# Me and My Stupid Old PMOS Converter

*At last, there's an easy way to get –12 V from a +5-V supply. Who said "trial and error"?*

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Stupid old PMOS. It's slow, it runs hot, it gives protective input diodes a workout because its output low can go below ground, and it needs weird supply voltages. Most of the newer NMOS devices have been designed to make do with one 5-volt supply, either by some design rethinking or by inclusion of a substrate charge pump on the chip itself, but stupid old PMOS has to have strange supply levels provided in order to operate.

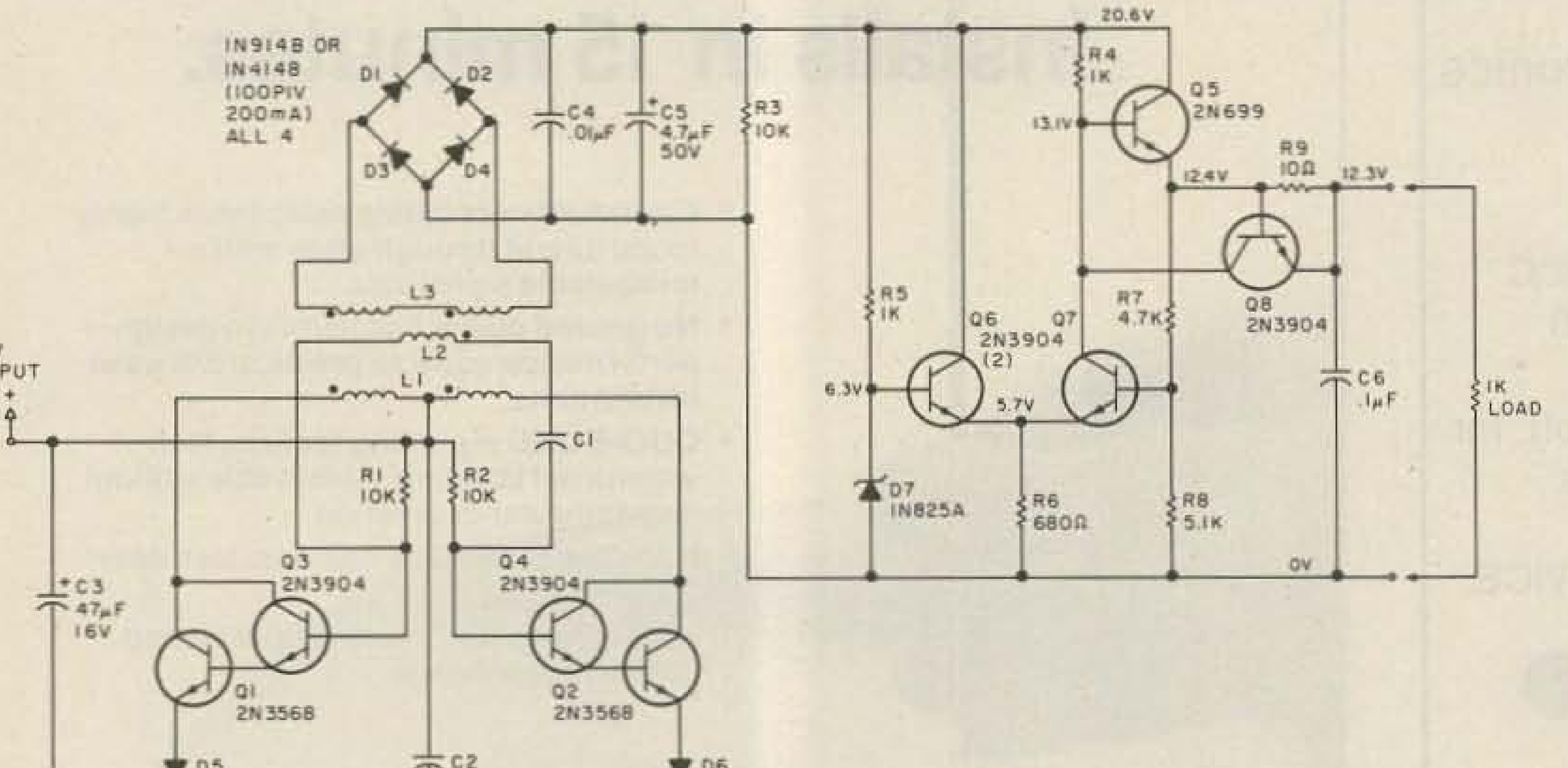



*Fig. 1. Initial version. With 9 to 19 volts input, and the right toroid, this circuit might provide 50 V output. L1 is 10 bifilar turns #28, L3 is 25 to 50 bifilar turns #28 (I used 25 turns), and L2 is 8 to 10 turns #26. The toroid is a .375-inch ferrite from a Radio Shack "Ferrites" package. Capacitor C1 resonates with L2 to determine oscillating frequency; 200 pF is probably a good minimum value to keep interwinding capacitance from getting into the act. The transistors came from my junk box; the numbers listed are their rough functional equivalents. With different devices, the regulator circuit could waste a lot less current.*

