Six Switching Transistors?

Answer this: Which Sony television power supply uses six (sometimes eight or more) switching transistors? Answer: That "dog" you've been working on for the last two weeks. You only have enough slots for two, but for some reason you've already used six. Want some tips on how to minimize the number of these you will need to fix the set and send it out the door? I thought so. Read on.

Picture this scenario: A Sony 27" television appears on your daily work order. Symptoms: Dead, no power. You already have a gut feeling of what you're up against. You remove the back cover and immediately check the fuse resistor feeding B+ to the switching transistors. It's open. Bummer. We know what's next. Might as well do the traditional ohms check on the switching transistors. Maybe there's that teensy weensy chance that the fuse resistor gave up the ghost for no reason. NOT!! Your little micro dream is suddenly shattered when the three zeros show up on the ohm meter display (needle to the far right for you die-hard Simpson analog guys) while checking the C-E junction of the switching transistors. You patiently unsolder said transistors and fuse resistor and replace them with Sony OEM replacements (of course). The traditional ohms check of the horizontal output transistor is also in order. No short there. Might as well bring up the supply with the variac. Staring at zero AC and climbing to 10...20..30 volts. All seems well. At around 65 volts the unit seems to come alive, humming and clicking the relay. Suddenly that strange sound appears like Homer Simpson opening his can of beer and then....silence. You know what happened.

The good old days of simple, analog regulating supplies is gone. Product energy efficiency is chic. Hence, the reason for switching power supplies. Our switch mode regulators generally appear in the dual transistor arrangement, push-pull style. The LN-1, AA-1, and AA-2 television chassis, along with all of the projection televisions over the last six years, utilize this type of power supply. Later versions bundle these two transistors in to a neat little IC package. It is actually a very reliable design. Rarely does it fail because one the transistors decided that life wasn't worth living any longer. Problems outside of the supply are what caused its demise. This is the most common cause of repeated failures of the transistors (along with repeated calls to your friendly tech rep).

What I plan to share with you is a proven method that will prevent you from losing our freshly installed transistors. Follow this procedure correctly and you should never hear that dreaded sound of failure again. We're going to talk pure troubleshooting from this point - no theory on how these things work. This article would have to be published in paperback in order to do this. For details and an excellent description of how these supplies operate, beg, steal or borrow (or better yet, purchase) a copy of our SMPS-01 training manual (part # SMPS11951). This well written, easy to read manual will familiarize you with the underlying theory and operation of these supplies and they are in stock at our Kansas City parts center. They are actually very simple in how they work. Understanding them makes the troubleshooting methods I am about to describe all the more easy to comprehend.

