

E2 Flash Development Testing

2020-05-14 – 2020-05-31

Tyler Gerritsen

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Results:..... 200

Test Data:..... 200

Series 1 – Baseline Testing and Improvements

Overview:

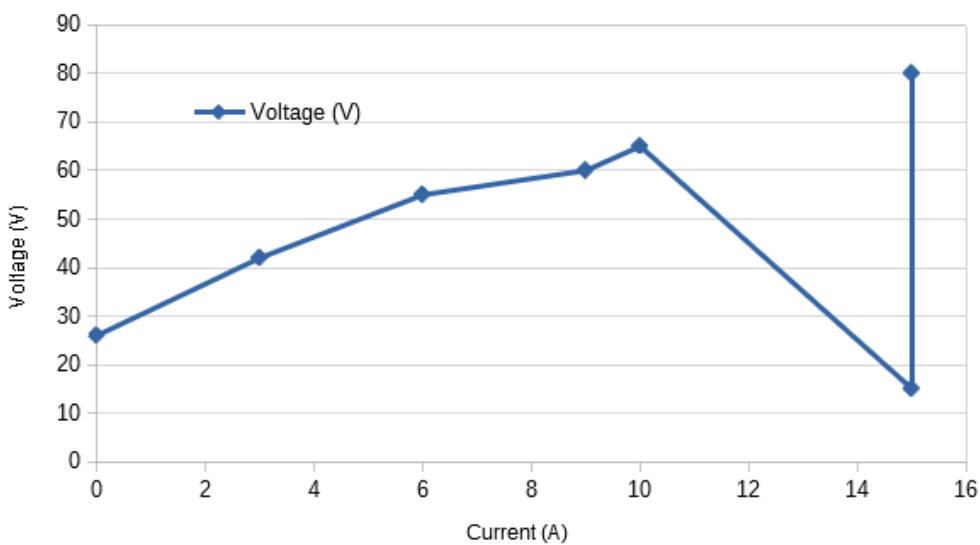
Purpose: To improve the MOSFET gate circuit such that rise time, fall time, and ringing are better controlled.

Equipment:

- E2 Prototype with four banks of LED's in various states of damage
 - IPPR60 MOSFET's

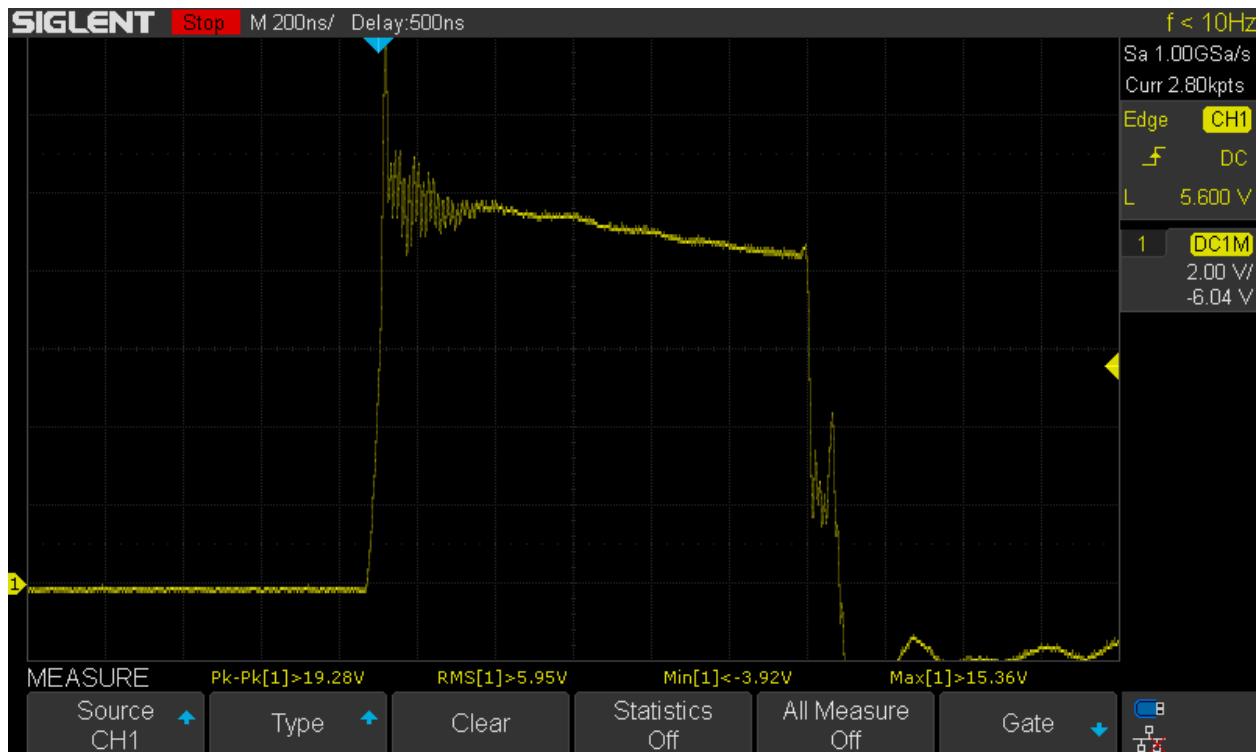
Results:

- The original flash design had the following characteristics:
 - The gate voltage rose rapidly (<100ns) with moderate overshoot (9.5V stabilized, >14V during overshoot period)
 - The gate voltage fell rapidly (<100ns) but the pause due to miller capacitance was significant (~100ns)
 - The following LED drive voltage (not including series resistor voltage drop) vs current relationship was established



Test Data:

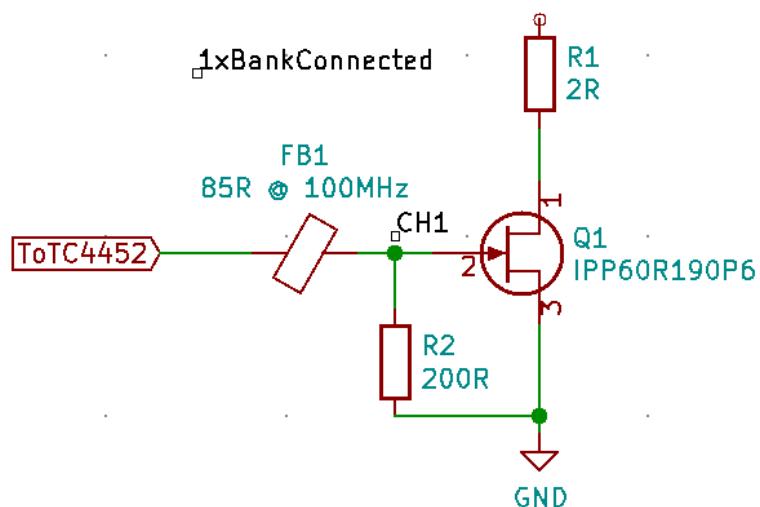
1 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



