Lessons Learned During a uv Lamp Debugging

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We recently picked up a large collection of short wavelength ultraviolet lamps and solid state ballasts at a SMT bankruptcy. Converting these into reliable and useful resellable products for our **ebay store** proved to be much more of a refurb task than expected. Hindsight tells us that **their production test setup may have been blowing up a certain transistor!** And might in fact even have been a major contributing factor to the bankruptcy.

We initially made the dead wrong assumption that at least some of these might be immediately useful. There is a tendency when you buy a full pallet or more of items to assume you can quickly get at least some of them working. After all, **there is no point in refurbing something that is not going to sell**. So fixing everything ahead of time can end up a near total waste of time and money.

Instead, a major rule...

> **Always have enough fully working deliverable product on hand to fulfill at least a few of the upcoming orders!**

Tracing a Schematic

The circuitry in new solid state ballasts can be both dangerous and confusing. The obvious object of the game is to preheat the filaments in the fluorescent style bulb and then applying a higher than normal voltage to "strike" the start of the plasma. From there, the ballast must switch to a lower voltage, **current regulated** operation. Solid state ballasts offer much less iron, lower noise, and freedom from strobe effects, compared to their traditional iron core coil+starter heritage.

These particular ballasts were intended for use in a faucet mounted water purifier. Which also added a second but seldom needed requirement: They had to provide a safety interlock that would turn on only when activated and would turn off ten seconds **after** the interlock signal was removed.

Another rule…

> **If you know you are going to have to trace any schematic, spend enough time to do the job right.**

Immediate problems with these units were they were awkward to handle and the double sided circuit traces were hard to view and interpret. A second problem was that my foregone conclusions over what a solid state ballast was and how it worked were dead wrong. Yet another rule…

> **Never assume any circuit "has" to operate in a certain manner. Almost always, this will end up dead wrong.**

Removing the lamp made the ballast infinitely easier to study and handle. Solder wick was used but the soldering iron could only reach three of the larger pins at once. But by prestressing the bulb pins, the bulb could be progressively removed after several pin reheatings.

Several magnifiers are a must. I also found a **2X Ottlight** to be a pricey but very useful magnifying lamp. Those new el-cheapo LED flashlights are extremely useful to backlight the circuit board when tracing the runs. This **53HD420** schematic also proved extremely useful. Plus the usual DVM in its audio continuity mode.

We'll throw in a reminder here that **OEM's Trade** is an exceptionally useful site to find out who makes what electronic component, how much they cost, and where they can be found.

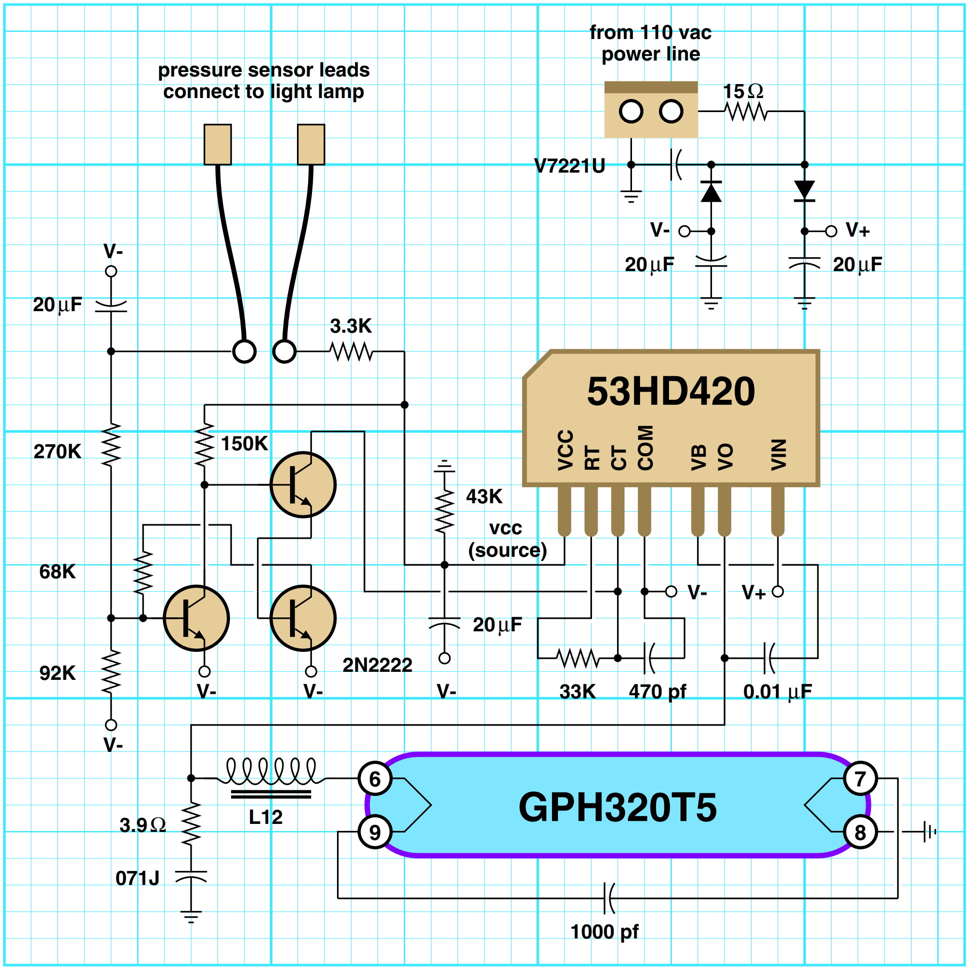
An assembled water filter revealed that the blue screw connectors were the 110 vac line input and that the black Faston leads came from a pressure sensor that acted as a passive switch. Apparently the sensor pulses whenever the faucet water is turned on.

