APC Smart Uninterruptible Power Supply

2018 RECF ELECTRONICS ONLINE CHALLENGE SPONSORED BY TEXAS INSTRUMENTS

VRC TEAM: 7682S

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***APC Smart UPS 750VA*[(1)]**

An uninterruptible power supply (UPS) is a device which provides power to a system whenever its primary input power source (e.g. mains power) fails.

It has 5 main components[(2)]:

- Battery (backup power source when mains power fails)
- Power inverter (changes DC from battery to AC)
- Battery charger (charges battery when mains power is available)
- Power relay (switches to backup battery source when mains power fails)
- Line voltage cut/boost (main voltage outside nominal range)

I chose to dismantle a decommissioned APC Smart UPS 750VA in order to discover any faults with the device. At some point, the UPS had started to get excessively hot and release fumes. However, the front panel indicated normal functionality and the device still passed self-test every day.

Device layout

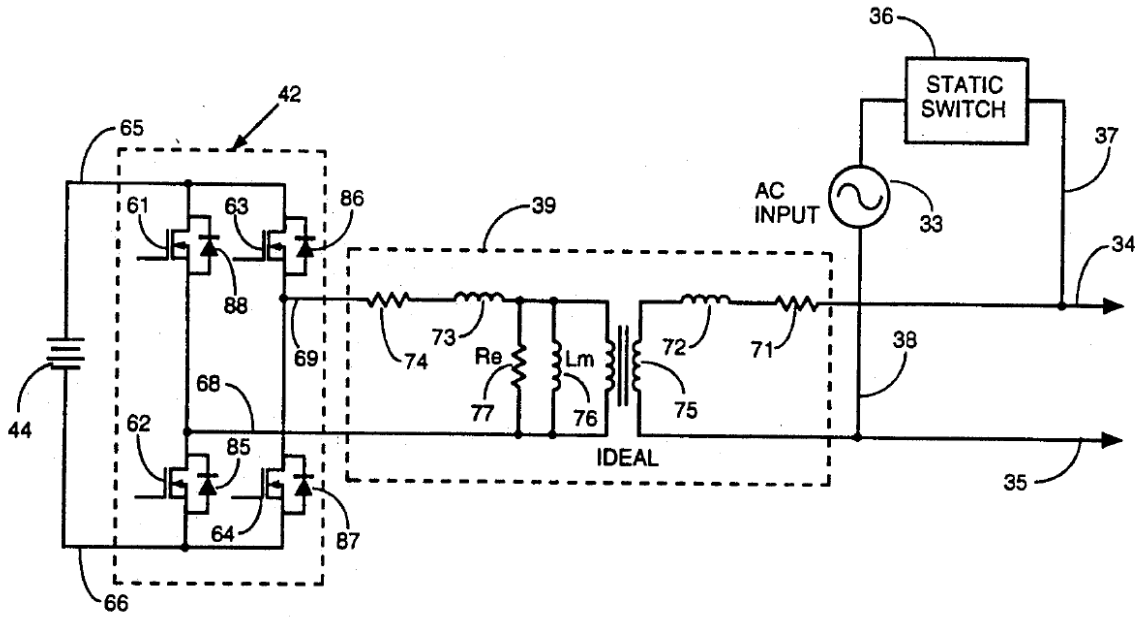


Diagram from patent application (method and apparatus for providing battery charging in a backup power system)[3]