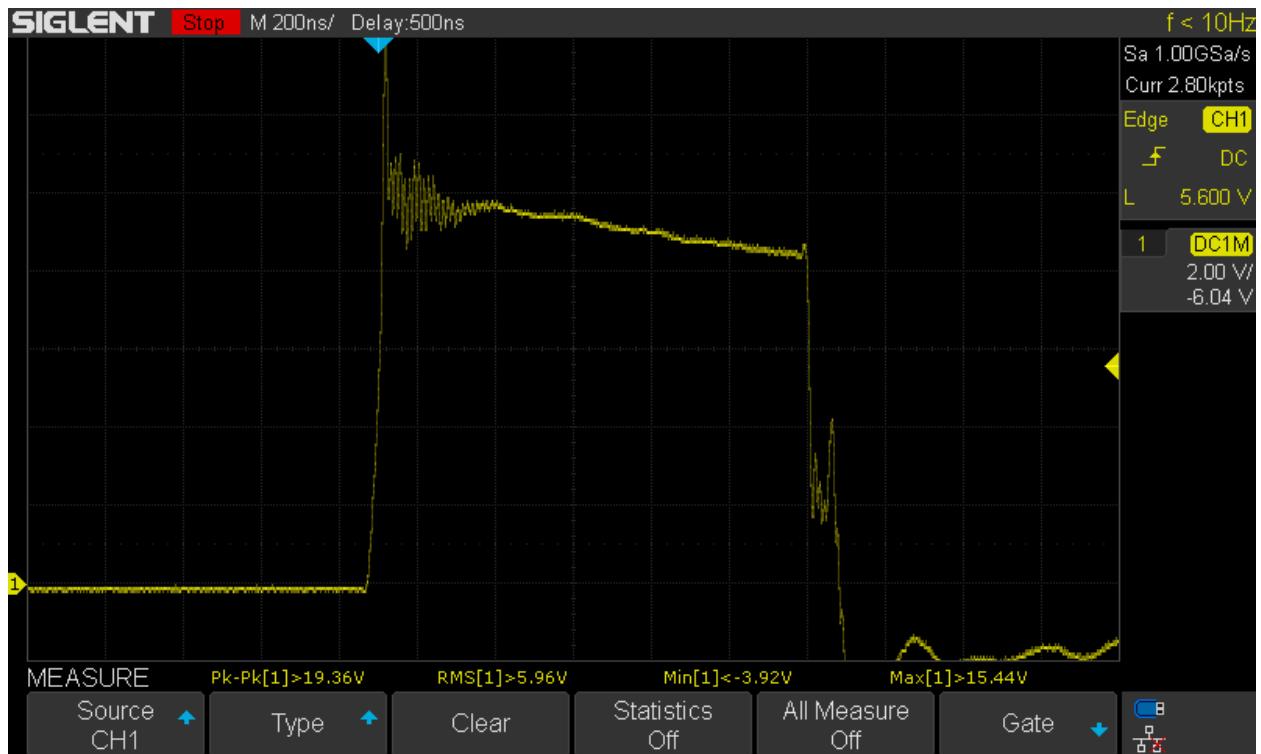
CH1 – Gate, Gnd – FET gnd

120V Cap Anode

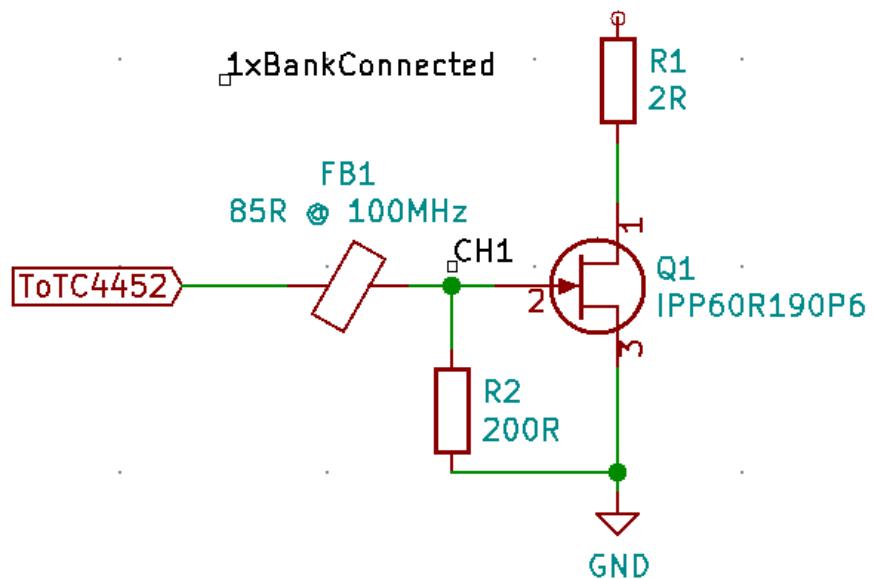
