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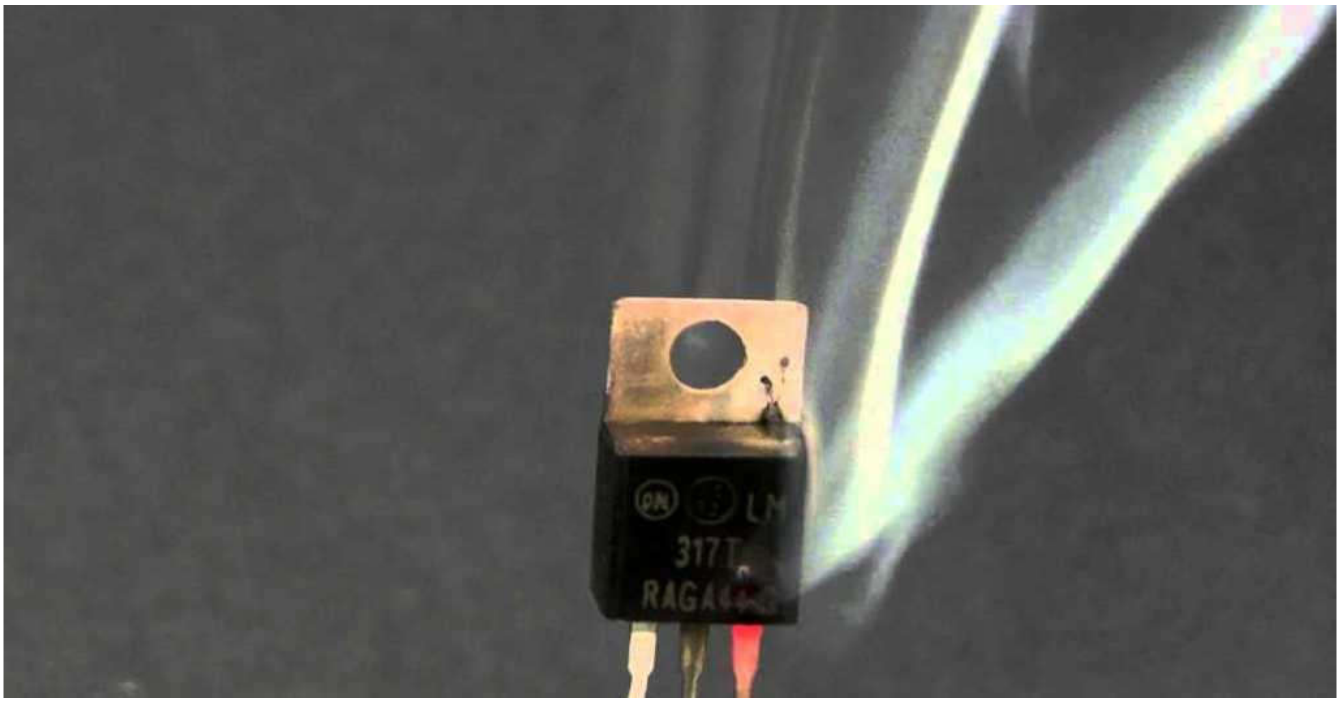
Integrated circuit power dissipation

Understand the principles that will keep your chips from smoking.



Responding to a customer, I wrote: If the Elantec part burns up so will the National part. I suspect that the greater current handling capacity of our part will cause less power to be dissipated in our part but I doubt that would account for more then a few degrees of steady-state temperature difference.

The heat that the part reaches is a simple relationship. All that matters is how much heat is added (by the current and voltage across the output transistors) versus the heat subtracted from the part to the air and the circuit board.

Putting a heat sink on the plastic part will have little value. The heat travels through the plastic package so slowly that a metal heat sink on the plastic does very little to cool the silicon die itself. The best place to remove heat is through the lead-frame that the die is mounted to. In most parts, that lead frame is also the ground or common or V- pin.

The circuit board designer should pour as much copper plane around this pin as he can. If it is OK with manufacturing there should be no thermal relief on this pin-- the whole point is to get heat out. This may require manufacturing to modify the thermal soak and temperature profiles for the IR soldering so that the pin gets soldered properly.

It is also helpful to use many many vias to connect this top side thermal plane with similar planes poured on the other layers. Naturally the top and bottom layers are best since it is easiest to get the heat to the air from these surfaces but even inner planes can take away heat. As a further measure if the outside copper pours can be bare-- with no solder-mask-- this helps get the heat out to the air. The solder-mask serves as a thermal insulator.