Figure 1. Excerpt from U.S. Patent No. 5,302,858

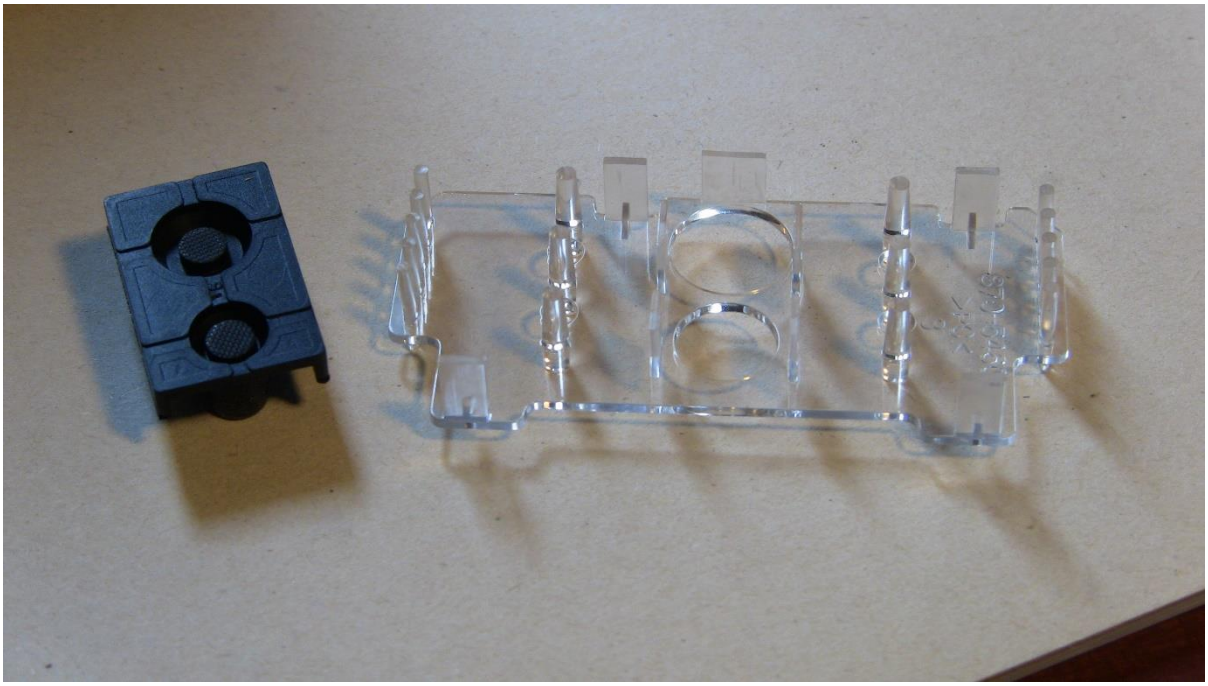
Disassembly

I carefully proceeded with dismantling the UPS and asked for advice. I was told to isolate and remove the battery as early as possible during process because of the stored energy danger.