It was that last gripe that had me stymied for a while. I have an old keyboard from some junked phototypesetter somewhere, bought for all of ten bucks. It's TTL throughout, with maybe ½ A drain on the 5-V, 3-A supply in my home-brew Cosmac Elf. (One miserable PMOS shift register does have to have a −12 supply if I want anything but smoke from it.) At that, the keyboard outputs some weird code that makes sense only to the machine for which it was designed. A local outlet sells a keyboard encoder, the AY-5-2376. If I kludge-wired that onto the keyboard in place of the original logic, I'd have good old parallel ASCII coming out of a single 40-pin chip, made of. . .PMOS. Yep—it needs a −12 supply, drawing maybe 4 mA. I should build an *additional* line-powered power supply for *that?*

I've seen a few upconverter circuits around; most use

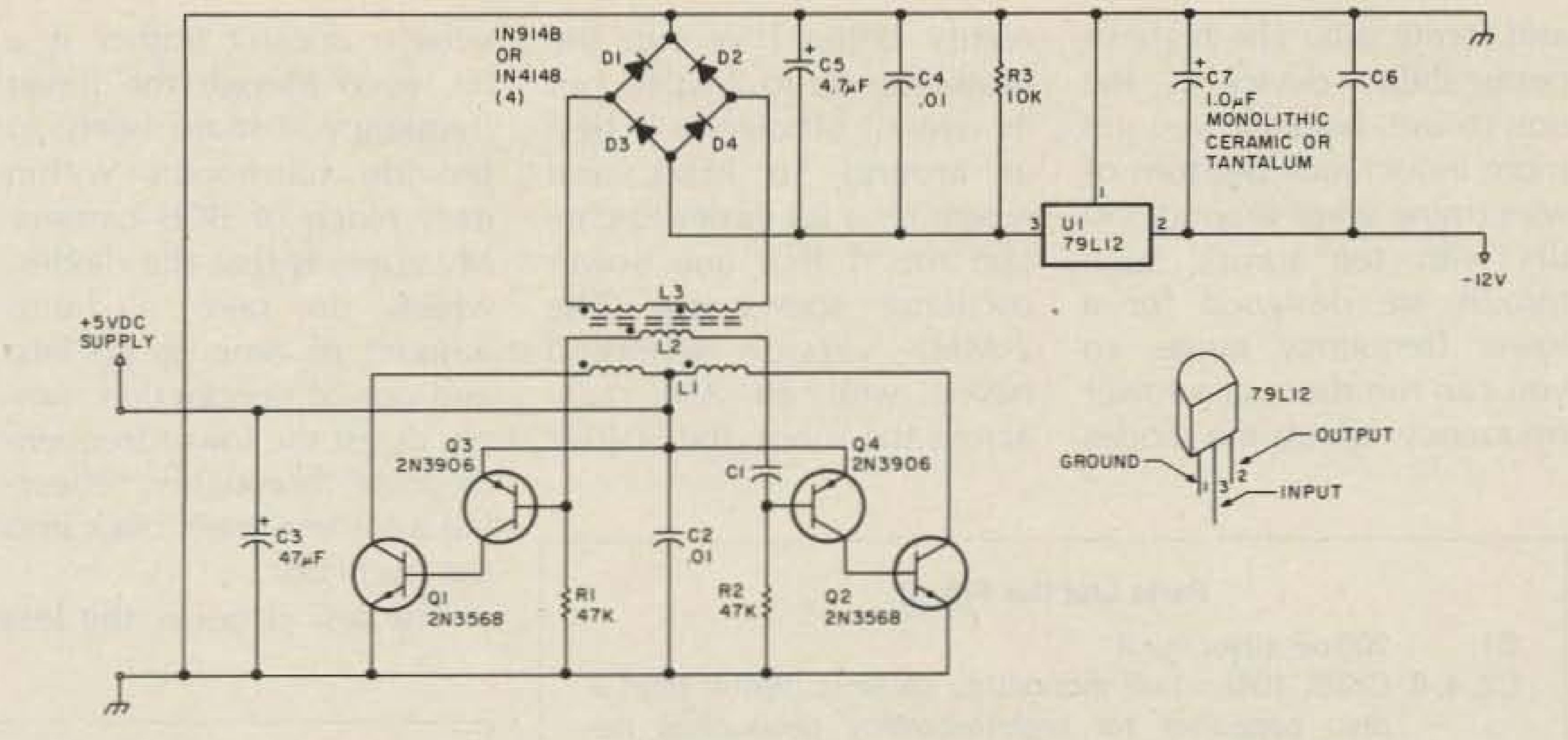



*Fig. 2. 5-volt-input version. Note that L2's phase is reversed. Equivalent transistor types again. The 79L12 only burns about 4 mA.*

555s and voltage-doubler chains. Motorola even has one with a 7406. Somehow, all these capacitor-pulse designs struck me as being wasteful, inadequate, or both.

I'm a bit of a QRPp nut, and I have the toroids to prove it—some from Radio-kit and Amidon, some from those blister cards Radio Shack started selling a year or so ago. I got out my dipper and my boxes of small-signal transistors, turned on the 'scope and the Weller, and waded in.

The first circuit I built does fine with at least 9 volts for a supply. The rectified secondary voltage soared up to 90 volts at one point in my experimenting—no load. That's why I put in the 10k load resistor, to keep the voltage within the survival zone of the diodes, to say nothing of any regulator I might care to put in.

As for the regulator circuitry, I must admit that I was playing. I had already decided to put a 79L12 in the finished unit, but I didn't have one on hand as yet, so I kludged this one up in order to see how much fun I could have putting together a regulator. If you look closely, you will see not only that I've abused the reference diode (which prefers to conduct only about 7.5 mA), but also that the converter is cranking out upwards of 25 mA, still with enough input headroom to the pass transistor for it to regulate. The medium-current pair of transistors in the oscillator got warm, but not hot, and nobody seemed to be hurting.

Then I dropped the supply rail to 5 volts, and the output got very mushy...maybe 8 volts across the output load resistor.

