

12VDC to 160VDC Low power Transformerless Inverter

This document describes how the circuit operates.

OVERVIEW

The power supply is best described as a "flyback switching regulator" supply. Although such a supply can be implemented in many ways, the one shown here is implemented with inexpensive, commonly available parts. It also uses an off-the-shelf inductor, so no special winding or transformer is needed.

As shown, the supply converts +12.0VDC into "high tension" voltage. The "open circuit" output voltage is about 172VDC, and the supply "idles" with 12V and 15 mA input. With a 75 mA load, the supply produces about 158 volts. At this point it is drawing 1.24A from the 12V source.

CIRCUIT

A CMOS 4049 Hex inverter package is used as the heart of the circuit. Three of the inverter sections are connected as a Schmitt trigger oscillator. The basic frequency is about 30kHz, but varies with line and load changes. The oscillator is U1A,B,C. The basic frequency is primarily controlled by R2 and C5. The "duty cycle" of this oscillator controls the output voltage and regulation of the output voltage. This uses one of the inverters (U1F) as a comparator. CMOS will sort of act as an inverting op-amp, whose output is "centered" when the input is "centered" on the supply voltage. Thus, with a 12V input, the output (pin 12) will be 6 volts when the input (pin 13) is 6V. The gain of this stage is relatively low (10-30) so the output regulation is not spectacular, but, no stability problems will be encountered. With "no load" pin 13 is about 8.2V, and decreases towards about 5V at maximum load.

The duty cycle of the oscillator is controlled by coupling this comparator into the oscillator via R7. R5 provides a "maximum" duty cycle control so the circuit always oscillates. If you have trouble with the oscillator producing too high a duty cycle, R5 may be lowered.

U1E provides a delayed "startup" of the supply, so that any circuit hooked to the output of this supply remains unpowered for about 40 seconds. This allows tube heaters to become warm before applying HT voltage. The delay time is controlled by R11, C7. The supply is "enabled" when Pin 10 goes low. If this never happens, the probable cause is leakage in C7 or D5 backwards.

The "switch" is powered by an isolating inverter stage U1D and "totem pole" transistors Q1 and Q3. These provide adequate drive to supply the gate capacitance of Q2. Q2 is the switch transistor. It "charges" inductor L1 when it is "on", and the inductor "discharges"

into D1 and the load when Q2 is "off". For output voltages of 190V or less, an IRF640 is the best choice of part. For output voltages greater than this, use an IRF740, which will work to almost 400V. There is a tradeoff between efficiency (how much power is consumed at 12V for a particular power output) and this part. For low output powers (20 mA or so at 170 volts) an IRF630 is a better choice, as it's lower gate capacitance provides better efficiency. The '640 allows output currents up to about 100 mA (and 150 volts), but is slightly less efficient, as it has increased gate capacitance. The IRF740 allows higher voltages and currents, but consumes more input power (relatively). Only a couple of watts is dissipated in Q2, so it doesn't need a LARGE heat sink, but does need to have some heat sinking. If you need to provide lots of power, (higher voltages and/or currents) use a larger heat sink.

D1 NEEDS to be a fast recovery part. A 1N4007 is doomed in this application.

The output voltage is determined by D2, D3 and the voltage division of R9 and R10. Note that D4 is "never turned on". This part is used as "overvoltage" protection. It may be successfully eliminated from designs using the IRF740, and sufficiently high voltage part at C6.

To change the output voltage, the simplest way is to change R9. One mA flows in this chain (at no load) providing a relatively easy way of calculating the open circuit output voltage (assuming you remove D4 for voltages greater than about 180V).

Vout approximately equals 139 + R9 value in kohms. For example, to provide 250 volts, use an IRF740, remove D4, and choose an open circuit voltage of perhaps 259 volts. Then R9 will need to be 120k. For 150 volts output, choose open circuit voltage of perhaps 157 volts, making the R9 value 18k.

INDUCTOR

This part NEEDS to be able to handle lots of current without saturating. To get more power output, the inductor value needs to be DECREASED somewhat. For the supply as shown, the 250 uH inductor shown in the Mouser catalog as 70-IHA-103 should work. For much higher power applications, the 70-IH3-250 or IH3-150 or IH10-100 can be used. Other suitable inductors from the Mouser catalog: 542-5254 (250 uH 2.5A) or 542-5252 (125 uH 3.5A). Notice that all these are "solenoid" style inductors. Getting a toroid NOT to saturate is tricky, and best avoided.

NOTES

Build the circuit with the connection going to Q2 gate missing, and the gate of Q2 grounded instead. You should be able to confirm oscillator etc operation. (If you don't have a 'scope, this will be indicated by the voltage at Q1/Q3 emitters starting about 0 volts,

then after the 40 second timeout period, this voltage should go to about 6-8 volts DC (NOT 12V, as it should be switching, not constant DC voltage). After you get to this point, disconnect the input 12V, and make sure there is not a short on the output, (ohming it out), and establish the connection indicated above, completing the supply.