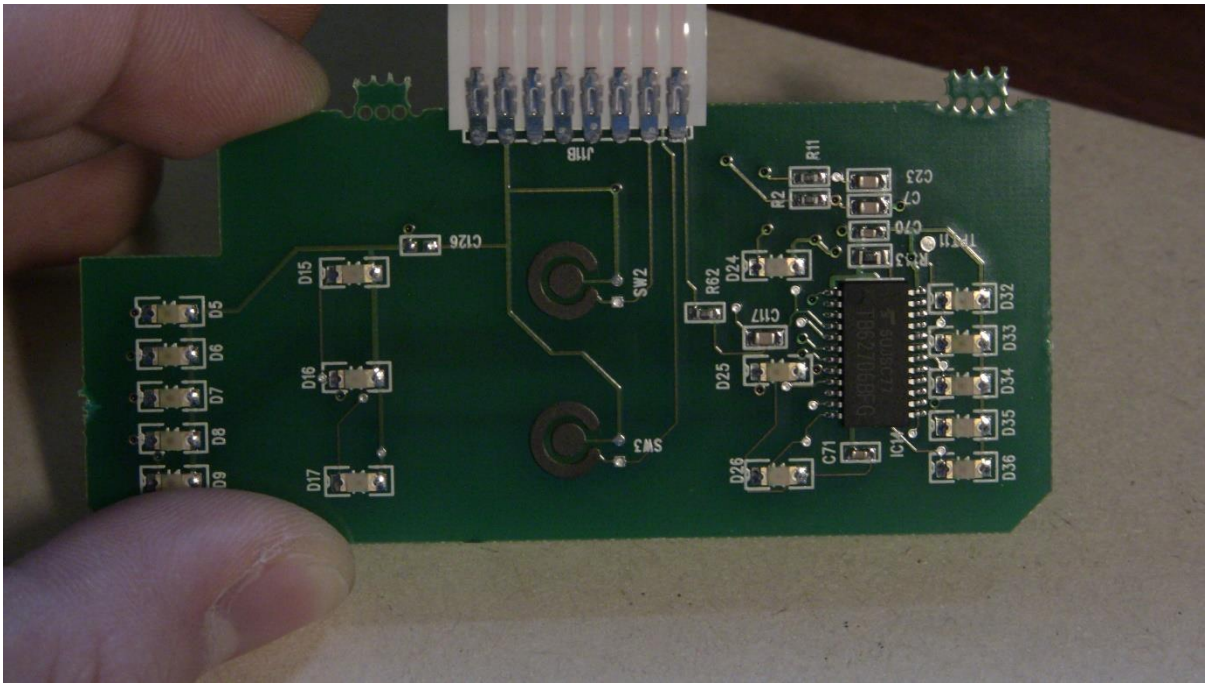
Step 1: Isolate battery

Step 2: Remove front panel and battery door

Step 3: Front panel controls board connected by flexible ribbon cable



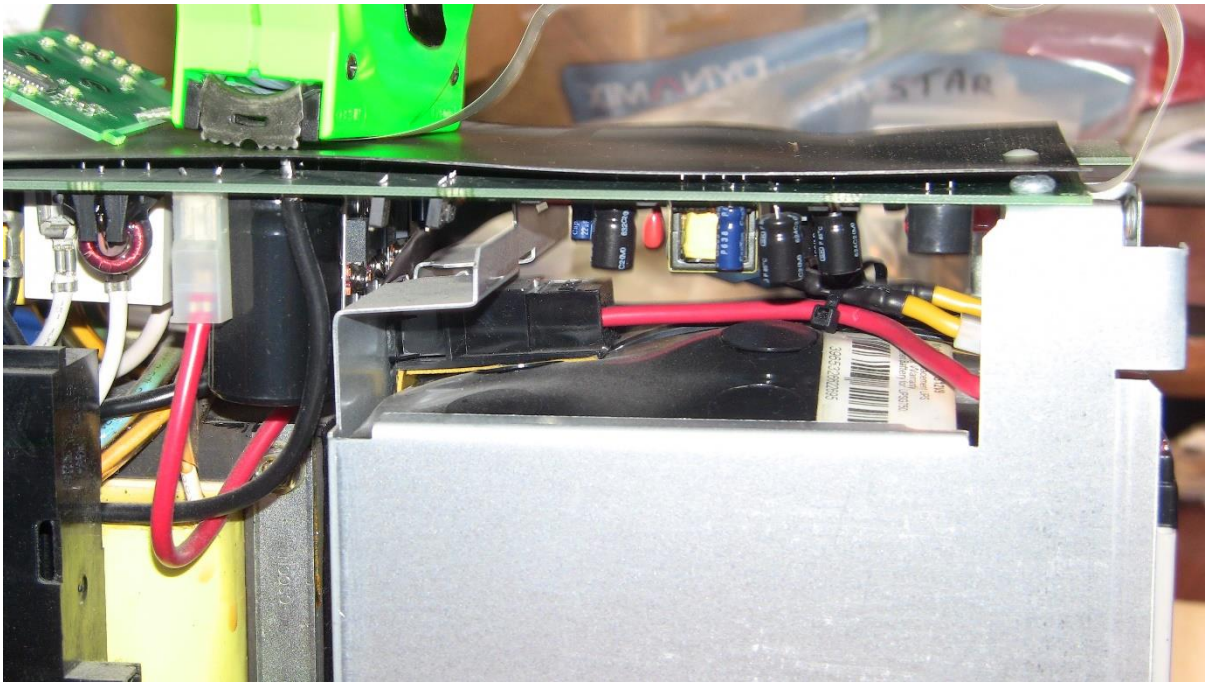
Step 4: Conductive buttons and lights pipes



Step 5: Front panel controls PCB with 16 LEDs and on/off button contacts

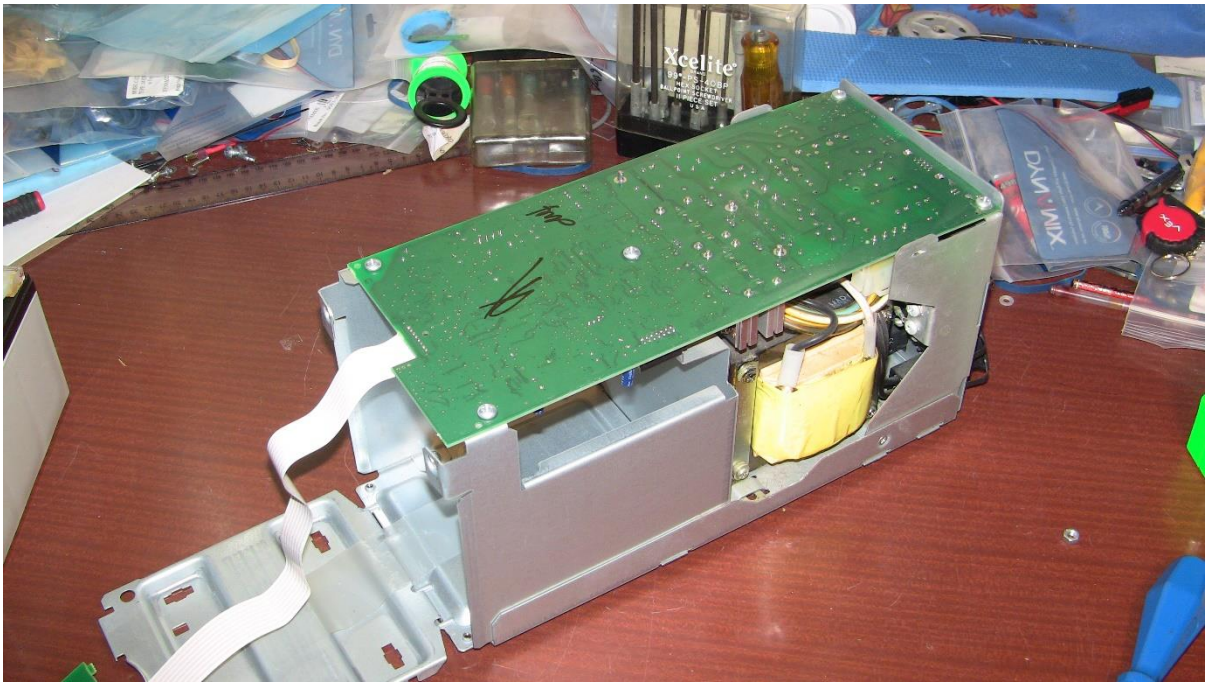
Step 6: Attempt to remove battery pack failed. Noted bulging top and sides.