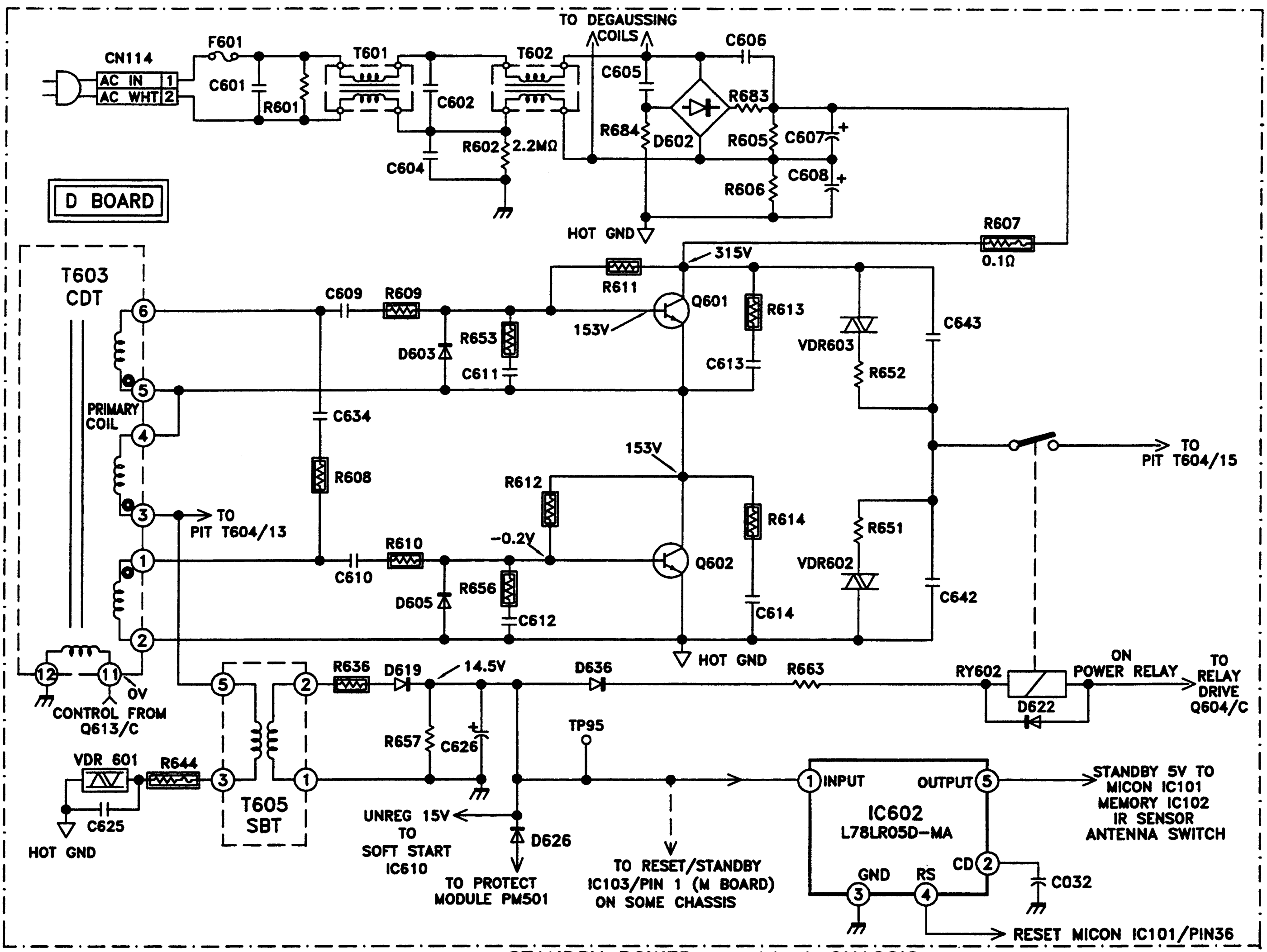
FIND THE CAUSE

The switching transistors almost always fail because of problems elsewhere. Too much input voltage, excessive current draw, or biasing problems of the transistors themselves are usual suspects. This is why we never replace them and plug the set in to see what happens. Let's cover the different reasons for their failure.

Excessive current: The most common cause of this is in the secondary supply lines with the 135V B+ line being the likely culprit. The most comforting situation a technician can come across is shorted switching transistors and then finding the horizontal output transistor shorted. At least we have the cause nailed down All we are concerned with at this point is whether or not something else caused the failure of the horizontal output. A failed flyback transformer or excessive loads on its secondary are of concern. The problem here is the potential of knocking out the horizontal output transistor again and, consequently, the switchers. Of course, other secondary lines could have excessive loads upon them. The procedure we will cover in a moment will prevent this scenario from occurring.

Transients: I once read that the average household receives at least one 5000 volt transient a year and at least one 1000 volt spike a month. They are very brief in duration and usually are suppressed by the protection circuits within the power supply. If you live in an area frequented by electrical storms you probably get more transients than normal. When large voltage spikes take out the switching transistors, there is usually physical evidence. Capacitors split in half, burnt diodes and resistors are not uncommon. The fact that an electrical storm occurred recently is also a good clue. Although we are certain that a recent storm may be the cause, physical symptoms may not always appear. Again, our procedure to follow will assist in locating these components.

Biasing: This is the tough one. Since the oscillator circuit utilizes a push-pull transistor arrangement (one transistor pushes the voltage up, the other pulls it back down to ground) *they cannot be on at the same time.* If the top transistor is turned on and heading towards saturation, the bottom transistor had better be off and vice versa. This is accomplished by out-of-phase feedback windings to the bases of the transistors along with the RC time constant of the coupling capacitors and resistors to the transistor bases. Figure 1 illustrates this point. Pins 1, 2, 5 and 6 of T603, along with R609, R610, C609 and C610, make up the feedback path. Any leakage of the coupling capacitors will affect the delicate "on time" of the corresponding transistor. As we can see, feedback is very important here.