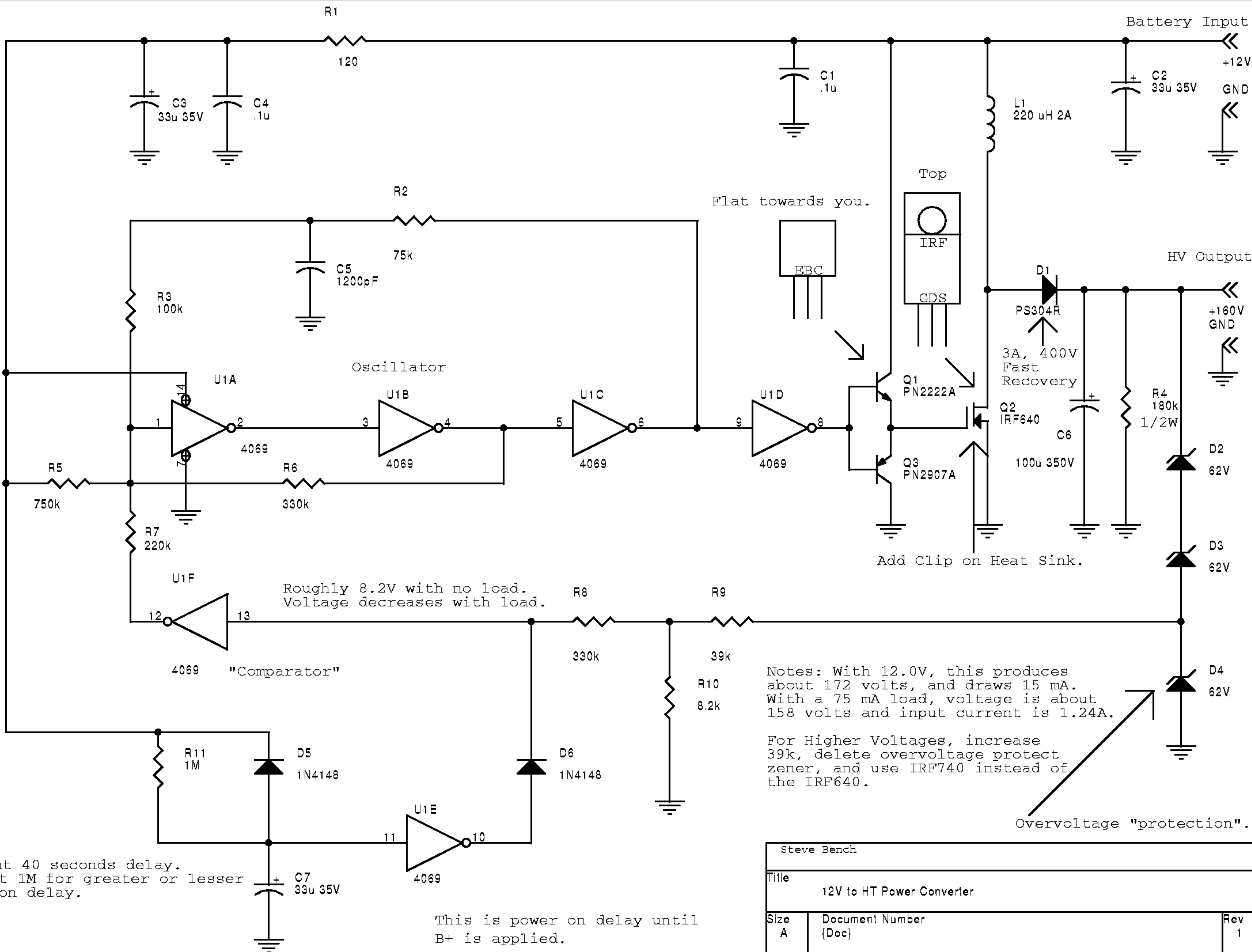
If the output voltage is WAY OFF, you will need to find out why, using the circuit description above.

When you have things operating, the FET should not be HOT, not the switching diode D1, nor the inductor L1, although they will get WARM in normal operation. U1, Q1, Q3 should never even get warm.

This circuit is REALLY not for beginners.

There is considerable RIPPLE current at the supply frequency on the battery. This can couple into your AUDIO circuit. Depending on your application, you may want to put an additional LC filter on the input 12V. (Say 200 uH and 1000 uF)

The output contains perhaps 50-100 mV of ripple on it. This can be eliminated with traditional RC or LC filtering.



Flat towards you.

Oscillator

"Comparator"

Roughly 8.2V with no load.
Voltage decreases with load.

Add Clip on Heat Sink.

Overvoltage "protection".

Notes: With 12.0V, this produces about 172 volts, and draws 15 mA. With a 75 mA load, voltage is about 158 volts and input current is 1.24A.

For Higher Voltages, increase 39k, delete overvoltage protect zener, and use IRF740 instead of the IRF640.

About 40 seconds delay. Adjust 1M for greater or lesser turn on delay.

This is power on delay until B+ is applied.

Steve Bench		
Title 12V to HT Power Converter		
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