Step 7: Removed main case screws and noted U.S. Patent Number 5,302,858

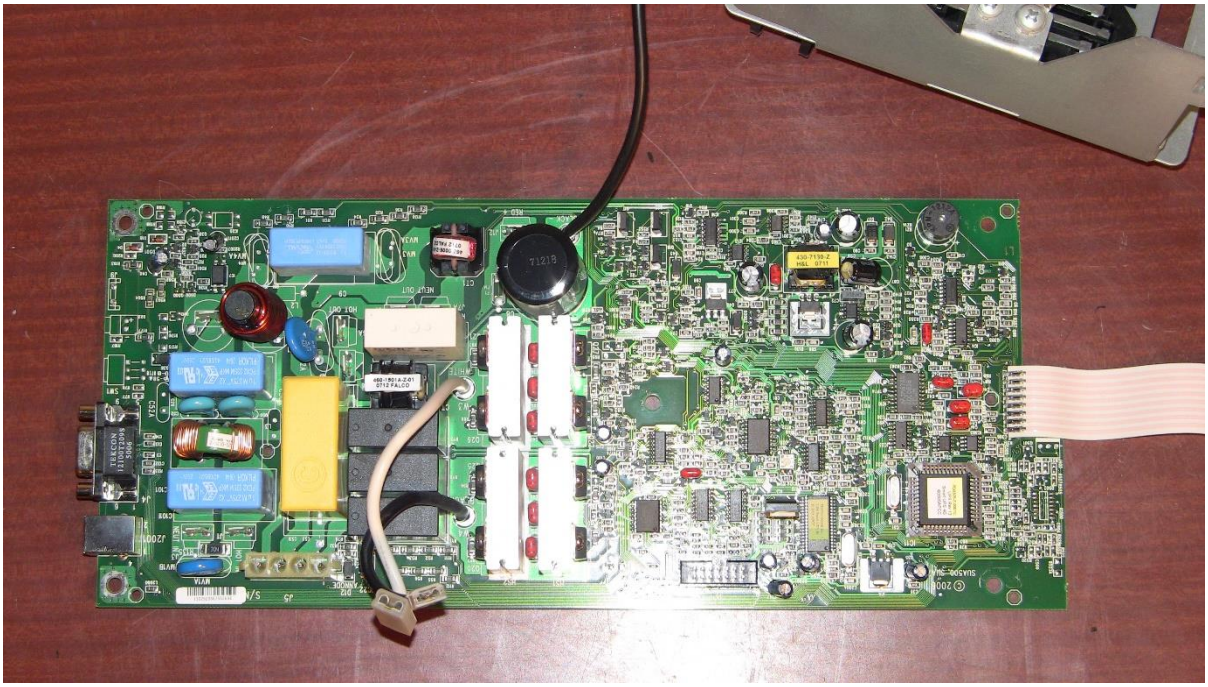


Step 8: Side view of battery pack with main case top removed

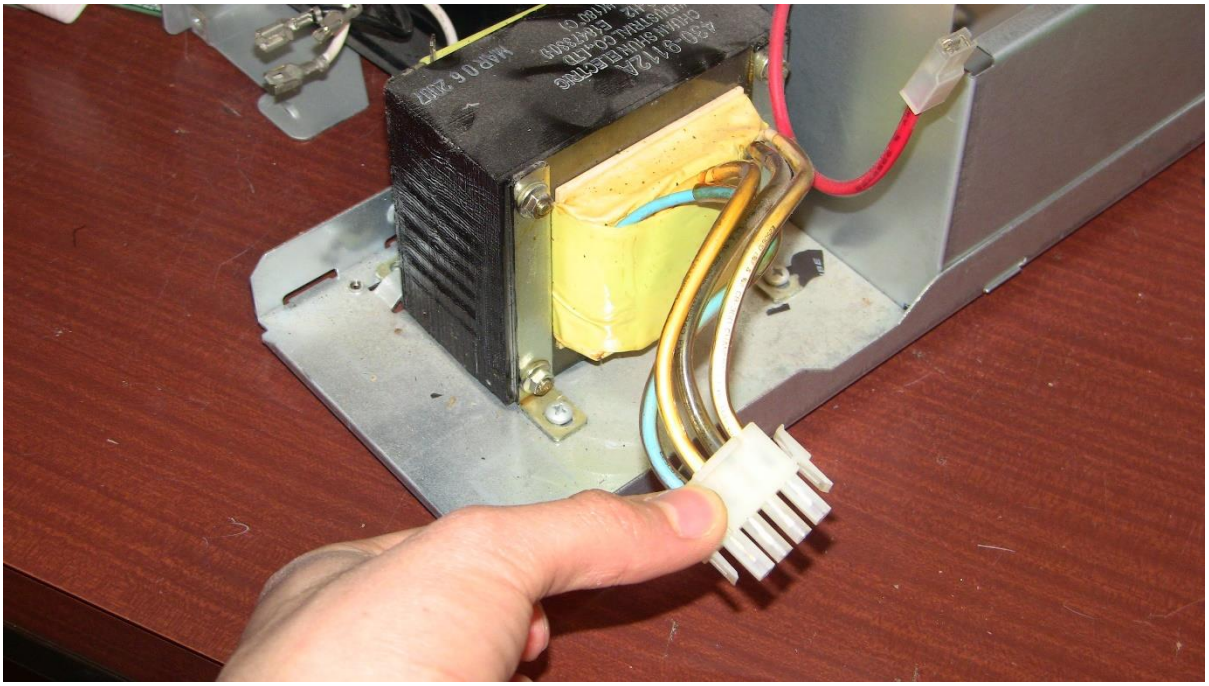
Step 9: Battery pack removed by levering from behind with large screwdriver. Blue 60A fuse still intact.



