Load-sharing techniques: Paralleling power modules with overcurrent protection

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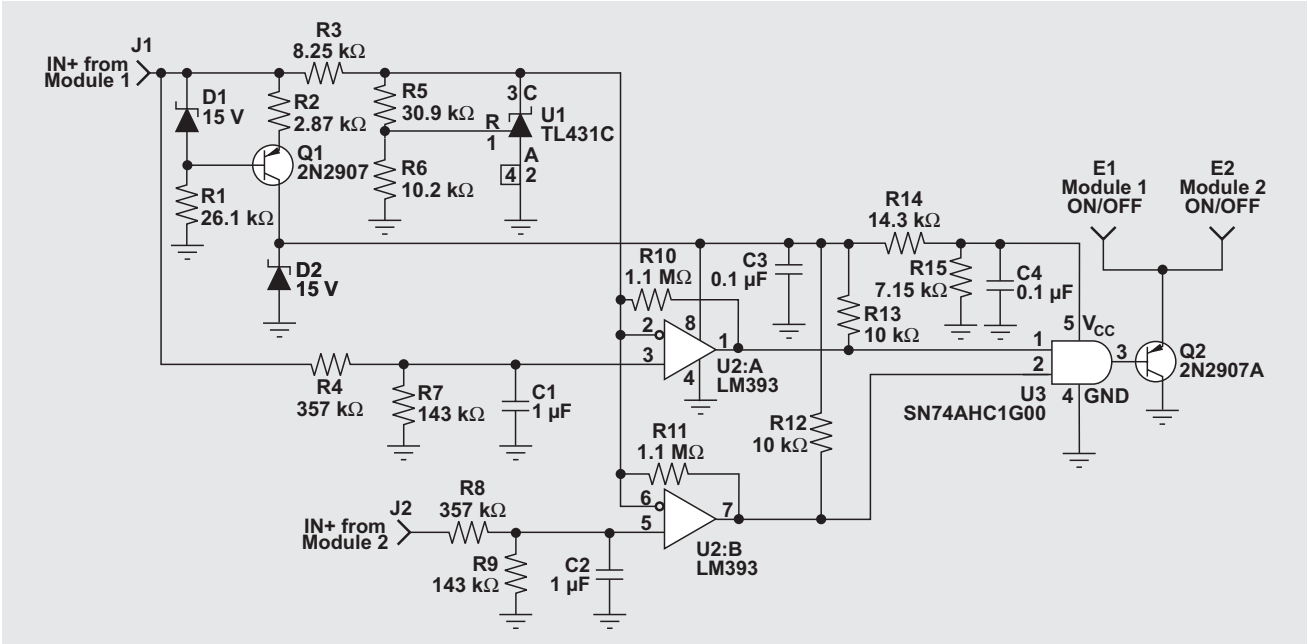
Paralleling low-current, low-voltage power modules for high-current, low-voltage applications has many benefits. Among them are: redundancy for enhanced reliability, hot-swap capability, distributed heat removal, and design flexibility. Paralleling power stages requires load sharing in order to equalize the stresses among the modules. One method of load sharing, based upon the automatic master/slave architecture, is to use a dedicated controller, such as the UCC39002, to provide for equal current distribution of the load current among the parallel-connected power supplies. The power modules must be equipped with true remote-sense capability or an output-adjustment terminal. The output current of each module is measured and compared to a common load-share bus. The positive sense voltage or the voltage of the output voltage adjust pin of each module is adjusted to provide equal current sharing.

Several modules are paralleled so that the entire assembly can support a full load much greater than an individual module would be capable of supplying. Due to manufacturing tolerances and component variations, startup delay times typically vary slightly from module to module. When the modules to be paralleled have an overcurrent protection circuit featuring constant current limit with automatic recovery, starting up fully enabled into the full system load does not pose a problem. Inevitably, one module will have a faster turn-on than the others. The eager module will carry as much of the load as it can, sometimes up to 140% of its individual current capacity, before its output voltage falters. Meanwhile, the next module will come up and contribute to the load. After a brief transition time, all of the modules will be up, the master will be recognized, and accurate load sharing will take place.

When the modules to be paralleled have an overcurrent protection circuit featuring a hiccup mode, starting up fully enabled into full system load, regardless of the load sharing technique used, does pose a problem. The module with the fastest turn-on profile will come up into an overcurrent condition. Immediately, in an act of self-preservation, it will go into hiccup mode, alternately sinking and sourcing current. The next module to come up into the load will also fall into this hiccup mode, sinking current when the other module sources it. Because the load-share circuitry essentially adds a voltage loop to the output of each module, this hiccupping overcurrent protection mode will prevent loop closure. Simultaneously enabling the modules will prevent this hiccup mode from starting, and load sharing can be successfully achieved.

Figure 1 shows a simple comparator circuit that will simultaneously enable two modules and can be expanded to accommodate more if needed. It assumes that the only

Figure 1. Logic circuit to turn on two power modules simultaneously



bias available for the logic gates is the 48-Vdc bus used as the input to the modules themselves. The circuit is designed to short the modules' on/off pins to ground simultaneously when their inputs reach 35 V, assuming that the modules' input range is between 36 V and 75 V and that they have a turn-on threshold of approximately 33 V.

The PNP transistor, Q1, its emitter and base resistors, and the two 15-V Zener diodes provide a 15-V, 5-mA bias to the comparators and the NAND gate from the input line, which could vary from 36 Vdc to 75 Vdc. The TL431 is set up to provide a regulated 10-V reference voltage for the inverted comparator inputs. The non-inverted comparator input signals are derived from resistively dividing the input voltages of the modules. Because the bias and comparator signals are from the same source, capacitors are needed to delay the comparator input signals long enough so that the LM393, U2, is operational and "smart." This circuit is added to the load-share board and successfully turns on the modules simultaneously into a full system load without triggering the overcurrent hiccup mode of the modules.

Related Web sites

analog.ti.com
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Replace *partnumber* with LM393, SN74AHC1G00, TL431 or UCC39002

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