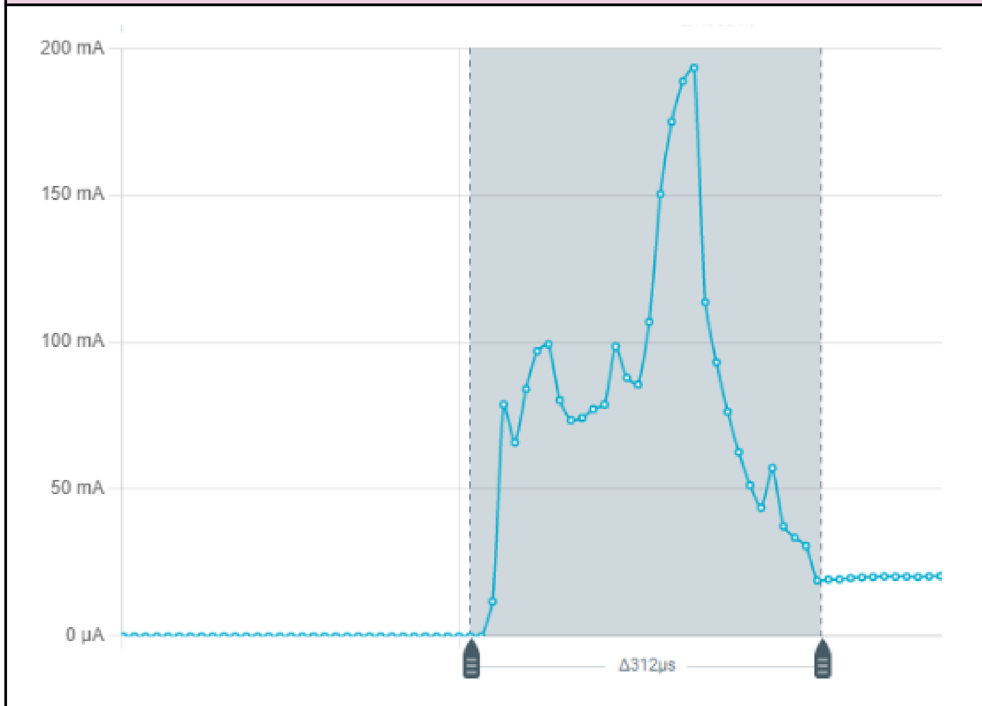
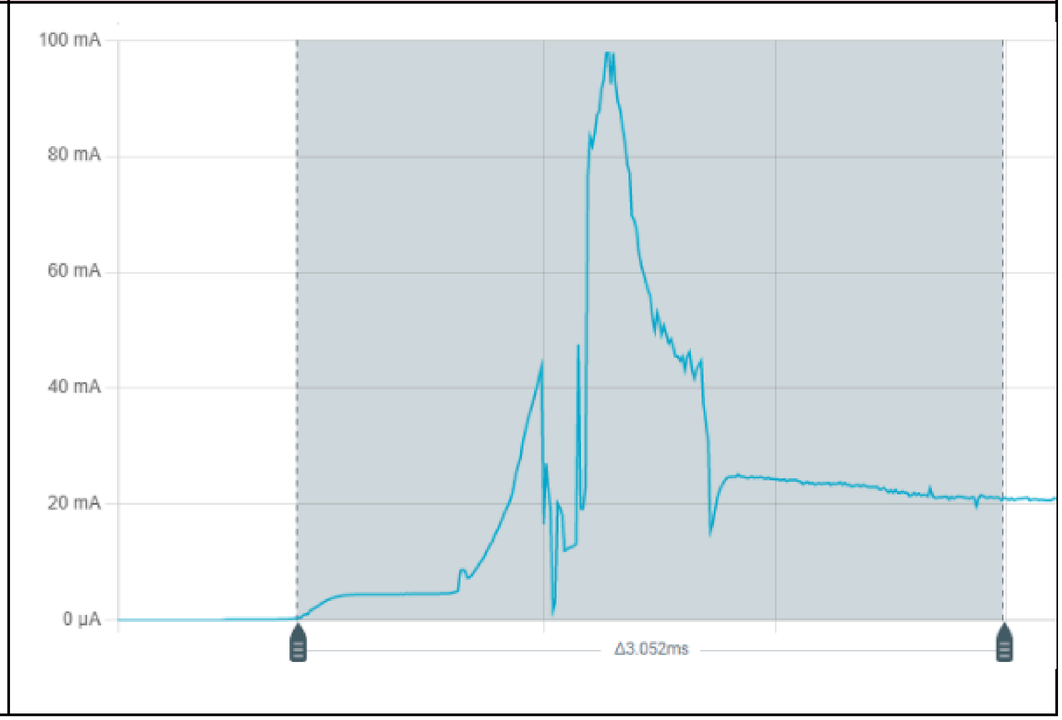
Results

You can substantially limit the inrush current of a sub-circuit you turn on with a microcontroller.

Using the approach below, a small circuit change was able to reduce the inrush current of the ATGM336H GPS module by 50%.

The inrush duration went from 300us to 3ms.

<table>
<tr><th>Before (200mA y-axis scale)</th><th>After (100mA y-axis scale)</th></tr>
<tr><td>


</td><td>


</td></tr>
</table>

It is possible to simulate these circuits as well, see Simulation section.

Summary

High-Side vs Low-Side Switching Concept

You want to electronically turn a circuit on or off (eg with a microcontroller).

You can interrupt the power to the circuit by cutting off its power supply (high side) or cutting off access to ground (low side).