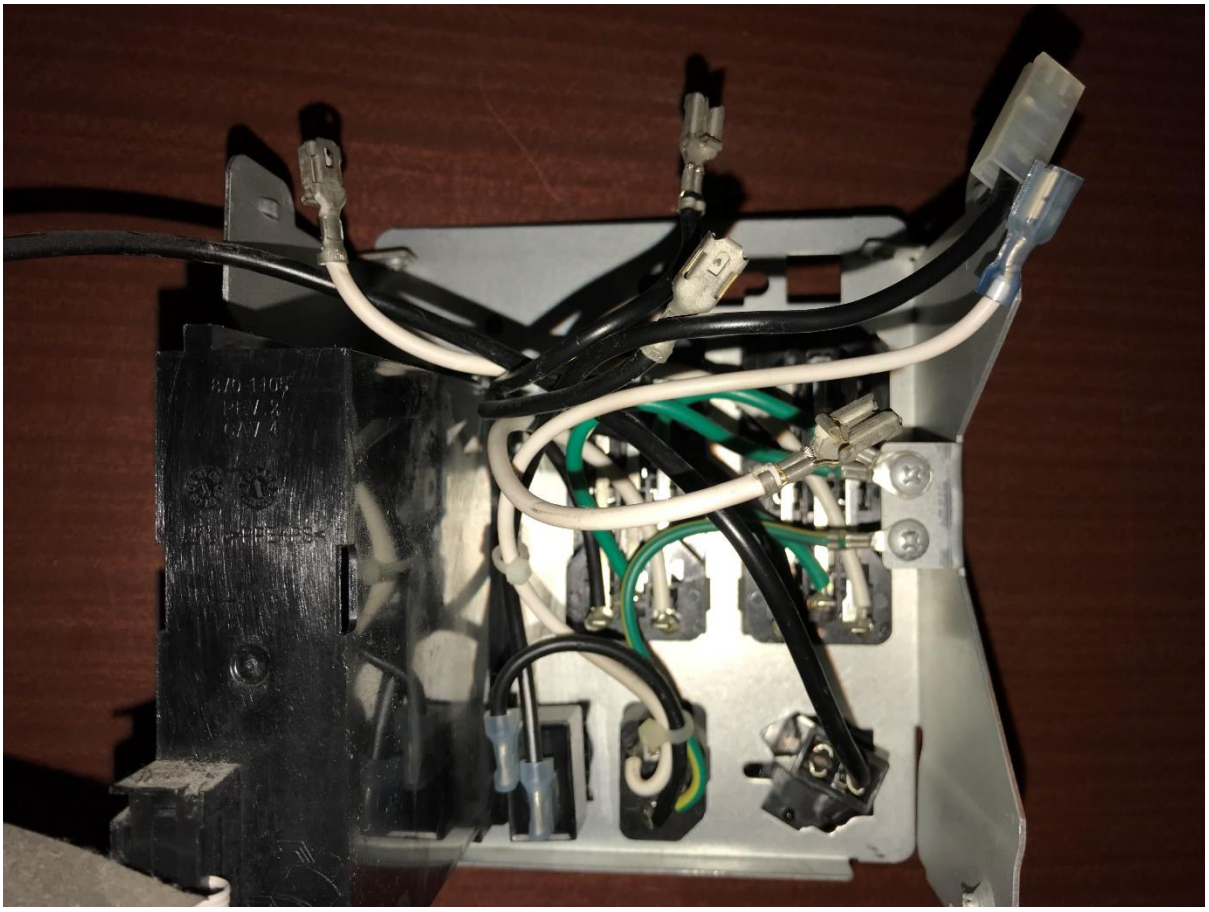
Step 10: Black protective plastic cover removed from main circuit board to expose 5 screws



Step 11: Main circuit board removed after unplugging power input, transformer and power output connection wires



Step 12: Power transformer primary side connector

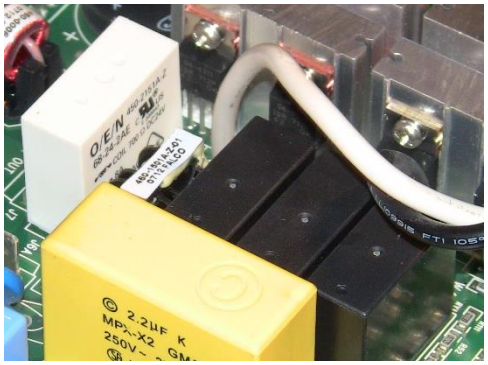


Step 13: Power input / output block view from wire side

Step 14: Interconnect cable with protective sleeve rated at 125°C brittle and cracking

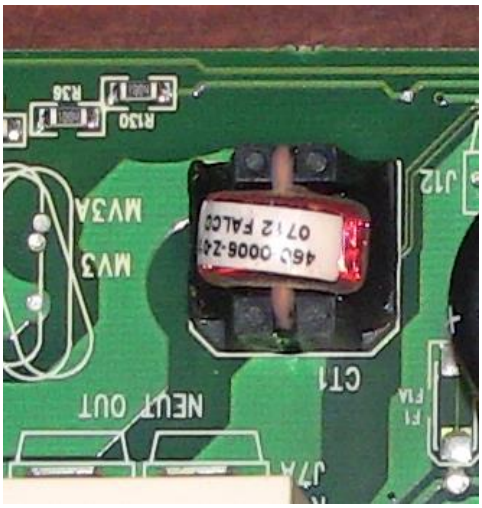
Electronic components found

The main circuit board has many components so I chose to focus on a few of them.