STANDBY POWER – AA-1 CHASSIS

Figure 1

I started out with this symptom as the "tough one". This is the one that causes the technician to call the tech support line. It causes repeat failure of the switchers. There is no evidence of outside transients and no signs of current loads on the secondary supply lines, yet the transistors fail with very little AC input to the unit. Once again, the procedure I am about to describe will spot this in an instant. Now that we have enough hype about this "procedure", let's put it into practice.

THE VARIAC AND THE AC AMP METER

Long ago I used a variac to work on power supplies. It was a crude type (something you'd see in a 50's Sci-Fi movie). I used it to run power supplies (analog type) at a reduced level to prevent things from overheating and burning up. I could tell by the buzzing sound it was radiating as to how much current the supply was drawing. If the variac began to walk off the bench, I knew I had a severe load problem on the supply. This worked fine for these types of power supplies. As long as the ambient room temperature didn't start rising and there were no strange smells, I could run the circuit at low AC levels and troubleshoot from there. The introduction of switch mode supplies changed this approach. They weren't as rugged as the old analog regulators. They had an ultimatum: Oscillate or die. Closer current monitoring was obviously needed.

Today's technician <u>must</u> include a variac with an integral AC amp meter. It is the only way to effectively eliminate the failure of a newly installed set of switching transistors. I still get the old die-hard technicians who tell me about how they use a low wattage light bulb in series with the AC input for troubleshooting purposes. <u>This is not really a troubleshooting tool. It is a safety device. It does not allow you to control current levels</u>. Precise current monitoring is a must when powering up switch mode supplies. Remember what we talked about earlier: Excessive *input voltage (line transients), current (loads on the secondary voltage lines) and biasing problems are what cause these supplies to fail.* Bringing the supply up with a variac will eliminate any voltage problems. Monitoring the AC current level will prevent any loading or biasing problems from blitzing the new replacement transistors. With the latter in mind, let us now walk through a step-by-step procedure for powering up a new set of switching transistors.

STATIC CHECKS: The first item to look for is obvious signs of component failures. Look and sniff are the rules. This should be the first routine of effective troubleshooting. Any burnt or smelly components in the primary oscillator circuitry are a good indicator of possible line voltage problems. Any other burnt components in the secondary voltage areas will provide valuable clues as to the cause. Traditional ohms-to-ground checks of the horizontal output transistor and any secondary voltage lines should be followed. Locate and replace any components that are obviously defective. (There is still a possibility that excessive loads may be appearing in the secondary lines of the flyback transformer. This is rather difficult in that these occur in a dynamic state once the horizontal circuits are running. It is normal for problems here to trigger the over-current protect circuits which will usually shut the set down before the switching transistors fail. We'll deal with this situation in a moment.) Once all static checks have been given the green light, it is time to start powering up the supply.

SWITCHING OSCILLATOR PROBLEMS: This is a very common cause of repeat switching transistor failures. There is no sign of burnt or overheated components and resistance checks of the secondary supply lines appear OK, but the transistors fail immediately upon applying AC power. The procedure for testing this differs significantly between the direct view and projection television chassis. Why? Our direct-view chassis runs the switching oscillator at all times while the projection television chassis only runs the oscillator during turn-on. An exception to this is our recent 35" XBR series that uses a power supply similar to the projection chassis. I am therefore going to provide two separate power-up procedures - one for all projection TV chassis manufactured in the last six years and another for the direct-view sets.

NOTE: At the time of writing this article, all of our newer 27" sets are being equipped with separate standby power supplies (which are switching supplies in and of themselves). This is to satisfy recent government mandates for power consumption. These new sets will require the same procedure as outlined for the projection televisions.

THE DIRECT-VIEW CHASSIS

Figure 2 shows a block diagram of a typical power supply for one of our direct-view television power supplies. This example is from the AA-1 chassis and can be found in the CTV23 training manual (part # CTV230996-1). Other similar designs include the AA-2 and earlier LN-1 chassis. These supplies oscillate immediately upon supplying AC power. The oscillator not only drives the television's main secondary supplies, but the standby transformer as well. Note that the main transformer (T604) is only active when the power relay is closed. If the power supply failed while this set was "on", the microprocessor would engage the relay automatically when at least 60VAC is supplied. The disadvantage of this arrangement is since the power relay won't kick on until at least 60VAC, we are going to be in for a big surprise when the relay engages and there is a problem in the secondary lines... POOF!