A rather infuriating feature of this particular circuit board: **Certain grounds and a few other leads may tunnel through a plate thru hole and continue**. Watch this detail carefully.

One more rule…

> **Always have someone else double check your work. The unexpected may be weird, but is usually flat out wrong.**

The circuit board ended up looking something like this…



The heart of the circuit is the **International Rectifier** 53HD420. This converts a positive and negative line driven power supply into a 170 volt square wave at 34 kilohertz. This drives a serial RLC circuit consisting of the ballast inductor, the filaments of the lamp, and a resonating capacitor.

Except that the RLC circuit is driven at 34 kHz, which is safely **below** its 124 kHz resonant frequency! At frequencies below resonance, the capacitor voltage will equal or slightly exceed the input voltage of the 170 volt square wave.

Which simultaneously runs current through the filaments and provides a high striking voltage. As soon as the lamp lights, the capacitor is more or less shorted out. The inductor then plays its main role as a current regulating inductive reactance ballast.

The three transistors act as a variation on a classic **Schmidt Trigger**. So long as the external passive switch contacts are closed, the input capacitor remains fully charged. This state of the circuit does not draw any output current and allows the 53HD420 to oscillate properly.

When the external switch contacts are opened, the input capacitor discharges with a ten second time constant. Eventually snapping the circuit to its other state. At that point the rightmost transistor sucks the timing RC circuit dry and shuts down the output square wave. Thus turning the lamp off. At least in theory.

Special Test Setups

Rule time again...

> **If you know you are having trouble with multiple circuit copies, create suitable test tools to isolate any problems.**

The first thing we note is that we have an **extreme** hot chassis situation with **dangerous shock hazards**. Sometimes we would like to connect our scope ground to the ballast ground. And other times to the **v-** trace. But either one will create instant fireworks. Thus, **an isolation transformer is essential for any work on this circuit!**

We were temporarily out of stock of isolation transformers, but I did have a 110/220/440 automation transformer. The 220 coils were separated and used as a 110 volt isolation transformer. Worked like a champ.

Learning more about the "below resonance" RLC circuit operation was made much easier by an adaptor that dropped the output of a sweep generator to under a tenth of a volt with a 5 Ohm source impedance. Make this from a BNC connector, a 47 Ohm resistor, a 5 Ohm resistor, two wires and two grabber clips.

Adding a **4-pin socket** to one of the ballasts let us separate bulb problems from ballast problems. To add measurement "convenience points", strip a quarter inch off a piece of #24 hookup wire, solder it to the point of interest, and clip off the quarter inch. While early test boards will end up looking like a porcupine, only a few points may be later needed.

Ah yes, safety. Even with uv goggles, the light is annoying. So a heavy piece of red paper was stapled into a loop to cover the bulb. A lit bulb only barely (and safely) can be seen. The isolation transformer was in turn plugged into a switchable outlet. For safety, a 100 watt light bulb was also attached and run several feet away. The bulb lights to warn you that things are hot.

Also needed are the usual soldering station, desoldering braid, desoldering pump, X-acto knife, and such.

The Problem and its solution

The first few boards checked all revealed the same problem: No light. And all were traced to the same culprit: **The rightmost 2N2222 was shorted!** This is unlikely a coincidence since the other two 2N2222's still worked just fine. A circuit board or soldering error was also unlikely as replacing the 2N2222 did resume normal operation. At least temporarily.

Now, a **2N2222** is a "cast iron" industry wide "gold standard" device. No way can you hurt it in any reasonable circuit. Especially a circuit that, at first glance, seems to be switching half of a mil at 15 volts.

Here is my (unproven) speculation as to what was coming down: **During startup, something very bad happens transient-wise to pin #3 of the 53HD420**. There are three power supplies involved that may come up in a strange sequence. And there are voltages up to nearly 400(!) lurking in the 53HD420. My best guess is that **the 2N2222's were being destroyed in avalanche mode** by excessively high voltage that was largely current unlimited.

And that their test setup may have been destroying their product!

One possible workaround might be to add a 2.2K resistor between the 2N2222 collector and pin 3 of the 53HD20. Should avalanching take place, it now might be current limited to something that ends up manageable. And the higher source impedance is still more than enough to clamp the RC oscillator.

A better solution is to simply cut the collector trace. This converts the main lamp circuit into a "power-on light-on" mode and eliminates all of the 2N2222's entirely. Which is what we elected to do on the ballasts we are offering on **eBay**.

Some Safety Reminders

Short ultraviolet anything can be extremely dangerous...

- **ALWAYS wear wraparound uv safety glasses.**
- **Provide 110 volt safety isolation.**
- **Interlock exposure to the application.**
- **Always match bulb to ballast.**
- **If needed, add quartz tube water isolation.**
- **Use an isolation transformer when testing.**
- **Avoid any long term skin exposure.**
- **Avoid life shortening bulb fingerprints.**
- **Dispose of in an approved and legal manner.**

For More Help

Some additional technical info on solid state fluorescent ballasts may be found **here**. A leading source of uv bulbs, accessories, and quartz protective shields is **Vortex uv**.

One of the less obvious uses for this **GuruGram** is ...

> **To resolve fuzzy details of any sticky problem, write a story that explains any confusing issues to others.**

Secondary benefits are that **the story can gather together all needed links and resources in one place**. And can provide useful supplemental information to potential customers.

A collection of uv-c lamps and lamp/ballast combinations appears on our **eBay Store**. Sourcecode for this document and its schematic appears **here**. With more creation details **here**. And more on **eBay** buying and selling **here**.

Additional consulting services are available per our **Infopack** services and on a contract or an hourly basis. Additional **GuruGrams** are found **here**. Seminars also available.

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