What is going on? As far as I can see, of about 20 presentations of this circuit idea (often as a "charge pump") in the internet, no one addresses this. That is, it is sometimes presented as data, but no one tells us how to calculate the DC level based on the load current.

(e) Below are some experimental observations:

Load Resistor	V_J "DC" at C1,D1,D2	Measured Output Voltage V_N	Calculated Current	Pin 3
infinite	-6.23 *	-13.9 *	0	0 to +14.7 **
	(0 to -14.7) ***			
3k	-5.16 *	-11.9 *	3.97 ma	0.1 to +13.3 **
	(+0.6 to -12.7) ***			
1k	-5.02 *	-11.6 *	11.6 ma	0.2 to +13.0 **
	(+0.6 to -12.5) ***			
510 ohms	-4.87 *	-11.1 *	21.8 ma	0.2 to +13.0 **
	(+0.7 to -12.0) ***			
200 ohms	-4.47 *	-10.3 *	51.5 ma	0.5 to +12.8 **
	(+0.7 to -11.3) ***			
100 ohms	-3.95 *	-9.04 *	90.4 ma	1.0 to +12.5 **
	(+0.7 to -10.2) ***			

* digital multimeter

** scope *** scope high and low of square wave

The other "observation" deals with changing the capacitors. Putting an additional 33 mfd capacitor in parallel with C1 changes nothing. Putting an additional 33 mfd in parallel with C2 reduces the AC ripple by a factor of 2, but does not change the DC voltage. So in looking for an equation for the output voltage, it seems that neither C1 nor C2, nor their ratio, is involved. Further, both C1 and C2 are pretty much fully charged to 10-12 volts. This can be measured directly (indeed the voltage on C2 is V_N). The voltage on C1 is also the difference between the square waves in the sketch above.

We note the voltage denoted V_J the “junction” between C1 and the two diodes. This is the negative-going square wave of the sketch. This we have carefully measured as the DC average of the square wave with a digital multimeter, and as the actual high and low levels with a scope. Unfortunately these two measurements don’t seem that consistent.

What we do find is that the most negative values of V_J are rather consistently just about a diode drop below the output voltage (0.8V to 1.16V). This is what we would expect, if we think of the D2-C2 circuitry as a damped (by R_L) “peak detector”. The other thing to note is that the voltage levels at pin 3 have a smaller range as the load is decreased. That is, we load down the IC as we might anticipate. Thus, it is the 555 dropping its output that is really the effect we see. In fact, if we take the level-to level output range at pin 3, and multiply it by a factor ranging from 0.95 (at $R_L=\infty$) to 0.79 at $R_L = 100\Omega$, this works reasonably well to give the negative output voltage.

So, while lacking the “design equations” we hoped for, we do confirm the conventional wisdom that you can expect to lose a volt or two in amplitude, should not try to draw more than about 20-30 ma, and can expect an AC ripple of perhaps 10 mV (which can be decreased by increasing C2).

That’s it, but……

Comments about this circuit are welcome.