The problem is in the Darlingtons. I put in the second pair of transistors, Darlington-style, because the medium-current transistors weren't being driven fully under load, thus, there was not enough gain at the frequency in use. The added pair corrected that but brought in a new problem: The saturation voltage ($V_{CE\text{-}sat}$) for a Darlington pair, measured from the ganged collectors to the lower emitter, is one $V_{CE\text{-}sat}$ plus one $V_{BE}$ for a typical circuit, because the driver-half emitter is held high by the final-half base-emitter diode (one $V_{BE}$), and their collectors are tied together. The collector of the driver-half can't do more than saturate—it can't go lower than its emitter. More current into either the driver's base or the two collectors only drives both voltages higher, making the problem worse. I was losing virtually 2 $V_{BE}$ on each side of the main winding, even with the protective series diodes shorted out. That's fine for circuits with, say, 9 volts or more rail-to-rail, but down at a 5-volt supply level, the missing voltage swing was proportionately too large to be ignored.

At this point I remembered the composite PNP in the final stage of National's LM380, and the final version started emerging on paper.

I have even more voltage gain here, because the driver stage is running common-emitter rather than the common-collector driver in the Darlington version. More important, the final stage is free to pull its end of the transformer's main winding as low as possible, roughly 0.2 volts with these particular parts. That means that the total possible swing for the transformer, ignoring coil losses, is 9.6 volts—much better. Of course, I've ignored here the effect of available voltage swing on circuit impedance, which affects the available juice (wattage) from what is, in effect, a self-excited balanced transmitter. I chose a more rudimentary approach, one within my immediate comprehension. In other words, I'm lazy, so I just called it an astable multivibrator and I played around with it until it worked.

It works. The keyboard converter starts up every time and feeds a dead quiet −12 volts to the shift register. It'll do the same for the 2376 instead, when I get around to the surgery involved. Then there's that Motorola character generator for translating ASCII into a video bit stream; that needs two weird voltages—and it's NMOS! That just means there'll be two secondaries on the toroid. I've even got a couple of PMOS character generators that need ±14 volts.