High-Side Switching Use Cases

Use when:

- Switching ICs or smart circuits you will communicate with
- Load voltage same as your control voltage

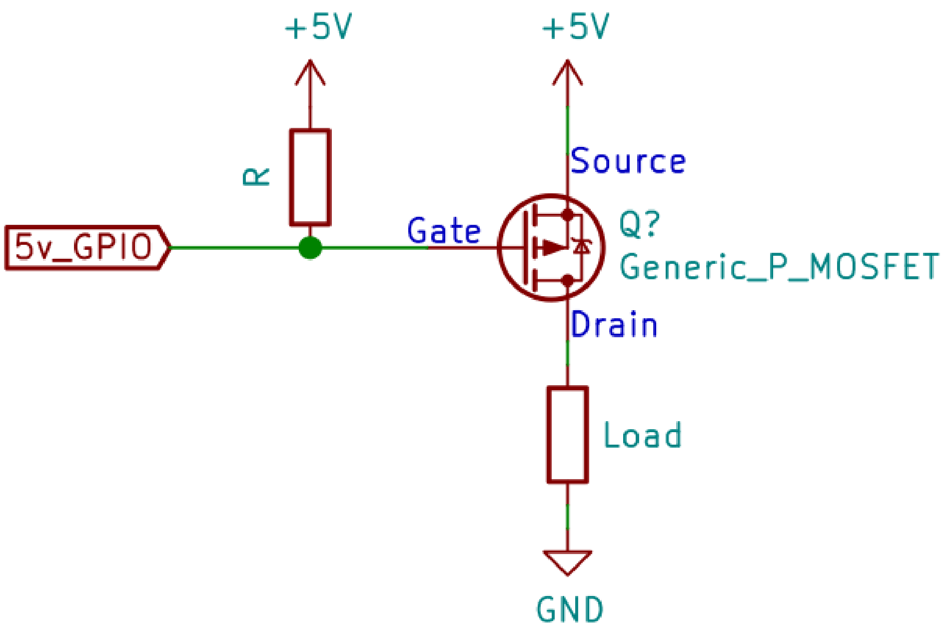
(link) Engineering hobby site elaboration

Generally, you want to keep the ground connected in a circuit and switch the power. One reason is that even when the transistor is fully turned on, there is still a small voltage drop across it. That voltage drop means the ground is not 0 volts for that device. It does not matter which you switch for something simple like an LED. However, an active device like a Microcontroller needs its ground to be ground! So when you have a load that requires ground, you NEED to use a high-side switch.

High-Side Switching Circuit

P-Channel Enhancement MOSFET
(not N-Channel, nor Depletion)

It is a good idea to have a pull-up resistor to ensure the gate is in a constant state regardless of whether your microcontroller is active or not.



Inrush Current Problem

When you suddenly activate the load circuit, the capacitance of that circuit will momentarily consume large quantities of current as the capacitors charge up.

This can be bad, as it may exceed the capacity of the power supply to sustain, and cause the power rail voltage to sag, potentially impacting other components negatively.

Inrush Current Mitigation Circuit

You can not change the capacitance of the load circuit.
You can change the rate at which you feed it current.

The Gate of the MOSFET does not have to be all the way ON or OFF. You can slowly change the voltage of the gate from OFF to ON over time.

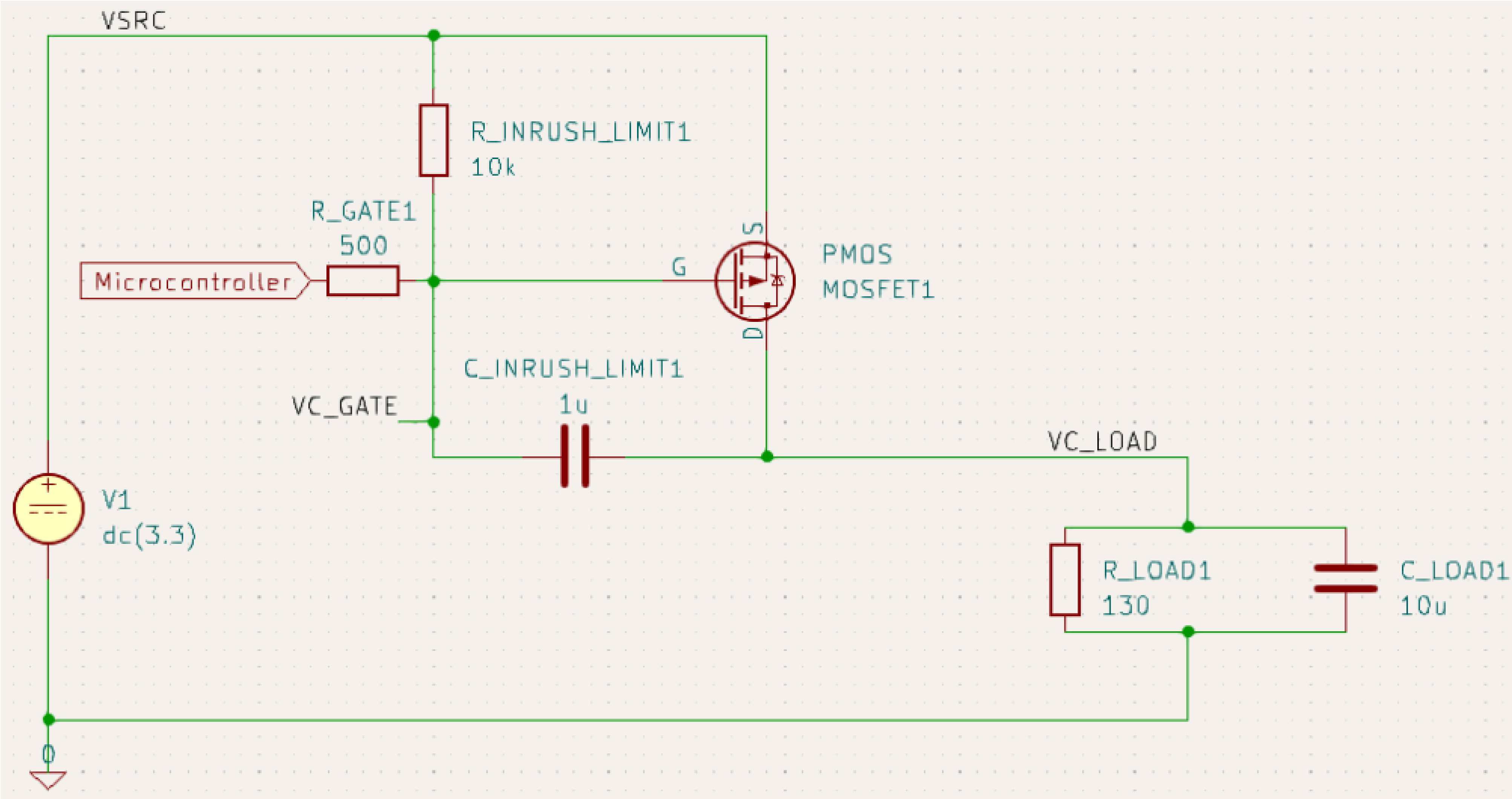
During the time the MOSFET is between OFF and ON, it is changing the rate it allows current to pass through, like a variable resistor.