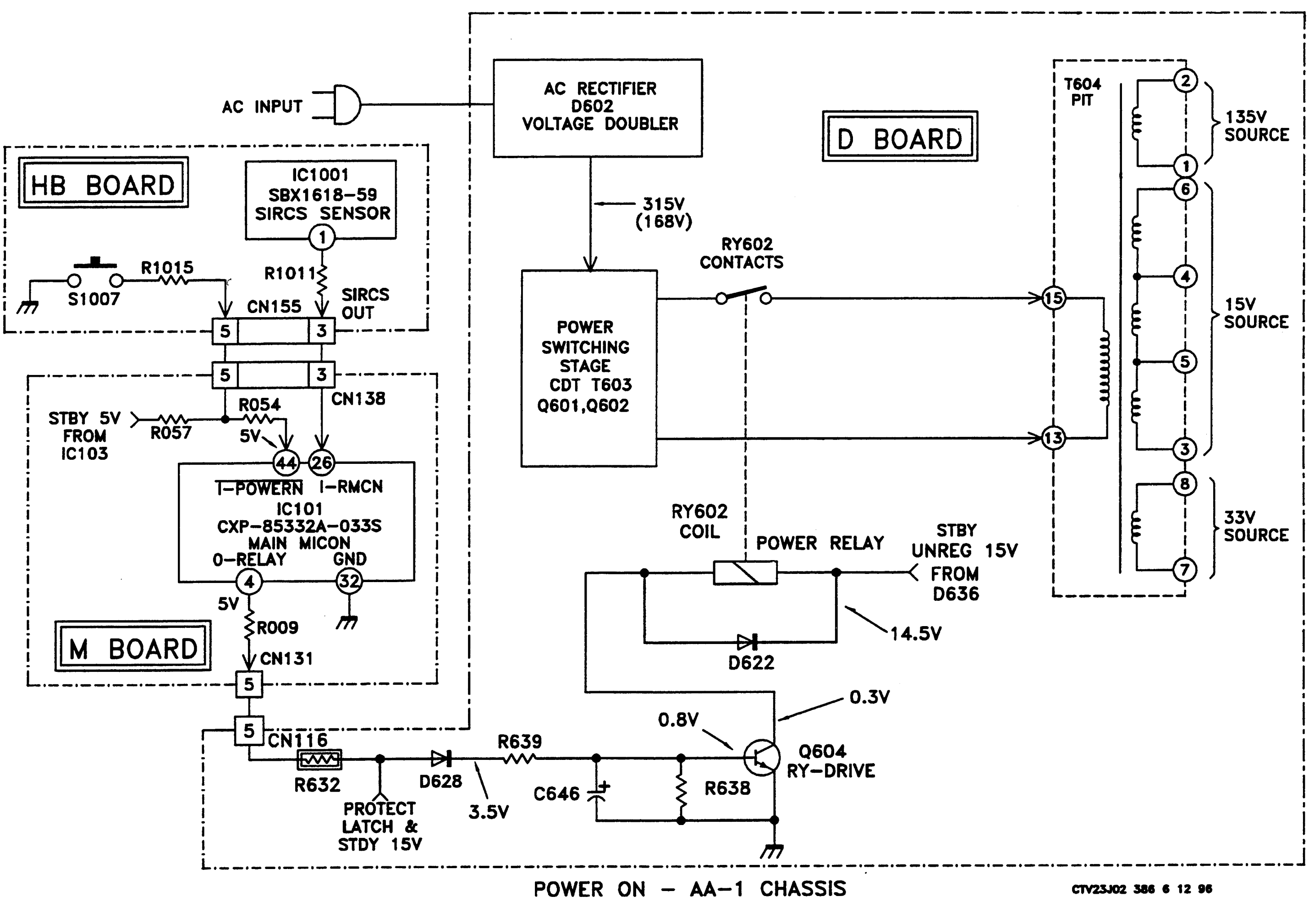


Figure 2

When first applying AC power to this set, do not exceed 30VAC. The oscillator will begin running at about 5 to 10VAC. This allows us to check proper biasing of the oscillator immediately upon application of AC power, along with any potential loading problems in the circuits fed by the standby lines. You should have a difficult time reading any current levels when only the standby circuits are operating. Once the oscillator has passed the initial test, we can "force" the secondary stage on to check for potentially damaging loads. Looking back at Figure 1 gives us a more detailed view of the switching oscillator. Notice how the oscillator is fed by constant B+ from the bridge rectifier D602. The circuit oscillates upon AC plug-in and drives a standby transformer T605. Notice RY602. It connects the already running oscillator to the PIT (**P**ower **I**nput **T**ransformer) T604. As mentioned earlier, it doesn't engage until the unit is turned on by remote or pressing the front panel power button. If the unit happened to be in the power-on-state when a failure occurred, the relay will automatically engage at about 60VAC.

Let's walk through a step-by-step power-up procedure for the AA-1 chassis and others like it.

STEP 1. Begin slowly applying AC power to the television with the VARIAC while monitoring AC current. It is normal to see a momentary spike of current in the beginning. This is the filter capacitors charging and the degauss circuit initializing. The current spike should disappear rapidly. Between zero and 40VAC, the current draw should not exceed 100ma. On most variacs, you should have a hard time determining if any current is being drawn. If the current continues to rise as you are turning the dial, **STOP.** You have a problem in the oscillator or standby circuit. Do not exceed more than two amps or you will lose the switching transistors. Something is wrong with the biasing of the oscillator or there is a short or heavy dynamic load in the standby circuits. Look for shorts in the 12V or 5V line. If the standby lines appear OK, check the feedback coupling capacitors connected to the base of the two switching transistors. They are probably leaky.

If little or no current is being drawn during this test, it is time to move on to STEP 2 and check the secondary loads on the Power Input Transformer. This is where all of the secondary voltages are generated for the television.

