HARDWARE HACKER

Solid state visible laser
Laser hacking resources
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Picking filter capacitors

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WE SEEM TO HAVE A PAIR OF REALLY unusual new hacker components for this month. One is a micropower FM stereo multiplexer, while the other is a solid-state red visible-laser diode. But first, let's discover a real simple answer to what seems to be an unduly complex question.

Ripple-filter capacitors

How do you pick the correct value of ripple-filter capacitance for a line-operated power supply? Some of the older textbooks will give you wildly wrong curves that just do not apply to today's circuit components.

But I will let you in on an insider secret—you can *instantly* choose the right value of filter capacitor for any line-operated power supply simply by memorizing a unique capacitor value of 8300 microfarads, and then remembering an ultra-simple rule.

These days, you usually use a *brute-force* capacitor AC-input power supply driven from a pair of silicon rectifiers, or else a full-wave silicone rectifier bridge. One or more voltage regulators will normally get placed between your brute-force supply and the actual circuit.

Figure 1 shows you two typical line-operated full-wave power supplies. We'll assume that a transformer is used to drop the voltage down to an acceptable value. You could use a center-tapped transformer and two diodes, or else an untapped transformer winding and a four-diode full-wave bridge.

NEED HELP?

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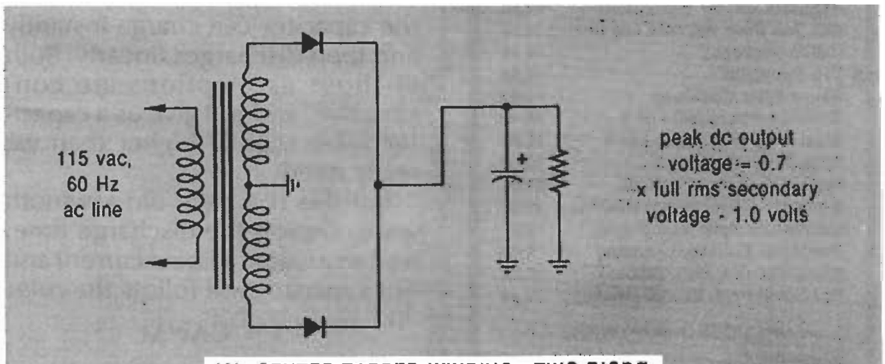
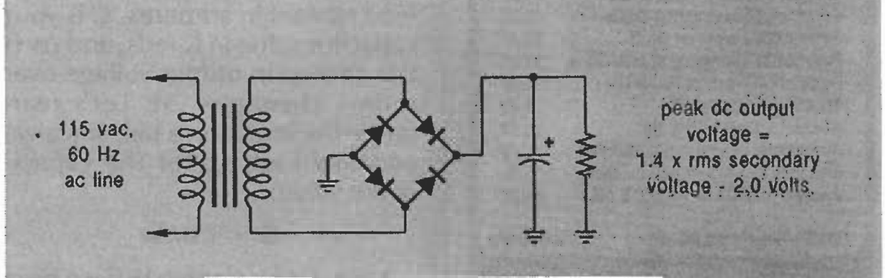
In Fig. 1-*a*, your peak output voltage will equal 0.7 times the full RMS transformer secondary voltage under load, minus a volt or so for the diode drop. In Fig. 1-*b*, the peak output voltage will equal 1.4 times the RMS transformer secondary voltage under load, minus two volts or so for the series drop of two diodes.

For instance, if you are using a 12.6-volt-RMS center-tapped filament transformer in the Fig. 1 circuit, the output voltage will be (12.6 × 0.7) − 1 = 7.8-volts DC peak voltage. In the real world, you'll allow a tad extra and expect a little less.

Contrary to a popular belief, those diodes do *not* conduct for an entire half cycle. In fact, each diode will intensely turn on very