The circuit below, using a technique described by ON Semiconductor (link), models this.

In short, the Gate voltage will be influenced by 3 components:

- Pull-up resistor
- Microcontroller series resistor
- Capacitor between Gate and Drain

The load is modeled as both resistive and capacitive.



VSRC
R_INRUSH_LIMIT1
10k
R_GATE1
500
Microcontroller
G
S
D
PMOS
MOSFET1
C_INRUSH_LIMIT1
1u
VC_GATE
VC_LOAD
V1
dc(3.3)
R_LOAD1
130
C_LOAD1
10u
0

Explanation

(don't forget this is a P-Type MOSFET, so HIGH is OFF, LOW is ON)

In the state where the microcontroller is HIGH (MOSFET is OFF):

- Voltage divider formed between pullup resistor and microcontroller inline resistor
  - This equals the input voltage, both the pullup and microcontroller are applying same voltage
- The capacitor charges to this input voltage

When the microcontroller changes to LOW (MOSFET goes to HIGH):

- The microcontroller voltage goes to 0
  - Now there is a voltage divider in effect between pullup and gate resistor
  - The capacitor still retains some charge (voltage) from prior state
    - So it slowly bleeds off its charge through the microcontroller resistor

In short, when the microcontroller goes from HIGH to LOW, the capacitor doesn't, it takes a little while.
That little while slowly decreases the resistance of the MOSFET, slowly turning the MOSFET all the way on.

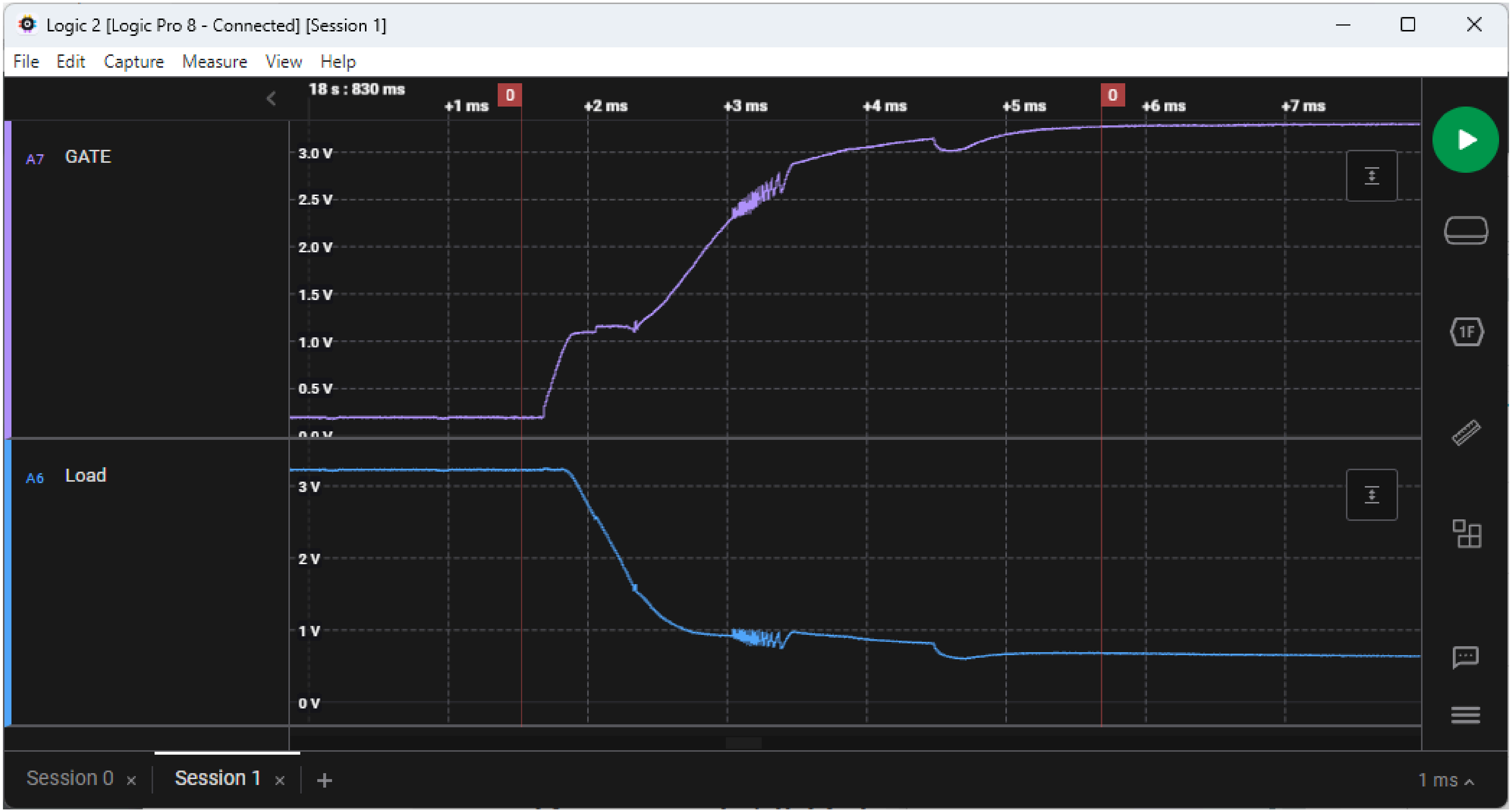
Implementation with ATGM336H GPS

All measurements were done on a breadboard, 3.3v supply.
AGTM nRESET, VCC, VBAT, ON/OFF tied together, all GND tied together.