Tip: Another culprit (particularly with the AA-1 chassis) are the VDRs (VDR601, 602 and 603) located in the oscillator and standby circuits. AC line transients easily damage them. They should be replaced anytime a power supply is serviced for switching transistor failure. Loads in the standby supply will usually open fuse resistors protecting that particular line. In the sample drawing of figure 2, an open R644 indicates a defective VDR 601 and an open R636 indicates a shorted IC610 regulator. The standby transformer T605 should also be visually inspected for overheated windings and replaced if necessary. Any one of the above mentioned components will knock out the switching transistors. These are actual failures I have seen on this chassis. Anytime shorted switchers are replaced and open fuse resistors are found in the standby or secondary circuits, be very careful.

STEP 2. If the standby circuit test passes, it is now necessary to check for current draw on the secondary supply lines. As mentioned earlier, the problem we encounter here is that this line does not become active until we reach at least 60VAC. This is high enough to destroy the switching transistors when the relay kicks in (on the AA-1 chassis). The AA-2 chassis does not have a power relay. All B+ lines are active immediately except for the switched 9V to the Jungle IC (see the next tip for how to deal with this chassis). The LN-1 chassis uses a transistor to complete the PIT transformer ground return. None-the-less, these supplies must be "forced" on so that we can start them from a low AC level. In the AA-1 chassis, we must jump the power relay. In the LN-1 chassis, a transistor completes ground return for the main transformer and we must jumper the C-E junction.

Jumping the power relay is certain to raise eyebrows in some individuals. After all, we are defeating a safety device in the unit. The relay is normally turned off during over-voltage and over-current conditions and, in some cases, high voltage problems. **Remember, however, that we are controlling the situation with a variac**. When one is careful, this can be done safely. Besides, what is the worst thing that could happen if you are not careful? Is the television going to explode and render the surrounding neighborhood uninhabitable for the next thousand years? Are you going to generate enough X-radiation to provide free chest X-rays for your fellow technicians in the adjacent service bays? Probably not. In the worst case, you will likely lose another set of switching transistors. Use some reasonable caution and watch the current on the AC amp meter and this will be a safe journey.