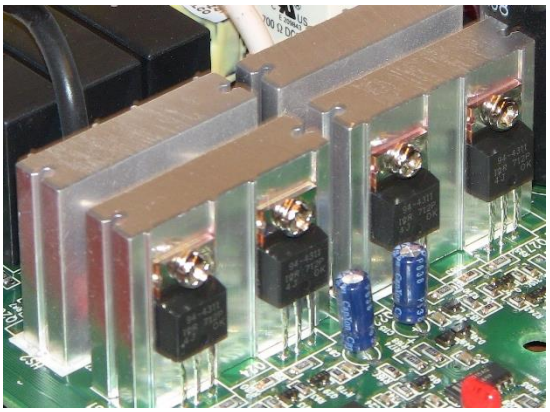
Relays 3x Zettler AZ697 10A 240Vac – Black colour

This group of relays is connected to the 3 primary voltage taps to boost or cut incoming AC power that is outside normal limits. The power transformer (Step 12) can also act as an auto-transformer.



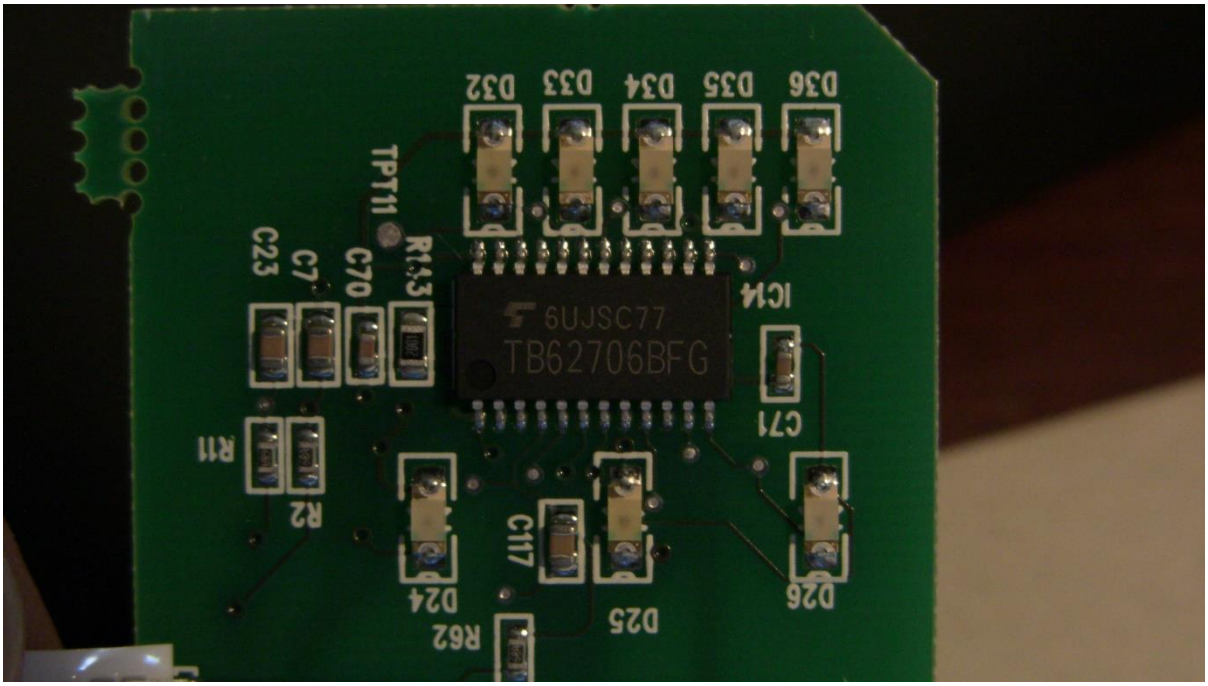
Current transformer – Note single large wire through round core is current being measured

High currents drawn by the UPS load are measured by this transformer and a low voltage signal produced which is further processed for the controller.