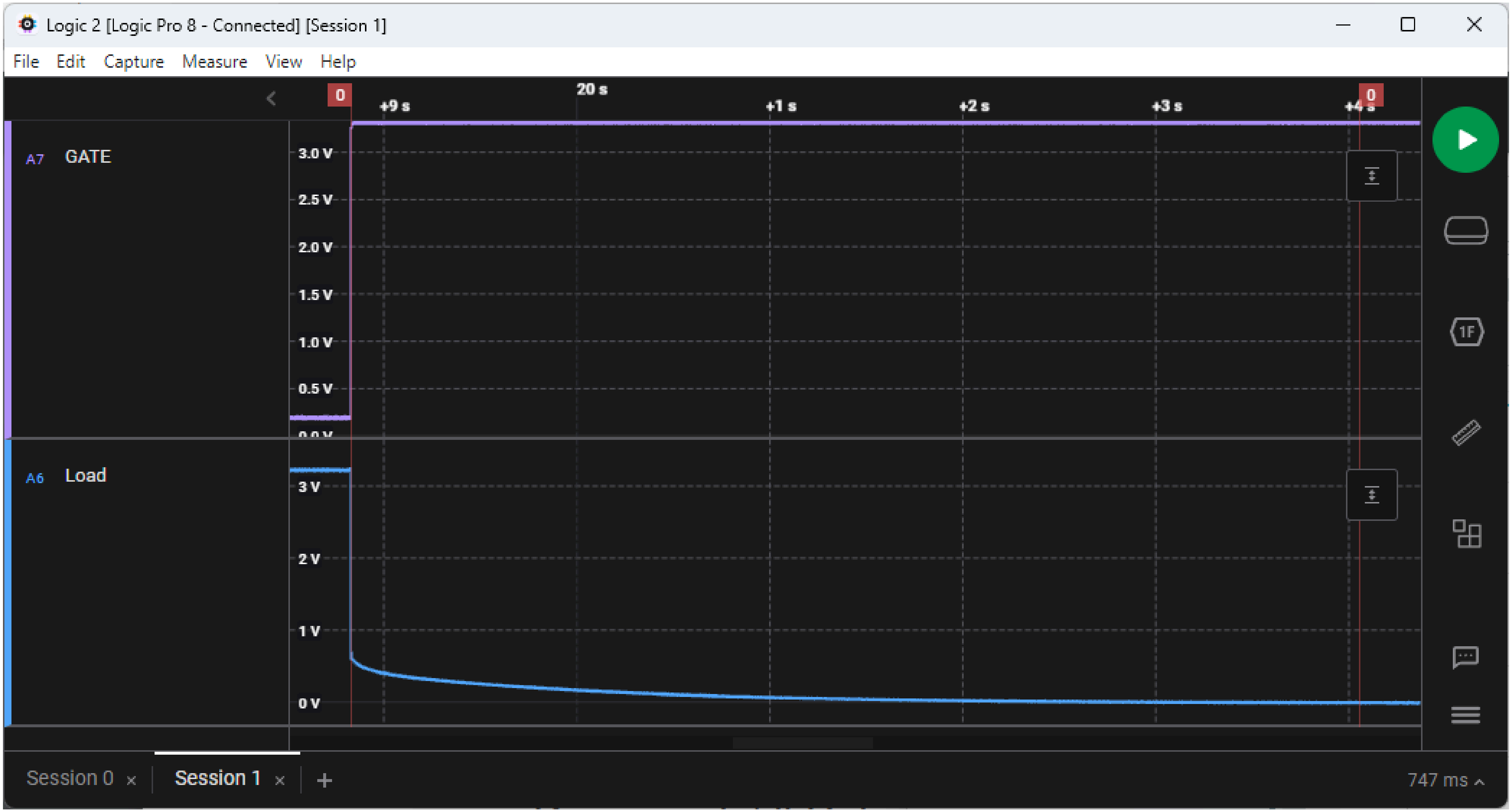
ATGM Inrush Caps - Turn On


Power Profiler v3.5.5: CD18951A6ACD
PPK2
CD18951A6ACD
DATA LOGGER
REAL-TIME
ABOUT
MODE
Source meter
Ampere meter
Set supply voltage to
3300 mV
Enable power output
SAMPLING PARAMETERS
100,000 samples per second
Sample for 600 seconds
Estimated RAM required 240.0 MB
10 us period
Start
DISPLAY OPTIONS
Timestamps
Digital channels
0 1 2 3 4 5 6 7
SHOW SIDE PANEL
LOCK Y-AXIS
10ms
100ms
1s
3s
10s
1min
LIVE VIEW
Δ5.082ms
100 mA
80 mA
60 mA
40 mA
20 mA
0 μA
Δ3.052ms
WINDOW
SELECTION
SELECT ALL
CLEAR
20.02mA average
97.77mA max
5.082ms time
101.76μC charge
24.88mA average
97.77mA max
3.052ms time
75.94μC charge
CLEAR LOG
OPEN LOG FILE
AUTOSCROLL LOG
SHOW LOG

