1 Effects of Gate RC Soft Start

The LM25066A has a power-limiting feature to help protect the external MOSFET (keep it operating under its SOA curve). However, for designs with large load currents and output capacitances, using a power-limit-based start-up can be impractical. Fundamentally, increasing load currents will reduce the sense resistor, which will increase the minimum Power Limit. Using a larger output capacitor will result in a longer start-up time and require a longer fault time. Thus, a longer timer and a large power limit setting are required, which places more stress on the MOSFET during a hot-short or a start into short. Eventually, no SMD FET in a 5x6 package can support such a requirement. An alternative is to limit the inrush current with a slew rate control circuit (also known as "soft-start" or "dv/dt" circuit). Below we discuss a simple implementation which consists of an RC circuit added to the GATE pin.

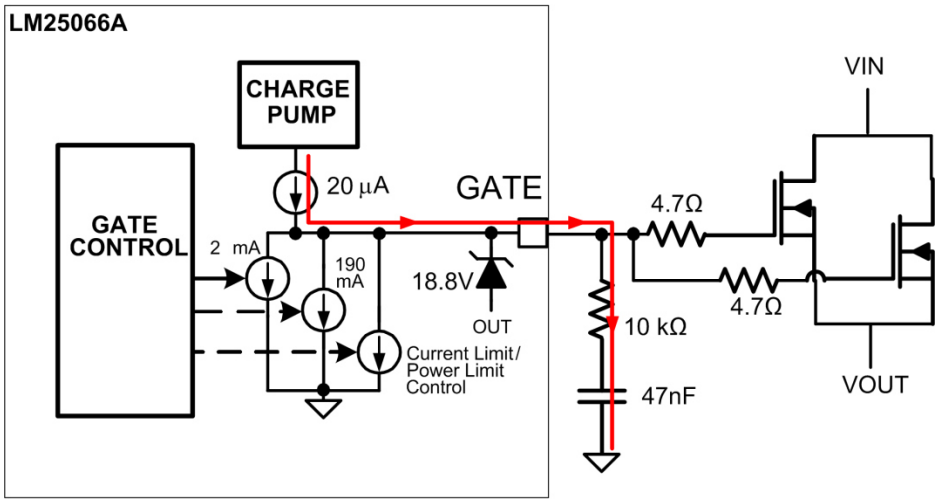

Figure 1 RC Based Soft Start Circuit. Path of charge during startup shown in red.

As shown in Figure 2, a 10kohm resistor and 47nF capacitor was added to the gate pin of the IC. This effectively sets a slew rate for the gate pin voltage. The slew rate would be I = C * dv/dt → dv/dt = I/C = 20uA / 47nF = 0.43V/ms. This slew rate effectively controls the inrush current rather than the LM25066A regulation circuit during startup (but this does not disable the LM25066A – it will still control current if it exceeds power limit or current limit).

The issue with this implementation occurs when the LM25066A sees a circuit breaker event. The logic of the LM25066A can be described as follows:

If (Current Measured > 1.9x Current Limit)

Then (Activate 190mA pull-down on GATE pin)

If (Current Measured falls below 1.9x Current Limit)

Then (Deactivate 190mA pull-down on GATE pin)

This ensures a fast response during severe over current events. Once the pull-down is deactivated, the normal power limit and current limit loop takes over. The 10kohm resistor serves two purposes:

- It blocks charge from the soft start capacitor to allow the 190mA to pull down the MOSFET gate as fast as possible.
- It prevents an excessive surge of charge from going into the GATE pin.

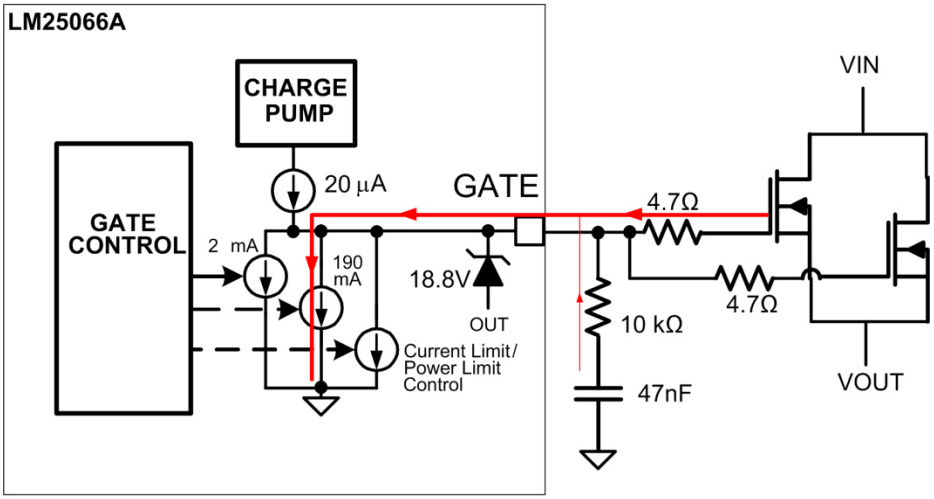

Figure 2 Path of current for pull-down circuit when using Gate RC.