(A) CENTER-TAPPED WINDING, TWO DIODE



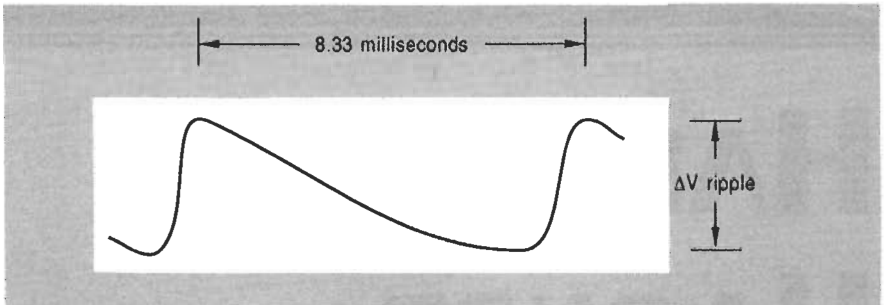
(B) SINGLE WINDING, FULL WAVE BRIDGE

FIG. 1—TYPICAL FULL-WAVE LINE-OPERATED "brute force" DC power supplies. Picking the correct value for a ripple capacitor turns out to be a lot easier than you might first suspect. The resistor can represent a voltage regulator or other circuit load.

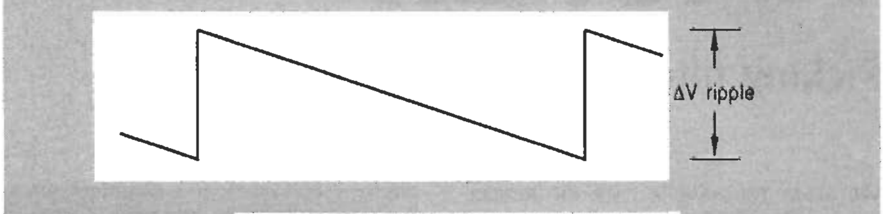
briefly during the *middle* of each half cycle, thus delivering a large current slug into the filter capacitor at that time.

Figure 2 shows you the actual and the simplified ripple waveform across your capacitor. Normally, you will want to design for some reasonable amount of ripple. Otherwise the capacitor value gets too high and the current slugs through the diodes get excessive. You do have to make sure that the ripple troughs do not crash into your regulator headroom.

What happens is that a diode will turn on only when its input voltage exceeds the capacitor voltage. That will occur only briefly at the very center of each half cycle. Twice during each AC line cycle, that capacitor will quickly charge. It will then discharge for the rest of the half cycle. The discharge rate is determined by the load resistance, or else by the load current drawn by the regulator and the circuit being powered.



(A) THE EXACT RIPPLE FILTER WAVEFORM



(B) APPROXIMATE SAWTOOTH WAVEFORM

FIG. 2—THE EXACT AND APPROXIMATE voltage waveforms as found across the ripple-filter capacitor. Note that the diodes conduct only briefly during the middle of each AC-line half cycle. The capacitor supplies the load energy for the majority of the time.

**In an 8300 Microfarad Capacitor,
the VOLTS of ripple will equal
the AMPS of load current.**

FIG. 3—MEMORIZE THIS MAGIC VALUE and do simple scaling to instantly calculate the correct-size filter capacitor. For half-wave supplies, simply double the final capacitor size.

Let us make several simplifying assumptions, which can clean up the waveform to make it much easier to analyze. Let's assume that the capacitor can charge instantly and then discharges linearly. Both of those assumptions are conservative, and will give us a capacitor value slightly higher than we really need.

But this is a plain old sawtooth wave. During the discharge time, we can assume a linear current and our capacitor will follow the rule:

$$i = C\Delta v/\Delta t$$

Here, i will equal your discharge load current in amperes, C is your capacitor value in Farads, and Δv is the change in output voltage over a time change of Δt. Let's rearrange the equation a tad, since we are now looking for the capacitance value:

$$C = i\Delta t/\Delta v$$

Next, let us assume that we have one amp of load current and discharge one volt during a half power cycle, which equals $\frac{1}{120}$ Hz, or 0.00833 seconds, or 8.33 milliseconds. The magic capacitance value that handles that is 8.33 millifarads, equal to 8330 microfarads—let's say 8300 μF for short.

Which leads us to the magic rule of Fig. 3: In an 8300-μF capacitor used in a full-wave line-operated supply, *the volts of ripple will equal the amps of load current.*

Any other capacitor value is found by scaling. You do not even need to use a calculator. For instance, an 830-μF capacitor will yield one volt of ripple with 100 milliamps of current drain. A 1660-μF capacitor will give you one volt of ripple for 200 milliamps of current. Or to get slightly fancier, a 700-mA supply allowing three volts of ripple will need a capacitor value of:

$$8300 \times \frac{700}{1000} \times \frac{1}{3} = 1917\mu F$$

Call it an even 2000μF to round off to the next highest stock value. The capacitance value will vary *directly* with your load current and *inversely* with the allowable amount of output ripple.