ATGM Inrush Caps - Turn Off



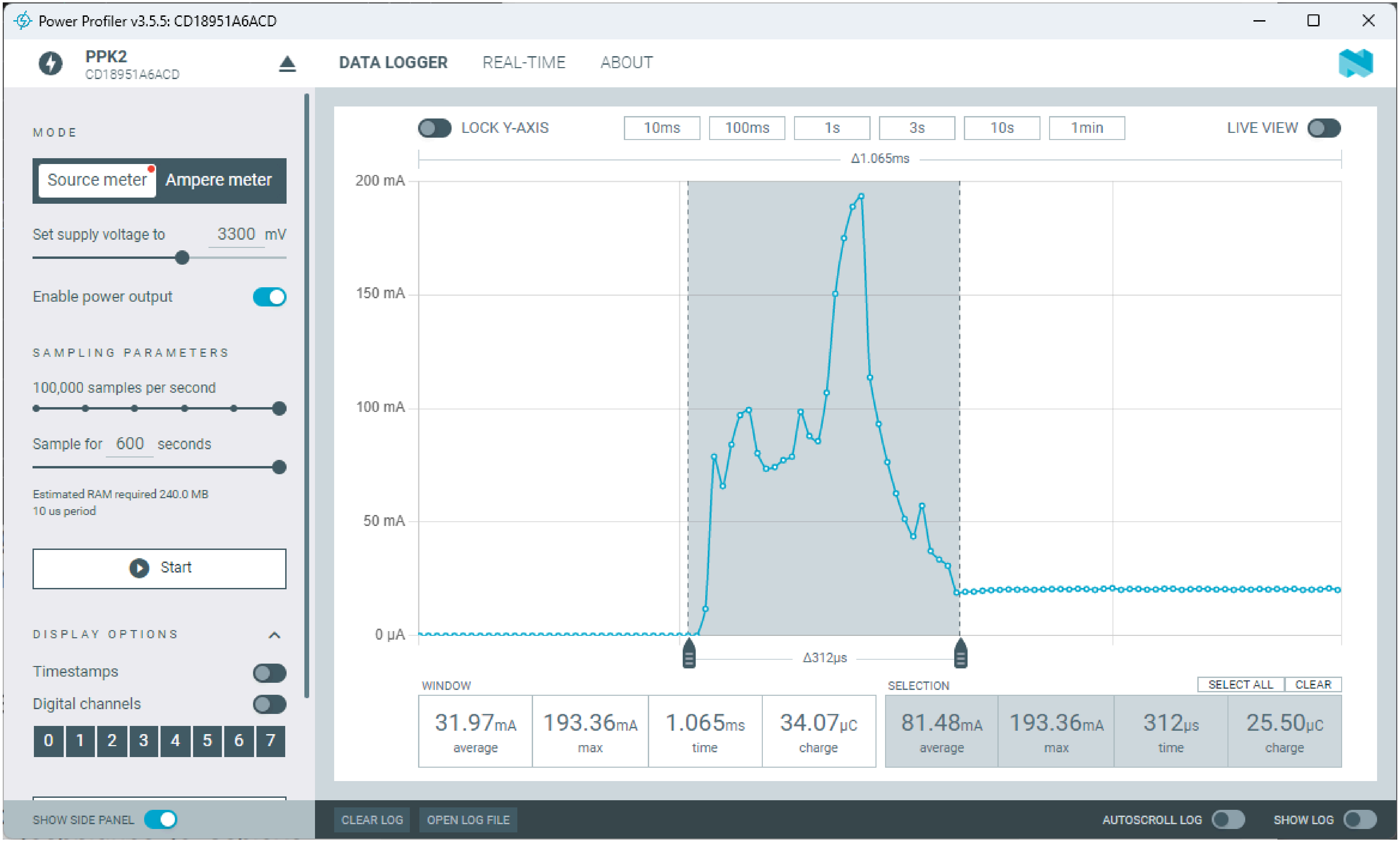
Takes seconds for caps to discharge



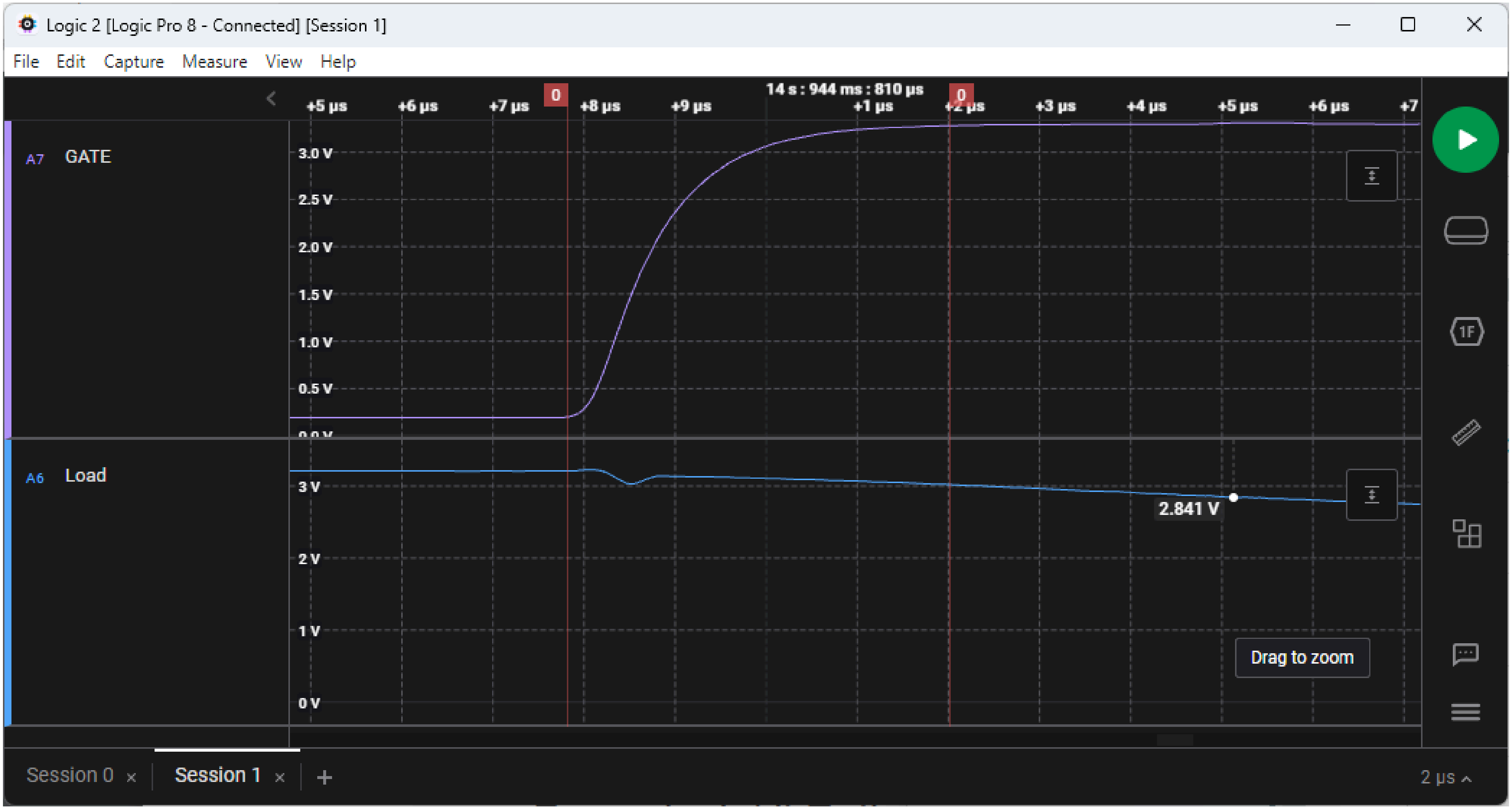
Logic 2 [Logic Pro 8 - Connected] [Session 1]
File Edit Capture Measure View Help
0
20 s
+9 s
+1 s
+2 s
+3 s
+4 s
A7 GATE
3.0 V
2.5 V
2.0 V
1.5 V
1.0 V
0.5 V
A6 Load
3 V
2 V
1 V
0 V
Session 0
Session 1
747 ms