Original circuit



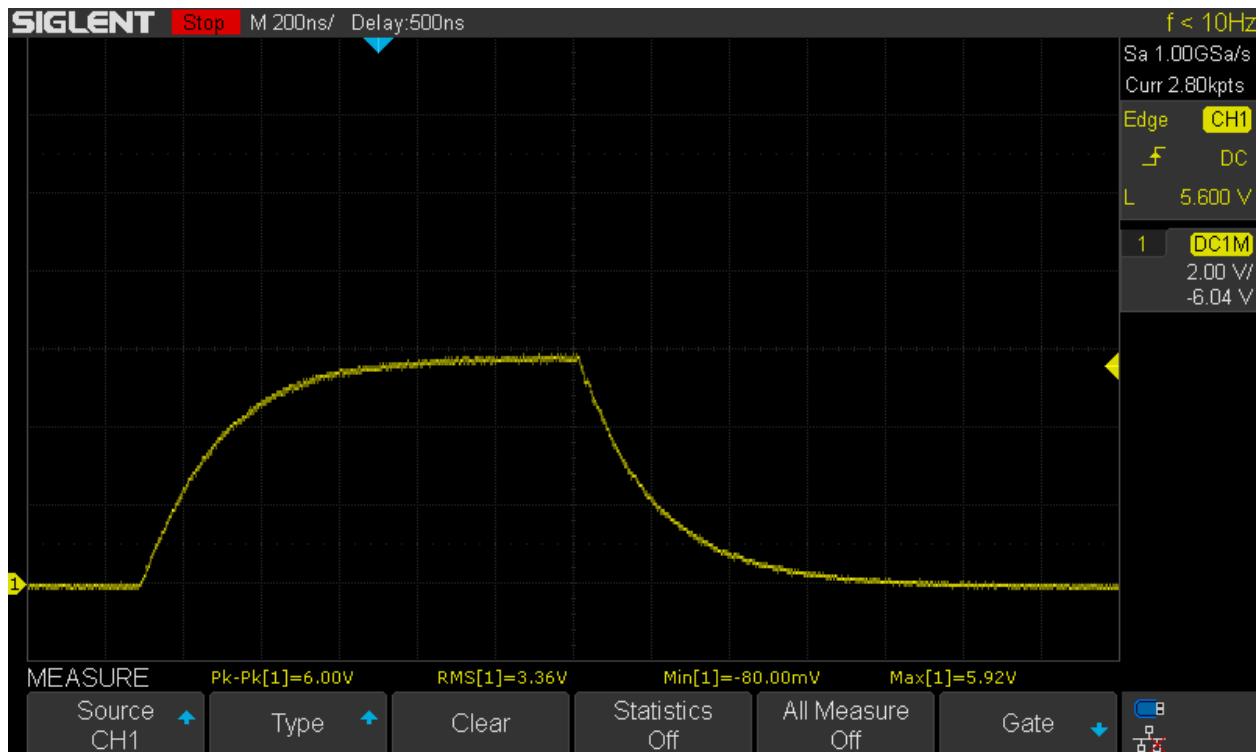
2 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