There are several points of design and technique to be mentioned here. First, most bipolar transistors behave very nicely like zener diodes when their bases are driven 5 to 10 volts more negative than their emitters (positive for PNPs). Unfortunately, the localized heat in the base region of the transistor chip causes permanent changes in the doping arrangement, so the beta goes down. This is why most multivibrator designs have diodes with high PIVs in them, to keep the sharp negative spike through the capacitor from doing damage. If you are running such a circuit with a supply higher than 5 volts, you must have them too. Otherwise, if the 'scope shows that the collector voltage has a needle-thin negative spike going lower than ground on the falling edge of its waveform, your transistors are being degraded even as you watch.

The second point is one of balance. Some of Doug DeMaw's QRP amplifier designs are *crawling* with toroids, just to swamp out tolerances and force a 50% duty cycle in the output signal. I got by with just one toroid by using the twisted-pair wiring shown, but a little artistic symmetry in windings placement is required too. Caveat constructor.

The third point is the toroid itself. I used some from those Radio Shack packages, and they work very well. The ones you will pull out of there might not—it's a matter of size and ferrite mix. The highest-permeability device is the one to use, because you get more inductance per turn of wire (mine were around 350 uH with ten turns). Such toroids are designed for a lower frequency range, so you can run them at a lower frequency, where the diodes rectify better (I've run the prototype up to 2 MHz, but its overall efficiency is best at around 50 kHz), and where it's a lot easier to contain the rf that any power oscillator spews out. The 2-MHz version wreaked havoc with an AM radio across the room; the 50-kHz version doesn't bother it a bit, even though the lower frequency is more likely to provide harmonics within easy reach of BCB carriers. My guess is that the diodes, which do take a finite amount of time to go into and out of conduction, simply digest the lower frequency more thoroughly, reflecting a lot less trash back into the oscillator.

The less rf noise, the less shielding is required, and the less hassle you have arranging for air flow to carry heat out of that shielding.

My converter simply sits parked in one corner of that keyboard, unshielded, kludge-wired into holes drilled in an etched-clean section, making less noise than the keyboard scanning clock.

Obviously, anywhere one or two greedy little circuits demand a strange supply

**Parts List (for Fig. 1)**

| | |
|---|---|
| C1 | 200-pF silver mica |
| C2, 4, 6 | CK05, 104k, .1-uF monolithic ceramic (Better than a disc capacitor for high-frequency decoupling because the internal sandwich construction results in a low-inductance package. Substituting for one usually involves a .01-uF disc ceramic paralleled with a .001 disc or a 100-pF silver mica. Here, a .01-uF disc will do.) |
| C3 | 47-uF, 16-V aluminum electrolytic |
| C5 | 4.7-uF, 50-V aluminum electrolytic (Up to around 25 uF is useful at this current level; more than that can cause start-up problems for the oscillator, due to loading.) |
| D1–6 | 1N4148 or 1N914B switching diodes |
| D7 | 1N825A temperature-compensated reference diode (It consists of a reverse junction in the same package with a forward junction; at 7.5 mA of current through the diode, the complementary temperature coefficients of the two junctions cancel each other out. With the voltages shown, the current through the diode in Fig. 1 is nearly double the correct value, which doesn't hurt it but wastes both the current and its compensation. Newark Electronics' Catalog 105 lists it for $1.90.) |
| L1, 2, 3 | See text |
| Q1, 2 | NPN medium-current switching transistors (The faster the better. I used 2N3568 equivalents; 2N2219A is easier to find.) |
| Q3, 4 | NPN switching transistors (The faster the better. 2N3904 is widely available.) |
| Q5 | NPN medium-current transistor (Speed isn't critical, but gain and wattage are. I used a 2N699, which is barely adequate. It should be at least a heat-sunk 2N2219A, maybe a TIP48. Better to be overcautious on wattage than to worry about its surviving a short or a still-air heat buildup.) |
| Q6, 7, 8 | NPN small-signal transistors (I used 2N3904 equivalents. With higher beta, resistor values in the regulator may be raised, conserving current. Beyond the voltages shown, start paying attention to the collector-voltage ratings of these devices.) |
| R1, 2, 3 | 10k, ¼-W (With the regulator in place, R3 isn't really necessary, but it's a cheap security blanket.) |
| R4, 5 | 1k, ¼-W (As mentioned, R5 should be a 1.8k.) |
| R6 | 680-Ohm, ¼-W |
| R7 | 4.7k |
| R8 | 5.1k (The regulator (Q5–7) regulates by keeping the R7-R8 voltage divider's tap at the same voltage as the reference (6.3 V in Fig. 1). Their ratio sets the output voltage.) |
| R9 | 10-Ohm (This resistor sets the current-limiting level. When the voltage across it reaches the .6-V turn-on threshold of Q8, Q8 will begin stealing base current from Q5, turning it off. With this value for R9, that's at 60 mA output.) |