Power Profiler v3.5.5: CD18951A6ACD
PPK2
CD18951A6ACD
DATA LOGGER
REAL-TIME
ABOUT
MODE
Source meter
Ampere meter
Set supply voltage to
3300 mV
Enable power output
SAMPLING PARAMETERS
100,000 samples per second
Sample for 600 seconds
Estimated RAM required 240.0 MB
10 us period
Start
DISPLAY OPTIONS
Timestamps
Digital channels
0 1 2 3 4 5 6 7
SHOW SIDE PANEL
LOCK Y-AXIS
10ms
100ms
1s
3s
10s
1min
LIVE VIEW
Δ4.071ms
30 mA
25 mA
20 mA
15 mA
10 mA
5 mA
0 μA
Δ1.050ms
WINDOW
15.48mA average
29.86mA max
4.071ms time
63.02μC charge
SELECTION
SELECT ALL
CLEAR
13.47mA average
25.74mA max
1.050ms time
14.15μC charge
CLEAR LOG
OPEN LOG FILE
AUTOSCROLL LOG
SHOW LOG

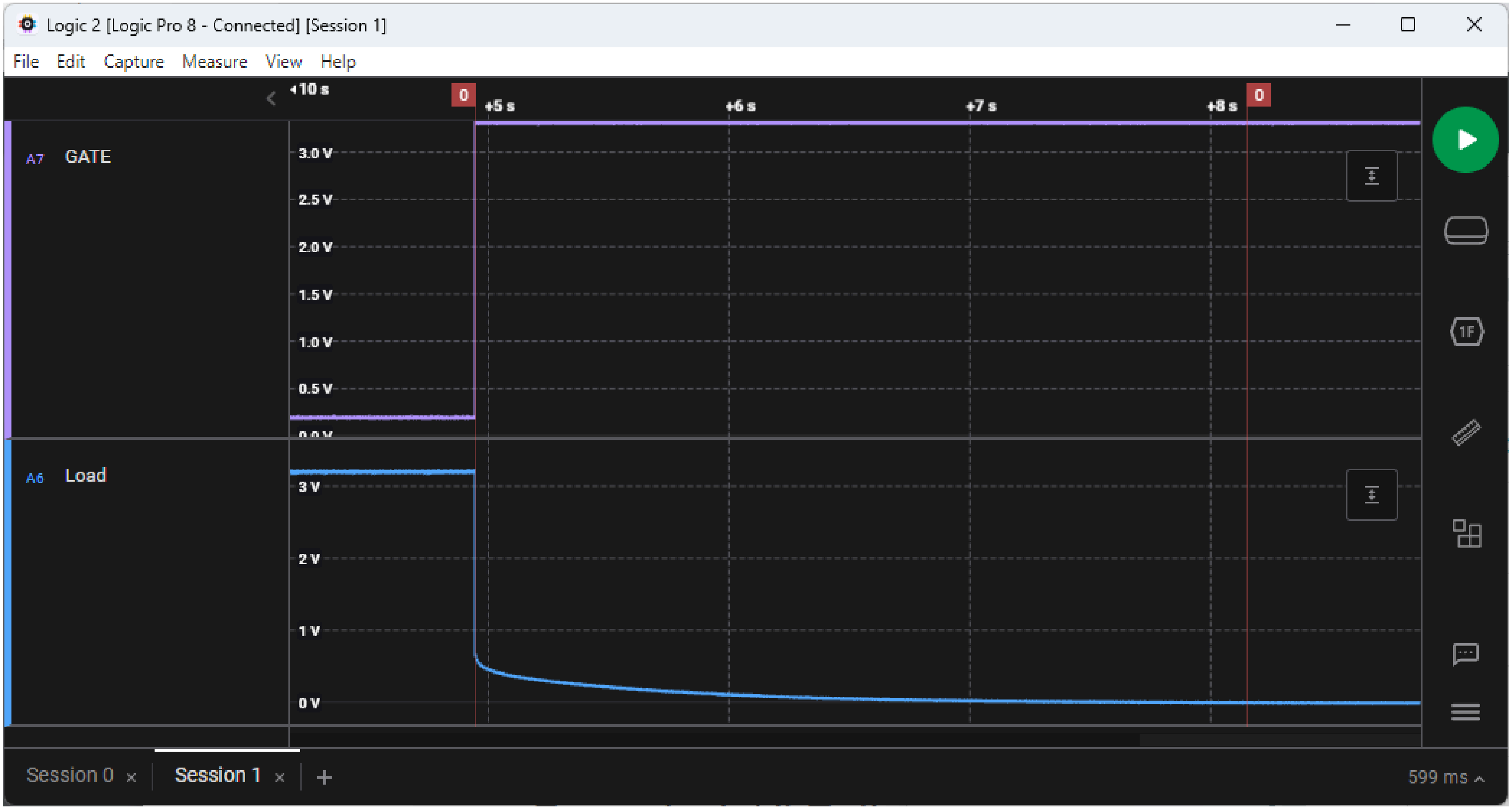