So much for getting the heat out of the part. How do we calculate how much heat gets added? It is a basic principle but often overlooked-- the heat generated in the part is from the power dissipated in the output transistors. The power dissipated in the output transistors is equal to the instantaneous voltage across the transistor times the instantaneous current through the transistor. The average power is the average of this instantaneous power. It is a little tricky to realize that the power dissipated in the load is completely independent of the power dissipate in our part. For instance, if our part was fully saturated and was putting 100mA into 100 ohm at 10 volts then the resistor is dissipating 10 volts times 0.1 amps or 1 watt. Say the part is operating with a 10 volt supply voltage. This means that the output transistor that is delivering current has almost no voltage across it-- it is fully turned on or saturated as we like to say. So it has the same 0.1 amps through it as the load resistor but only perhaps 0.2 volts across it because it is fully turned on. Then the power being dissipated in the part is only 0.1 amps times 0.2 volts equals 0.02 watts. So when the load is dissipating the most power the part is dissipating a small amount. Now everything changes if the output transistor is not fully turned on. Since the voltage and current through a resistor has a linear relationship it can be guessed that it is worse-case when the output transistor is supplying current to the load at one-half the power supply voltage. Using the same situation as above-- let 5 volts be put across that 100 ohm load resistor. That would make 50 milliamps flow. So the power dissipated in the load is 5 volts times 0.05 amps or 0.25 watts. But now look at the part. The output transistor is still fed from a 10 volt supply rail so the transistor is putting 5 volts across the load so it must have the other 5 volts across the transistor. The output transistor is no longer fully on-- it is acting like a resistor and limiting the current and voltage across the load. So the output transistor has 5 volts across it and is delivering the same 0.05 amps the load sees so it also is dissipating 0.25 watts. From this we can see that the worse waveform for power in our part is DC at one half the supply voltage (if the other end of the load resistor is tied to ground).

Now if the load is capacitive (like a TFT panel) or inductive then things become even harder to analyze since the voltage and current are no longer directly related. You can have a lot of voltage across the part and no current or current and no voltage. The scope photos you took show that the voltage and current are pretty well related in the TFT however, so then it is simple calculating the power dissipated when the part delivers current and averaging that over time. In order to lower the power dissipated in the part you have to reduce the current it delivers or the voltage across the output transistors.

In this application you could lower the power supply voltages to the part, or put resistors in the power and ground leads of the part. Then the power will share and be dissipated in both the part and the resistors. You can also put a resistor in series with the part's output. This resistor can be inside a feedback loop so that the transient response is still good but the current and voltage across the output transistors will be made smaller and less heat still be produced. It is also possible to put diodes or zener diodes in the power leads of the part to lower the supply voltage but this may be too expensive for the customer.

You asked if we had any questions and I must confess I do. The schematic shows that the TFT uses two Vcom drivers that are connected to the panel in four places. This does not make sense to me. Their is only one Vcom electrode in the TFT and it covers the entire front side of the panel. There is also no load capacitance shown and a TFT panel looks very much like a capacitor -- there is no real physical capacitor on the schematic-- the panel electrodes themselves form a capacitor and it is this capacitor that the Vcom driver must charge. I suspect that Samsung has two Vcom drivers connected to the panel through current limiting resistors or the resistors are also not discrete resistors but just the equivalent resistance in the Indium-Tin -Oxide electrodes that connect to the Vcom electrode. The wires without the resistors I suspect go to the "-" feedback pin of the op-amp. It would make no sense to connect two wires with resistors and then short these resistors out with two other wires. We also need to know the power supply voltage that the Vcom driver is supplied with for it is this voltage less the output voltage that appears across the Vcom driver output transistor.

So in short-- to reduce the heating of the part-- increase the copper area connected to the ground pin, reduce the power supply voltage and add resistance to the power and ground leads or to the series resistance in the output. It would be most beneficial to run the feedback lead of the op-amps from the far pin of the series resistor-- with the right resistor value this would allow the part to almost fully turn on the output transistors to charge the Vcom electrode thereby keeping power disipated in that part to a minimum.

Oh, and before I go (or put you to sleep from all this writhing!) I must warn you to pay attention to the unused outputs of the LM6584 if you try it in this circuit. You cannot just tie the unused amplifiers to power or ground-- you must tie them to a mid-supply or the large base-drive currents the part can be capable of will only add more power into the part. You could tie the minus and output pins together and then tie the plus pin to the output of the amp used for the Vcom amplifier-- this would keep the unused parts operating mid- supply. Paul

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