However, the gate RC interferes with the power limit loop of the LM25066. Since the external MOSFET will shut off before the soft start capacitor has had sufficient time to discharge, then the soft start capacitor will immediately inject charge into external MOSFET gate, causing it to turn back on.

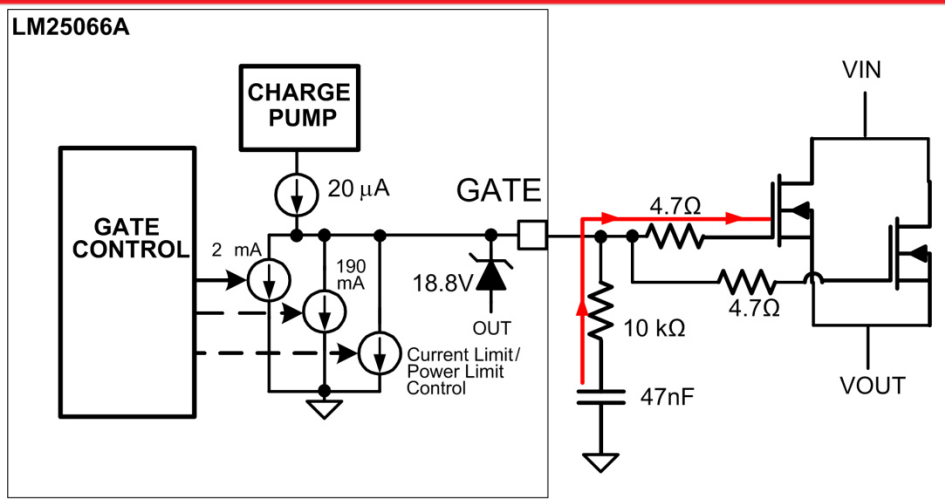

Figure 3 Injection of charge from soft start capacitor to MOSFET gate.

The fast FET turn on results in a large current through the FET and this triggers the circuit breaker response again. This cycle will repeat several times while the soft start capacitor slowly drains a pulse of current during each pull-down cycle and each time it charges the MOSFET gate. Eventually, the capacitor will be depleted and the IC will regulate a power limit as normal.

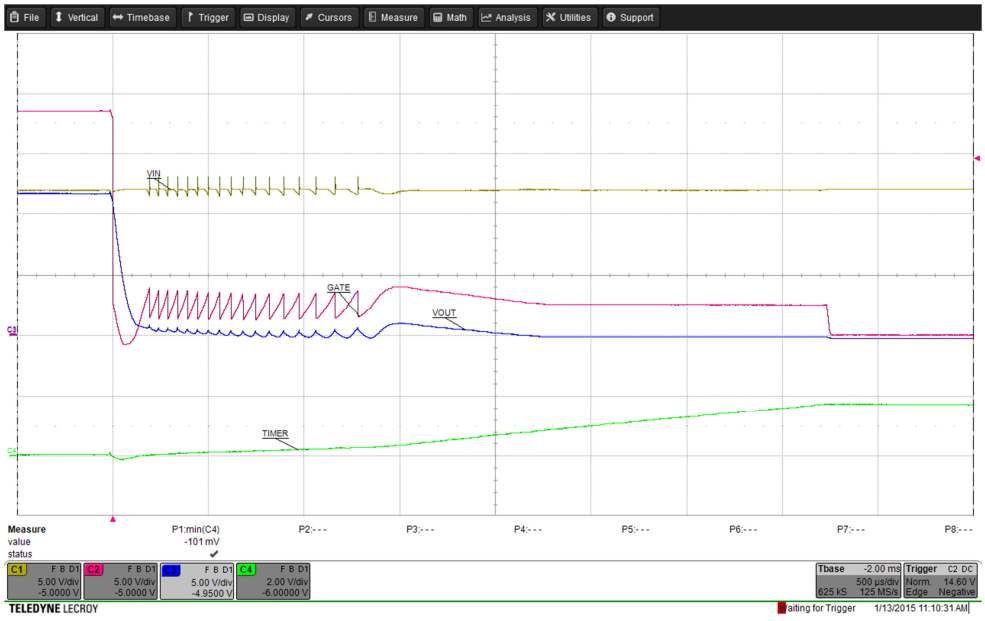

Figure 4 Hot Short on Sochi board showing cyclic behavior caused by the RC soft start circuit.
VIN – Yellow, GATE – Red, VOUT – Blue, TIMER - Green

Note that the gate pulled down and re-started 17 times in ~1ms in the waveform above. This cyclic behavior adds stress to both the LM25066 device and the external MOSFET.