**Parts List (for Fig. 2)**

| | |
|---|---|
| C1 | Select in test (200-pF starting value, may end up at .01 uF or higher. In order of preference: NPO ceramic, polystyrene, silver mica, mylar™, disc ceramic. The higher the frequency, the more the capacitor's quality matters. 220-pF silver mica: Jameco DM15-221J, 49¢.) |
| C2, 4, 6 | .1-uF monolithic ceramic or .01-uF disc ceramic (.01 uF: Jameco DC.01/50, 8¢.) |
| C3 | 47-uF, 10-V electrolytic (47-uF, 16-V: Jameco A47/16, 24¢.) |
| C5 | 4.7-uF or more electrolytic (Working voltage should be at least 1½ times unregulated output voltage. 4.7-uF, 50-V: Jameco A4.7/50, 19¢.) |
| C7 | 1.0-uF tantalum or 10-uF aluminum electrolytic. (Working voltage should be significantly higher than regulated output voltage. 1.0-uF, 35-V tantalum: Jameco TMI/35, 29¢.) |
| D1–4 | 1N4148, 1N914B, or other silicon signal diodes (Should be rated for minimums of 50 PIV, 50 mA continuous forward current, maximum switching time 10 ns or so. 1N4001-type rectifiers can't switch fast enough. 1N4148: Jameco, 15/$1.00. Fairchild rates these devices at 100 PIV, 200 mA, 4.0 ns.) |
| L1, 2, 3 | Windings are determined by application and circuit values. See text and schematic for prototype values. Bifilar windings are prepared by twisting twin lengths of pretensilized wire with electric drill to 10–20-turns-per-inch pitch. Toroid is from Radio Shack package of ferrites. A good equivalent is Micrometals FT50-43: Radiokit, 60¢. |
| Q1, 2 | NPN medium-current switching transistors—2N2219A, MPSU06, 2N3568 (Dissipation limit should be at least ½ W. 2N2219A: Jameco, 2/$1.) |
| Q3, 4 | PNP switching transistors—2N2907, 2N3906 (The faster the better. 2N3906: Jameco, 4/$1; Priority-One #052N3906, 5/$1.) |
| R1, 2 | 47k, ¼-W (Priority-One #05RCQ473L, 50/$1; Radio Shack #271-1342, 5/39¢.) |
| R3 | 10k, ¼-W (Priority-One #05RCQ103L, 50/$1; Radio Shack #271-1335, 5/39¢.) |
| U1 | Motorola 79L12 in prototype (Device choice depends on application. PC layout will accept 78XX, 79XX, LM340, and LM320 devices with inline pins (L, P, M, T types). Check pinout before installing. Positive regulator may be used to regulate negative voltage by making regulator output common. 79L12: Priority-One #05MC79L12CP, $1.00.) |

Converter will be most efficient in a frequency band whose low end is determined by transformer reactance and whose high end is determined by transistor and diode speeds and capacitor quality.

voltage, you can now satisfy them, literally on the spot.

This circuit can go in any number of directions. A better design could probably run an 8080A chip set with just 5 volts input. If you have both phases of a convenient frequency clock available, you can slave the converter to the clock and save yourself a few parts, guaranteeing the converter start-up in the process. A couple of VN10KMs (VMOS) would probably suffice, provided only that the clock signals swing fully rail-to-rail. (TTL typically needs a pull-up resistor to hoist its output above 3.5 volts.) Somebody else will probably put me to shame with the efficiency of their version, but that's okay; I just wanted to get that keyboard running on just a +5-volt supply. Stupid old PMOS.■