With the relay jumped, *slowly* apply AC power to the unit with the variac and watch for excessive current draw. What is excessive? These sets should draw no more than 1.25 amps *while on low AC input.* The amps should actually drop as the AC voltage is increased. Normal AC current at 120VAC is between 500 and 800ma on a 27" set. If the amperage is dropping as you increase AC, take it all the way to 60VAC. If you are still at one amp or less, you more than likely have a green light to remove the jumper from the relay and go for a 0 to full 120VAC turn on. If you see current continuing to rise as you increase AC power, **proceed to step 3.** NOTE: ***If you have a problem anywhere in the secondary circuits, you will achieve current readings well above 1.5amps long before 60VAC.***

Tip: The AA-2 Chassis does not utilize a relay for power switching. The secondary B+ lines are hot at all times, except for the switched 9V to the jungle IC. We are faced with the same problem here as the other chassis types. The switched 9V does not turn on until we reach 65VAC. Try this: Supply external 9V to the SW9V line or jump the input and output of the regulator/switch. I know some of you flinched when I stated the latter but the regulator input is 10 volts and we are starting the unit on low AC so I fail to see the danger here.

Step 3. If the current rises as the AC voltage is increased (two amps should convince even the most daring of us), back off and try the following suggestions: Short the base of the horizontal output transistor to ground. If you're not sure where cold ground is or whether the emitter is attached to cold ground, go for a B-E short. The idea here is to disable the horizontal deflection circuit. This takes a lot of things out of the picture for the moment. Slowly apply AC power again and see if the over-current condition still exists. If it does not, you have a bad flyback transformer or something is loading it. If the current continues to rise above normal (you should draw a maximum of 250ma with the horizontal circuit disabled), start disconnecting lines from the other secondary sources until the problem disappears and troubleshoot the guilty line accordingly.

Tip: Horizontal circuit problems can be annoying in that they occur in a "dynamic" state (unless the horizontal output transistor is shorted). This presents a problem in that the power supply must be up and running in order to activate this stage of circuitry. Allow me to share with you a real life scenario dealing with this problem:

A KV27XBR10 was received by the Sony service center at which I am located. The unit had arrived with shorted switching transistors. The technician replaced the failed components and fuse. The unit was plugged in and powered up (obviously I had not shared the previous procedures with him at this time). The unit went into immediate shutdown. After being called to examine the problem, I asked the technician to turn the unit on while monitoring AC current on his variac. The current spiked at three amps before the unit shut down. Notice how the variac provided us with valuable information as to what caused the shutdown. I immediately knew we had an excessive load on the supply. I then asked the technician to short the horizontal output transistor base to ground and turn the set on. It came on without shutting down and current draw was 250ma - a problem in the horizontal stages without a doubt. He stated that he had replaced the flyback transformer (for failure history reasons). I knew then that we were in for some further analysis. Time to jump the power relay.

The power relay was jumped and a scope probe attached to the wire feeding the collector of the horizontal out transistor. We must use this method of attachment since most scopes cannot handle the large spikes directly from the collector. While bringing the AC voltage up we noticed that current rose dramatically. We had 1.75 amps at 30VAC. Just above 30VAC the horizontal spike began to flutter, a clear sign of flyback secondary loading. The AC power was removed and resistance readings were taken of all scan-derived voltage lines in the flyback secondaries. No apparent problems. This wasn't looking good.