No Change

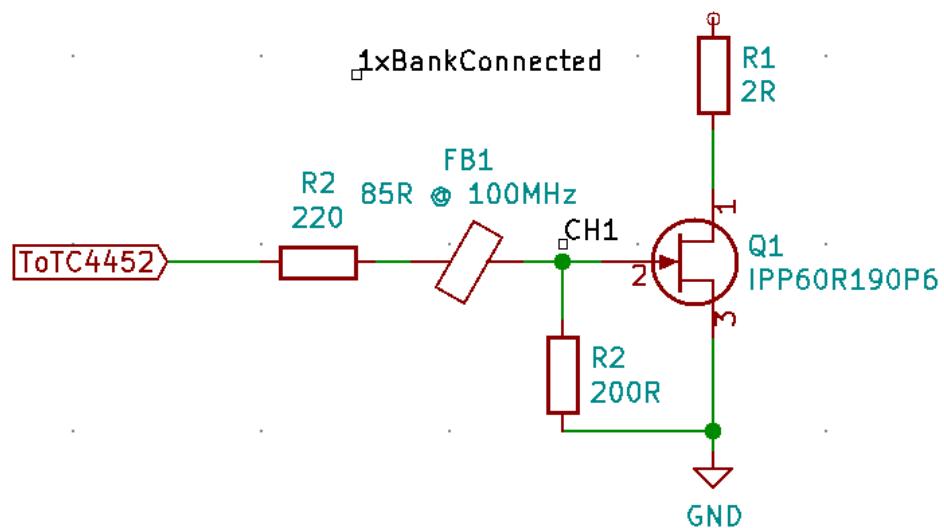


3 GATE: 10V? CAP ANODE: 45V SERIES RESISTOR: 2R DURATION: 1us



Capacitor Anode Voltage reduced to 45V