ATGM No Inrush Caps - Turn On

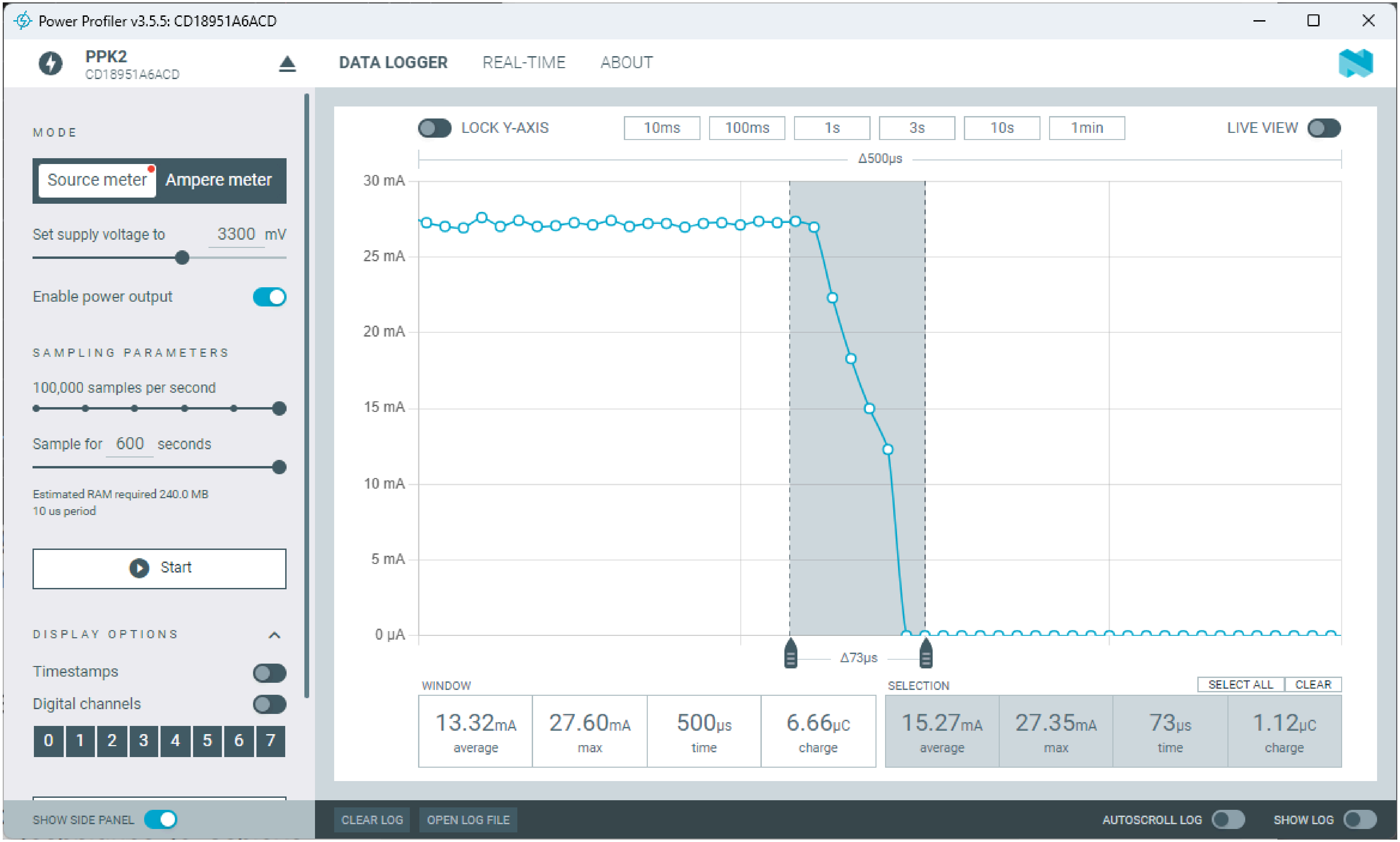

Power Profiler v3.5.5: CD18951A6ACD
PPK2
CD18951A6ACD
DATA LOGGER
REAL-TIME
ABOUT
MODE
Source meter
Ampere meter
Set supply voltage to
3300
mV
Enable power output
SAMPLING PARAMETERS
100,000 samples per second
Sample for
600
seconds
Estimated RAM required 240.0 MB
10 us period
Start
DISPLAY OPTIONS
Timestamps
Digital channels
0
1
2
3
4
5
6
7
SHOW SIDE PANEL
LOCK Y-AXIS
10ms
100ms
1s
3s
10s
1min
LIVE VIEW
Δ1.065ms
200 mA
150 mA
100 mA
50 mA
0 μA
Δ312μs
WINDOW
31.97mA average
193.36mA max
1.065ms time
34.07μC charge
SELECTION
SELECT ALL
CLEAR
81.48mA average
193.36mA max
312μs time
25.50μC charge
CLEAR LOG
OPEN LOG FILE
AUTOSCROLL LOG
SHOW LOG