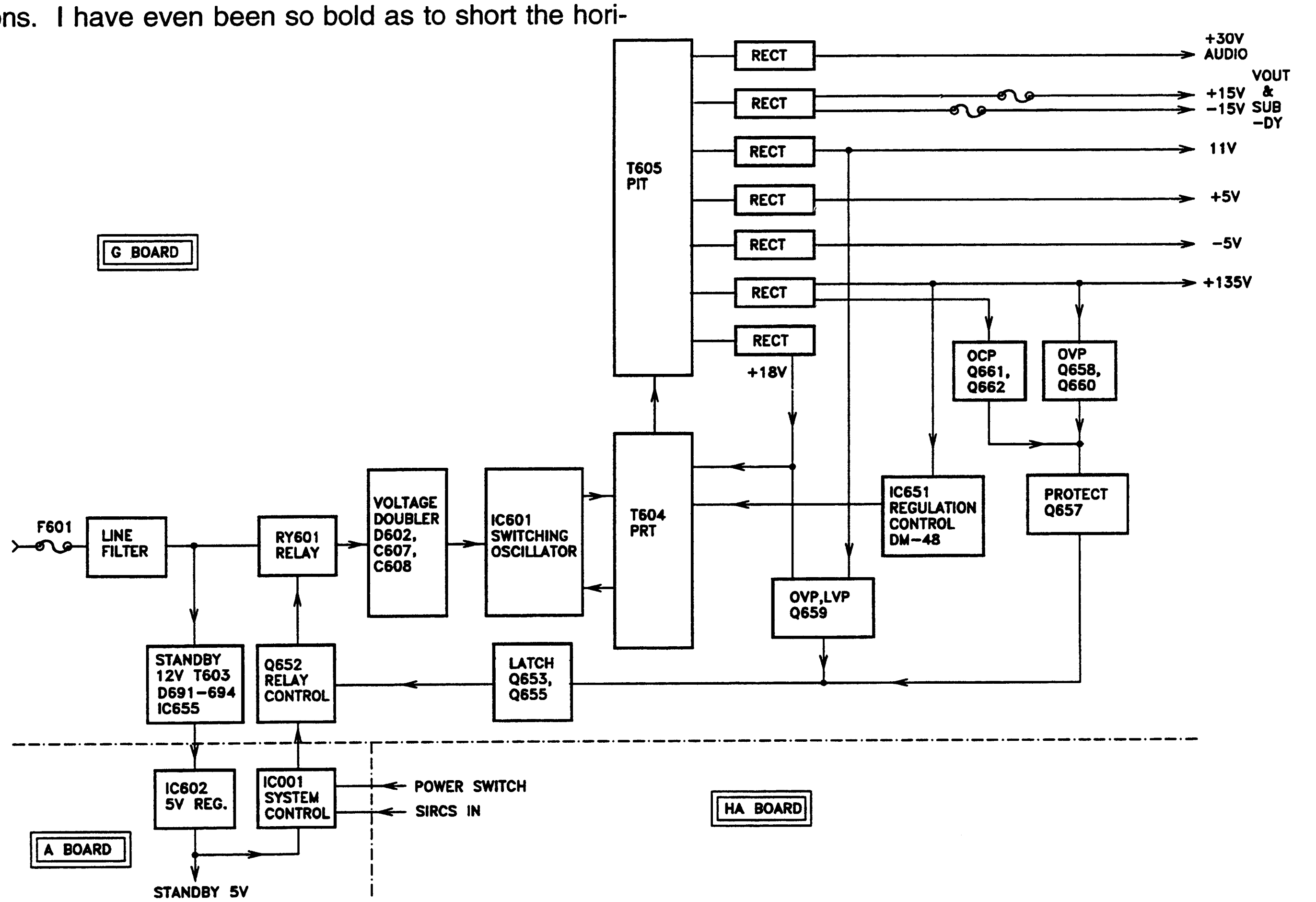
AC power was re-applied (with the relay jumper still intact). We brought the voltage up until the horizontal spike began to "dance" and backed it down until it stopped. AC current draw was 1.5 amps. Safe for now. The idea here was to check the scan-derived voltage lines in a dynamic state. Voltages seemed to be OK except for the +15 and –15 lines. They were slightly out of proportion with the other lines. While scratching my head and wondering what to look at next, a plume of smoke began to rise from the chassis. BINGO! In our rush to observe the suspect component, we created turbulence in the air and couldn't tell where the smoke was coming from. It was time to shut the unit down. Running the supply in excess of 1.5 amps for more than 30 seconds will cause the switching transistors to overheat and fail.

After waiting a few minutes for things to cool down, we brought the AC voltage back to the point where we left off (while monitoring the current and horizontal pulses) while patiently (and motionlessly) waiting for the smoke to re-appear. The vertical output IC was the culprit. It had shorted the +15 and –15 lines together. This is why we couldn't detect a short during the static resistance check.

The above example demonstrates how one can safely utilize a variac to troubleshoot. ***We were able to run the switching oscillator with the relay shorted and a dead short between the + and – rails of the flyback derived 15V lines without taking out the newly installed switching transistors.*** With caution, you can literally "smoke out" a bad component in certain situations. I have even been so bold as to short the horizontal output transistor collector to ground with a clip lead and bring the set up to 1.5 amps on the variac without damaging anything on the set. **It's all a matter of current control.**

PROJECTION TELEVISION CHASSIS

Figure 3 illustrates a typical power supply block diagram found in our last two projection television chassis. It is also found in recent 35" direct view sets and a similar arrangement will be used in our BA-4 chassis on the 27" sets. Notice the difference in how standby power is generated and where the on-off relay is located. Standby 12V and 5V comes from an independent AC transformer and are present without the switching oscillator running. The oscillator is turned on by the power relay when the set is turned on, unlike direct-view sets where the oscillator is running constantly and generating all standby voltages. Notice RY601, which applies AC power to the bridge rectifier D602. This applies power to IC601 and T604 to start the oscillator. IC601 is actually a dual transistor pack.