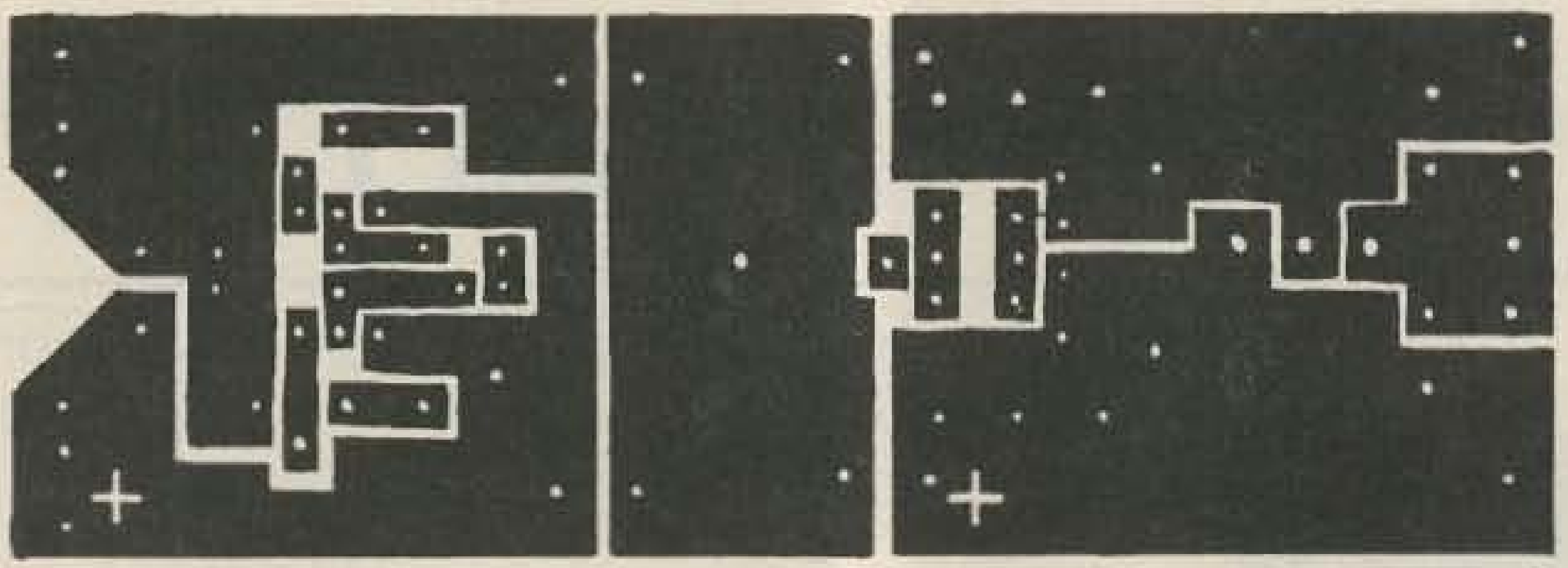
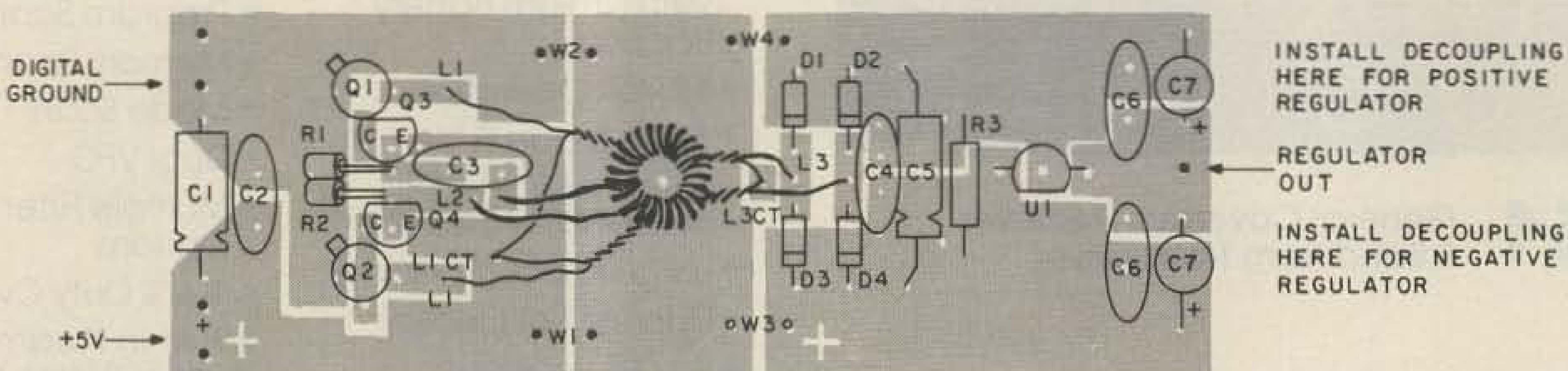


*Fig. 3. PC board for the 5-V version.*




JUMPERS W1-W4 ESTABLISH GROUNDING, IF ANY

(U1 MAY BE 78XX OR 79XX DEPENDING ON APPLICATION. TO-92, TO-220, VERSAWATT PACKAGES WILL FIT.)

*Fig. 4. Component layout.*