2 BJT-based Soft Start Circuit

The previous soft start circuit implementation caused repeated switching and additional stress.

The current recommended implementation removes the previous effect entirely. The circuit consists of a 1kohm resistor, Cdv/dt capacitor, but adds a diode D1 (1N4148) and a PNP BJT Q3 (MMBT3906).

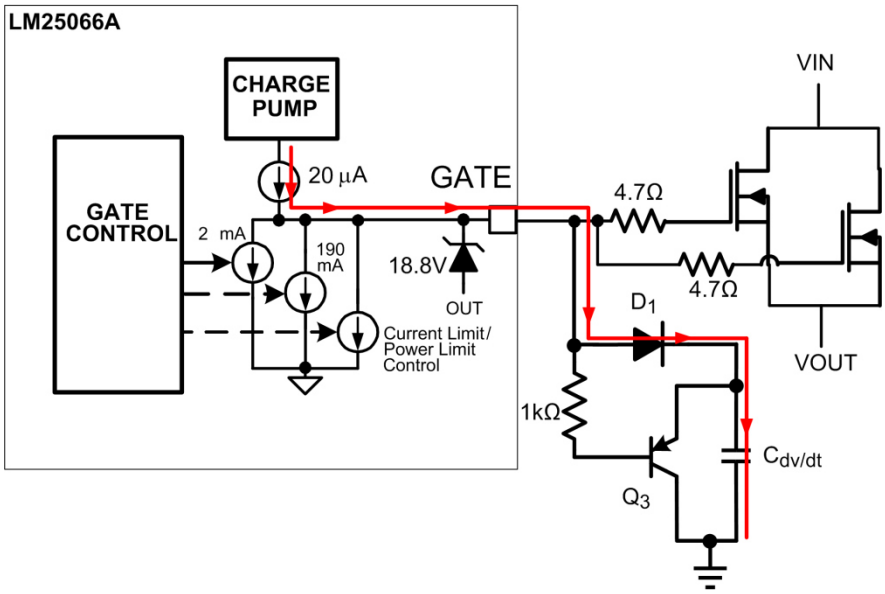

Figure 51 Charging path of the soft start capacitor in red.

The capacitor and diode do not affect the soft start equation which still holds: I = C * dv/dt where I is the charge pump current (20uA typ), C is the Cdv/dt soft start capacitor and dv/dt is the resulting slew rate.

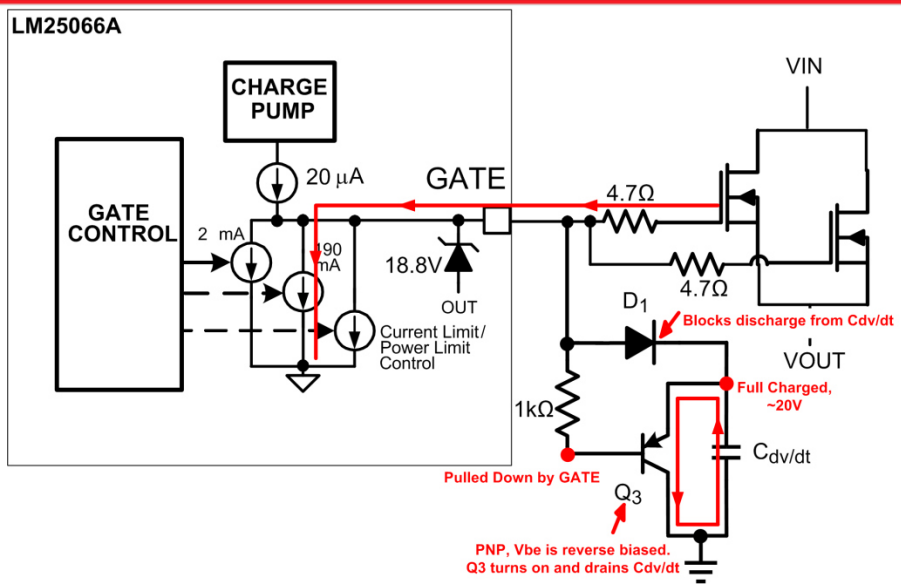

Figure 62 Path of current during circuit breaker response.

Where the RC circuit caused problems was its inability to discharge the soft start capacitor during its pull-down cycle (see Section 2.2.2 for more details). The BJT solution avoids these problems by using Q3 to discharge the Cdv/dt cap entirely whenever the GATE has a strong pull-down. See Figure 14.

This new BJT circuit will reduce stress on the gate pin and external MOSFET, thereby improving system reliability. It is recommended for all new high power designs.