POWER SUPPLY BLOCK DIAGRAM

Figure 3

Testing of this type of supply requires a slightly different approach. This oscillator only runs when power on is engaged. When bringing this supply up on a variac, the relay will not close until approximately 65VAC. This is too high since the supply is quite capable of producing full secondary voltages at this level. If there is any excessive load on one or more of the secondary lines or any bias problems in the oscillator itself, you will lose the switchers. It is therefore necessary to have the relay (RY602) jumped in order to start the oscillator at a low AC voltage. As mentioned earlier, these oscillators will start with as little as 5VAC. Following is a sequence I recommend that has always been safe and reliable for me:

Step 1. Check the switching oscillator. Remove all connectors from the secondary voltage lines. Do a static resistance check on all of the secondary lines on the power supply board while these connectors are off. This will help to locate any shorted or leaky filters and diodes in the secondary lines. If these check OK, short the power relay, connect a scope to junction of Q601E and Q602C and slowly apply AC power to the unloaded power supply while monitoring current and the waveform on the scope. Other than an initial current spike caused by charging filters, you should draw virtually no current while the oscillator is running. Monitoring of the oscillator waveform is primarily to verify start of oscillation although we will be on the lookout for fluctuations. Any fluctuations in the waveform, however, will almost certainly cause high current readings at low AC levels. If AC current rises with voltage, you have a problem. Look for leaky or shorted components (diodes and capacitors) in the oscillator section. Pay close attention to feedback capacitors (C610 and C612 in the Figure 1). If all checks well, proceed to step 2.

NOTE: Do not exceed 40VAC input while performing this test. Any problems in the oscillator or secondary circuits will appear at low AC voltages. The reason I suggest this maximum voltage is that I am uncomfortable with running any switched mode supply unloaded. Although I have run all of these Sony projection supplies unloaded with full AC power, other types (particularly other manufacturer's) I have worked with in the past do not take well to this. There is no reason to run the oscillator at full AC while unloaded since any problems will appear well below that point.

STEP 2. We are now going to check the secondary voltage lines. Reconnect all secondary lines and with the relay still jumped, slowly apply AC power. Current should rise as we increase voltage. What we're concerned with here is when we start nearing 1.5 amps on the AC amp meter. If current continues to rise from this point, we have a problem. Do not exceed two amps or you'll be late for supper this evening (or lunch will be less enjoyable depending on the time of day). Proceed to step 3 of the direct view television power supply mentioned earlier in this article. Everything is common from this point on.

NOTE: It is probably a good idea to disconnect all three CRTs when performing the above step while working on projection televisions. There is a possibility of loads on B+ and B- supply rails, which affect main and sub deflection circuits, which could cause burning the phosphor of one or more of the CRTs. A good example is our RA-1 projection chassis in which one section of the protection circuit monitors loss of horizontal deflection. A separate circuit generates the high voltage. If the horizontal driver transistor were to short (and show up as excessive current during the variac test) we would stand a good chance of burning the tubes since there would be high voltage with no horizontal deflection. Be extremely careful when jumping the relay in a projection television. There are usually many protection circuits with some of them designed to guard against CRT damage. ***Always disconnect the CRTs when you have the relay jumped.***

As you can see, with a little caution, common sense and a variac/AC amp meter, the above steps will assist you in accomplishing more effective repairs on not only our power supplies, but also in other manufacturer's as well. While the procedures mentioned in this article help prevent immediate failure of the power supply, there will come times when they fail hours, days or even weeks later. This will not always be an easy fix. Based on prior experience, bad solder connections on the horizontal drive transformer, bad horizontal drive transformers, soft start circuit failures and solder connections on the power supply itself have been known to cause delayed failures of the switching transistors.

Happy Troubleshooting

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