ATGM No Inrush Caps - Turn Off



Takes seconds for GPS caps to discharge




Power Profiler v3.5.5: CD18951A6ACD
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Timestamps
Digital channels
0 1 2 3 4 5 6 7
SHOW SIDE PANEL
LOCK Y-AXIS
10ms
100ms
1s
3s
10s
1min
LIVE VIEW
Δ500µs
30 mA
25 mA
20 mA
15 mA
10 mA
5 mA
0 µA
Δ73µs
WINDOW
13.32mA average
27.60mA max
500µs time
6.66µC charge
SELECTION
SELECT ALL
CLEAR
15.27mA average
27.35mA max
73µs time
1.12µC charge
CLEAR LOG
OPEN LOG FILE
AUTOSCROLL LOG
SHOW LOG

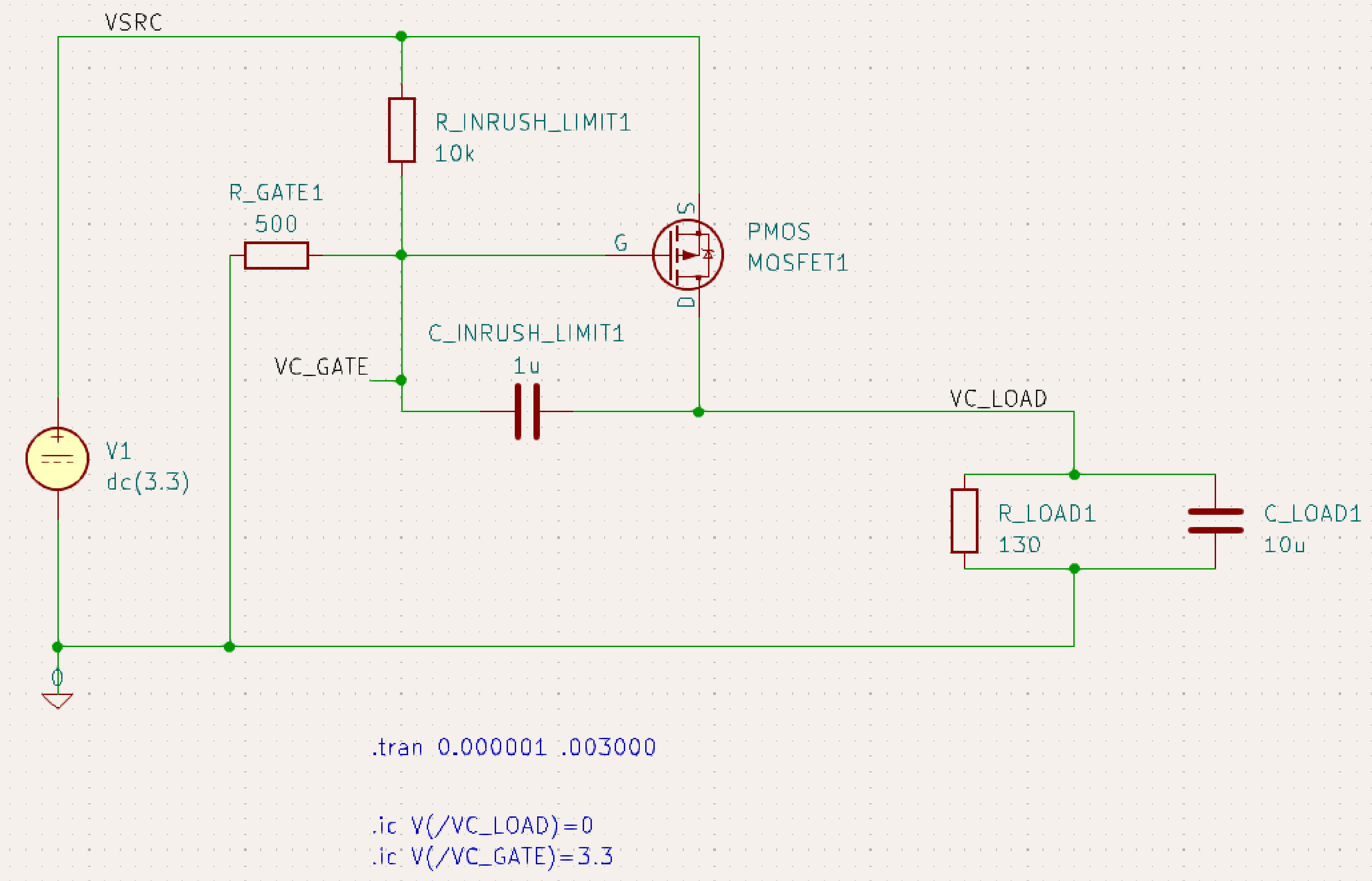
Simulation

(link) YouTube video on how to use KiCad spice simulations

I originally simulated this circuit in KiCad.
I subsequently tested it with a breadboard and misc components.

The results were similar, but not exact, neither were the components though.

Here I have adapted the circuit above to tie the Gate resistor to ground, simulating the microcontroller turing the MOSFET on.
The initial conditions are simulated to be as though the MOSFET were off for a long time.


VSRC
R_INRUSH_LIMIT1
10k
R_GATE1
500
G
S
D
PMOS
MOSFET1
C_INRUSH_LIMIT1
1u
VC_GATE
VC_LOAD
V1
dc(3.3)
R_LOAD1
130
C_LOAD1
10u
0
.tran 0.000001 .003000
.ic V(/VC_LOAD)=0
.ic V(/VC_GATE)=3.3

Useful to be able to use the simulator to vary the values of the various components interactively (sliders) to graph new without changing the schematic. Lets you play with values quickly to see the result.