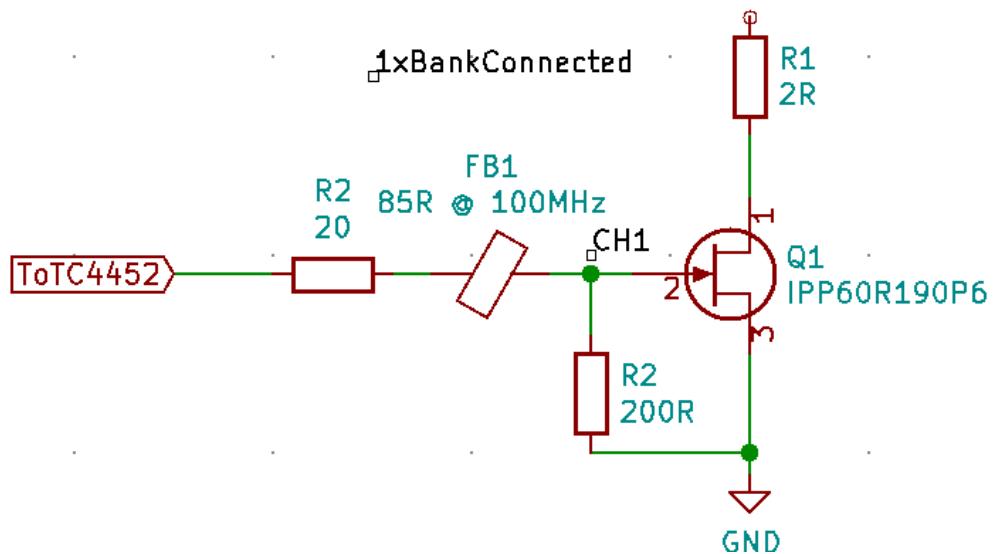
220R added between control board and Ferrite bead



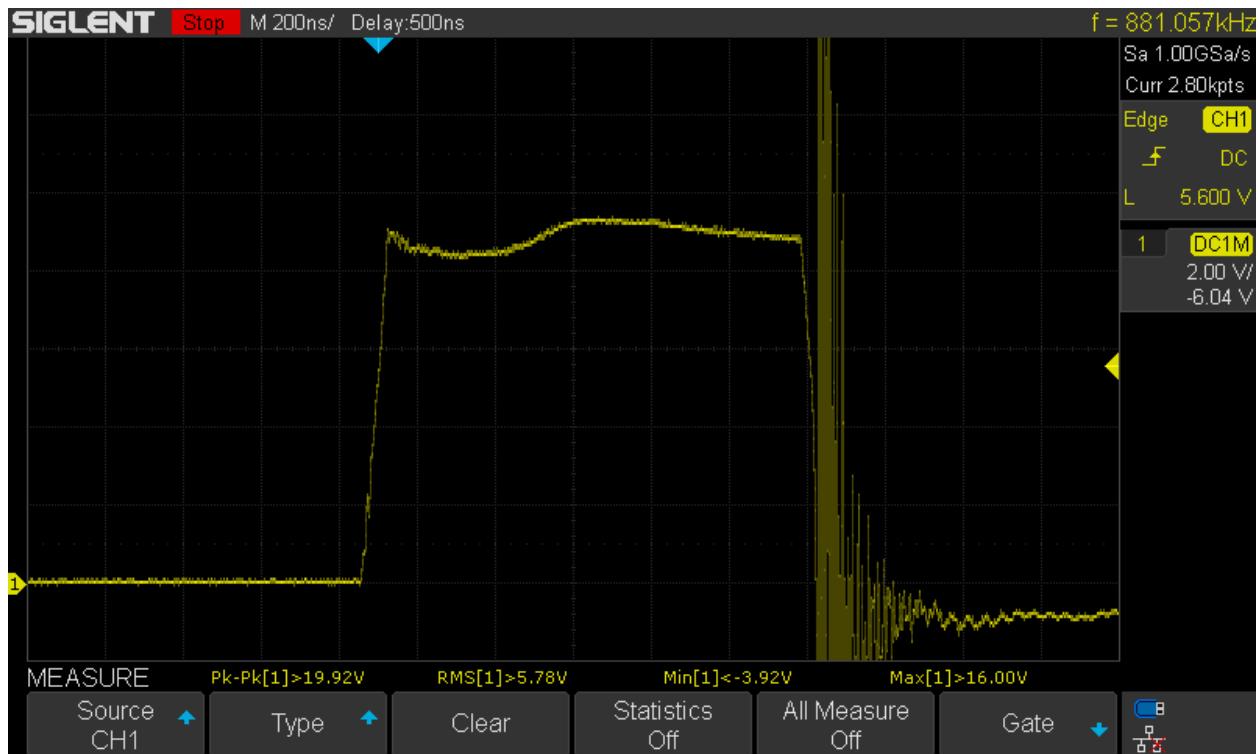
4 GATE: 10V? CAP ANODE: 45V SERIES RESISTOR: 2R DURATION: 1us