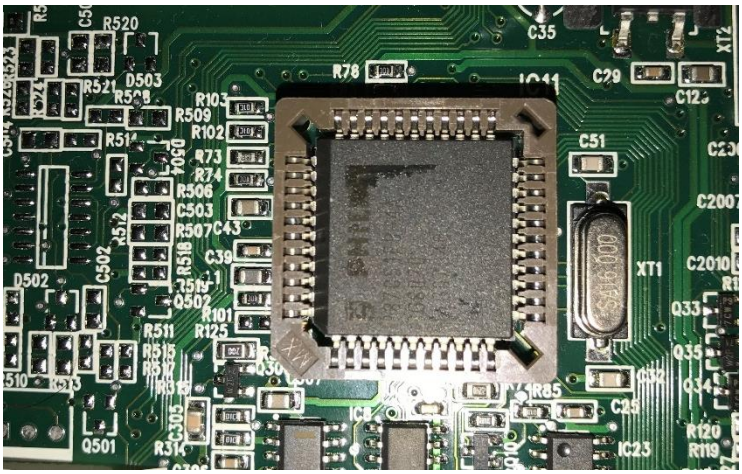
IRF712P Power MOSFETs mounted to heat sinks in H-bridge configuration (see Figure 1)

Parallel pairs of MOSFETs (8 total) are used to switch the 24Vdc battery power into a semi-sinewave shape AC waveform which is fed into the power transformer secondary (Step 10 black and white wires). This produces the 240Vac output.



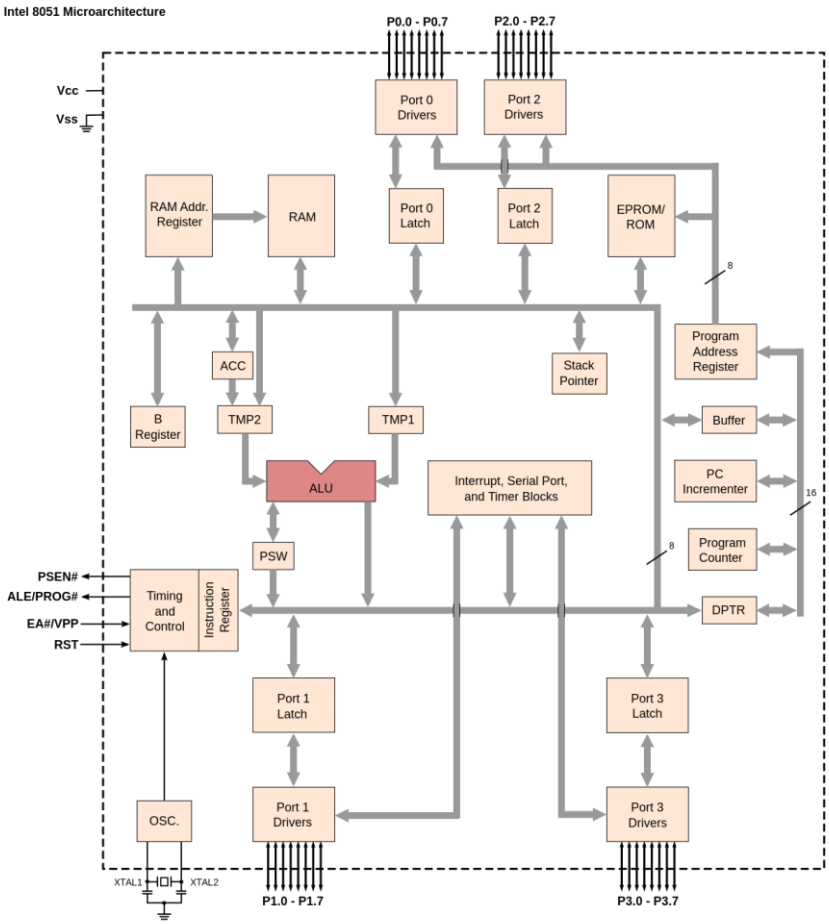
TB62706BFG 16-bit shift register, latch and constant current driver chip. Manufacturer: Toshiba

Designed specifically for LED driving with constant current output. Three signal lines are used; Data, Clock and Latch.