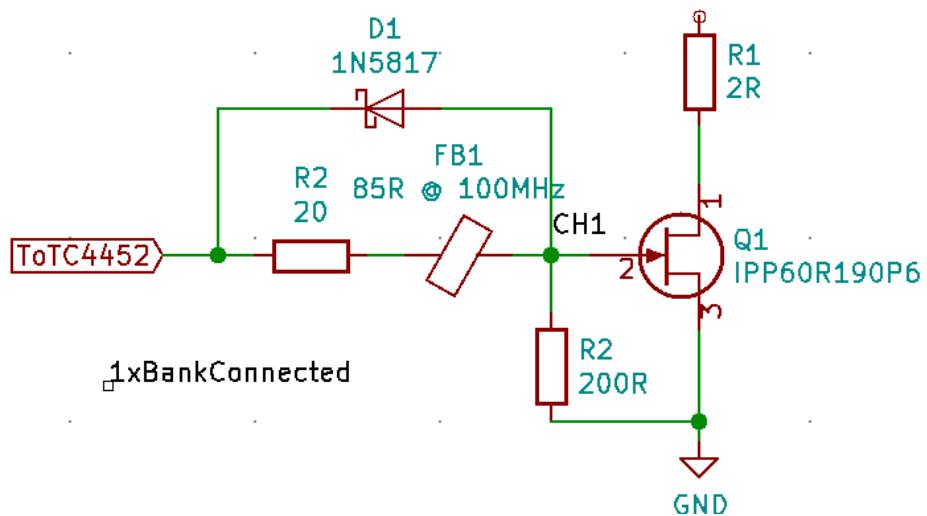
Replaced 220R Gate Resistor with 20R



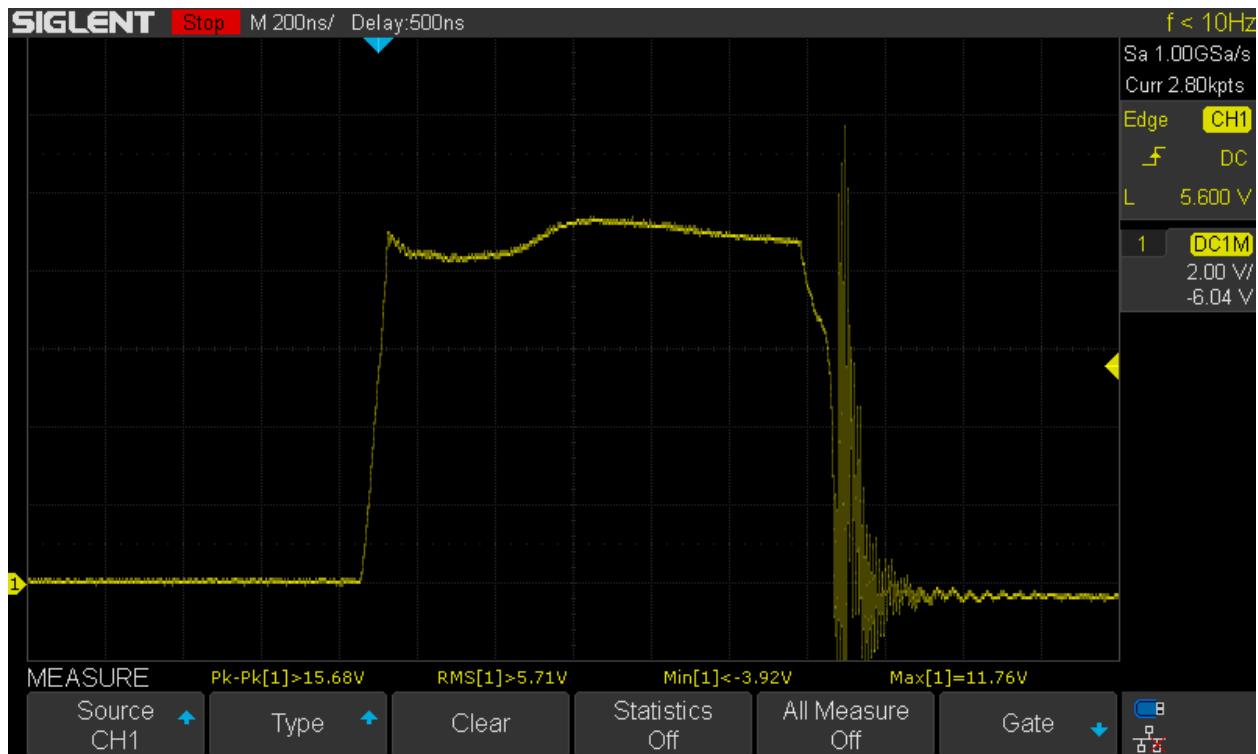
5 GATE: 10V? CAP ANODE: 45V SERIES RESISTOR: 2R DURATION: 1us



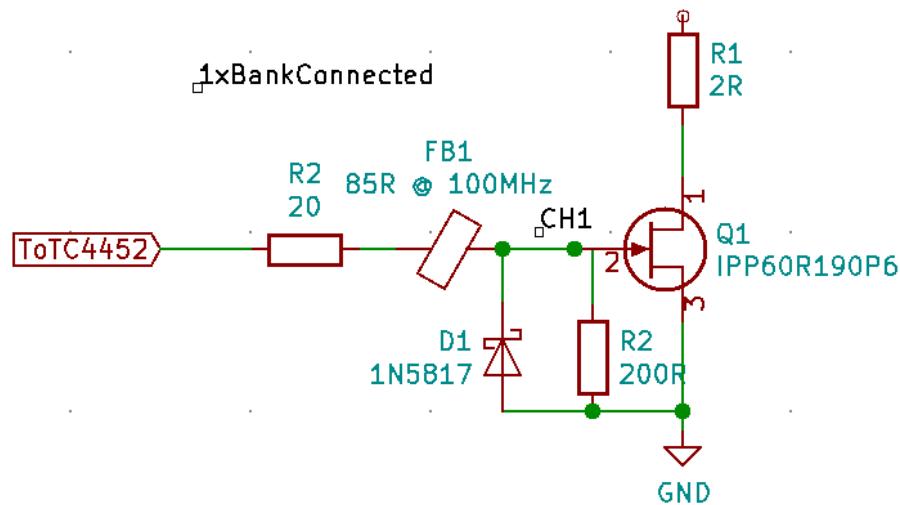
Added 1N5819 Schottky to decrease fall time