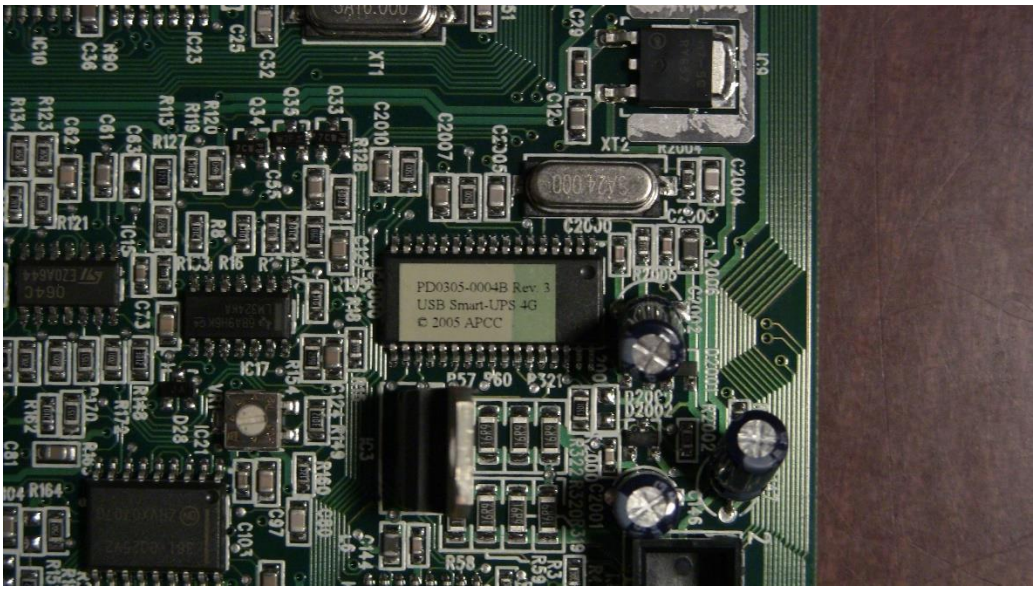


87C51FB 8-bit microcontroller. Manufacturer: Philips

This is a descendent of the original Intel MCS-51 developed in 1980. It is an 8-bit microcontroller with 16kB OTP (one time programmable) ROM (read only memory) and 256 bytes of RAM. Block diagram over page.

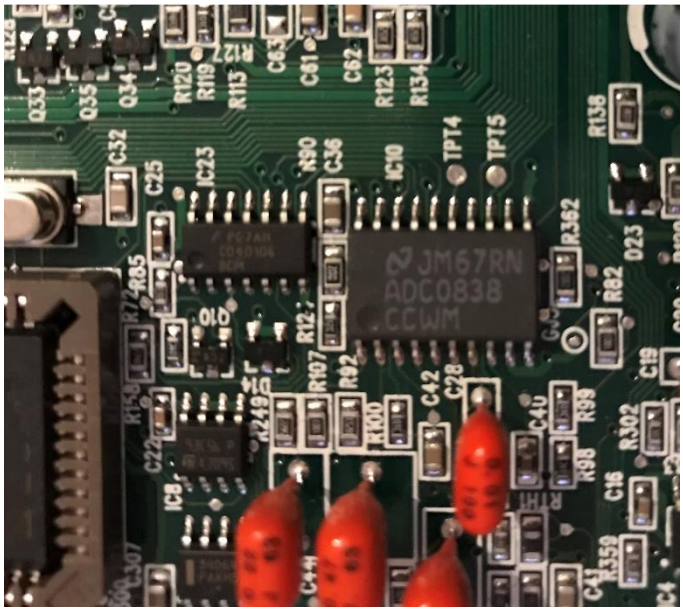


Block diagram of 8051 microarchitecture from wikipedia (By Appaloosa - Own work, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=5221629)



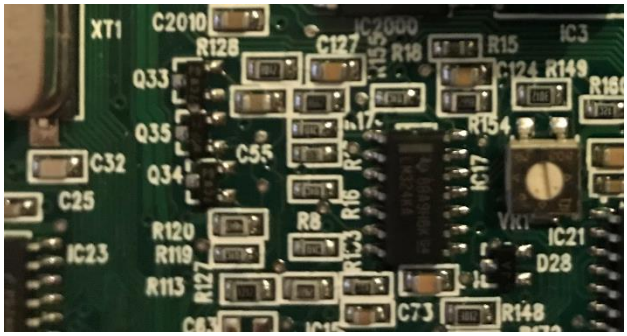
ST72F63BK4M1 8-bit microcontroller. Manufacturer: ST Microelectronics

Looking at the number of circuit tracks this is likely used just for USB interfacing, as the Philips 87C51FB microcontroller does not have this capability.



ADC0838 Analog to Digital converter. Manufacturer: Analog Devices

This chip converts analog signals to an 8-bit digital value for the microcontroller. Signals such as incoming supply voltage, output load current and battery voltage need to be measured in a UPS.



LM324KA quadruple operational amplifier. Manufacturer: Texas Instruments

Operational amplifiers are used for many purposes to level shift, filter and amplify analog signals. In this UPS they are preparing signals to be fed into the ADC0838.

Issues with device and conclusion

Despite still passing self-test this UPS clearly has suffered damage due to over temperature conditions. SLA batteries are designed to vent when over charged but the bulging suggests long term over charging so perhaps there is a fault with the UPS charging circuit or measurement components.

This was an interesting disassembly because it was also a forensics job trying to piece together what caused the overheating. The UPS will now be e-recycled because I believe it could be a fire hazard.

Bibliography

1. http://www.apc.com/shop/ng/en/products/APC-Smart-UPS-750VA-USB-Serial-230V/P-SUA750I
2. https://www.jaycar.co.nz/upsforsecurity
3. http://pdfpiw.uspto.gov/.piw?PageNum=0&docid=05302858&IDKey=88F7058A3309%0D%0A&HomeUrl=http%3A%2F%2Fpatft.uspto.gov%2Fnetahtml%2FPTO%2Fpatimg.htm

Datasheets:

Component	Source
TB62706BFG	https://www.verical.com/datasheet/toshiba-display-driver-tb62706bfg-437597.pdf
87C51FB	https://www.nxp.com/docs/en/data-sheet/8XC54_51FX_51RX.pdf
ST72F63BK4M1	https://www.radiolocman.com/datasheet/data.html?di=142775&/ST72F63BK4M1
ADC0838	http://www.ti.com/lit/ds/symlink/adc0831-n.pdf
LM324KA	http://www.ti.com/product/LM324KA