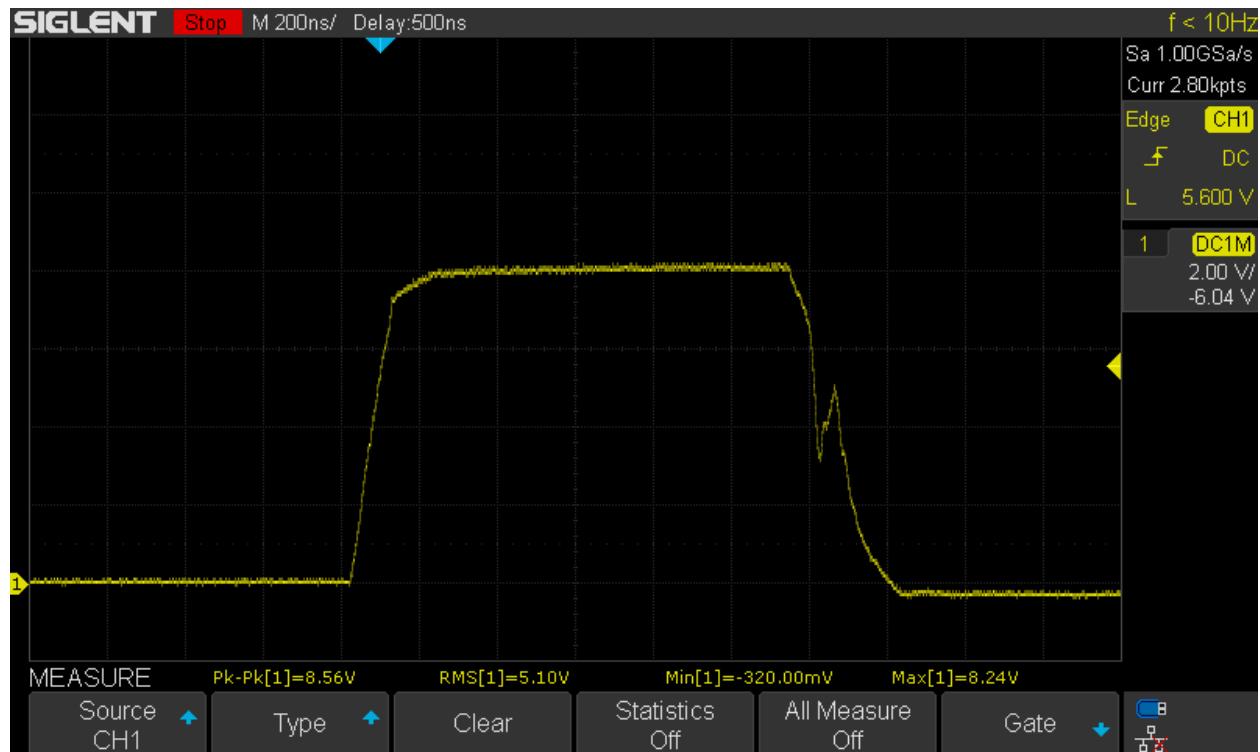
6 GATE: 10V? CAP ANODE: 45V SERIES RESISTOR: 2R DURATION: 1us



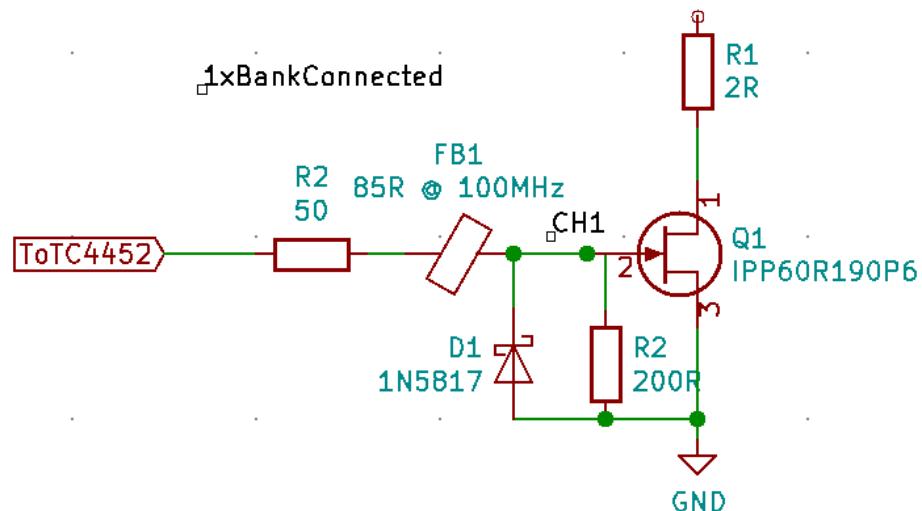
Moved schottky



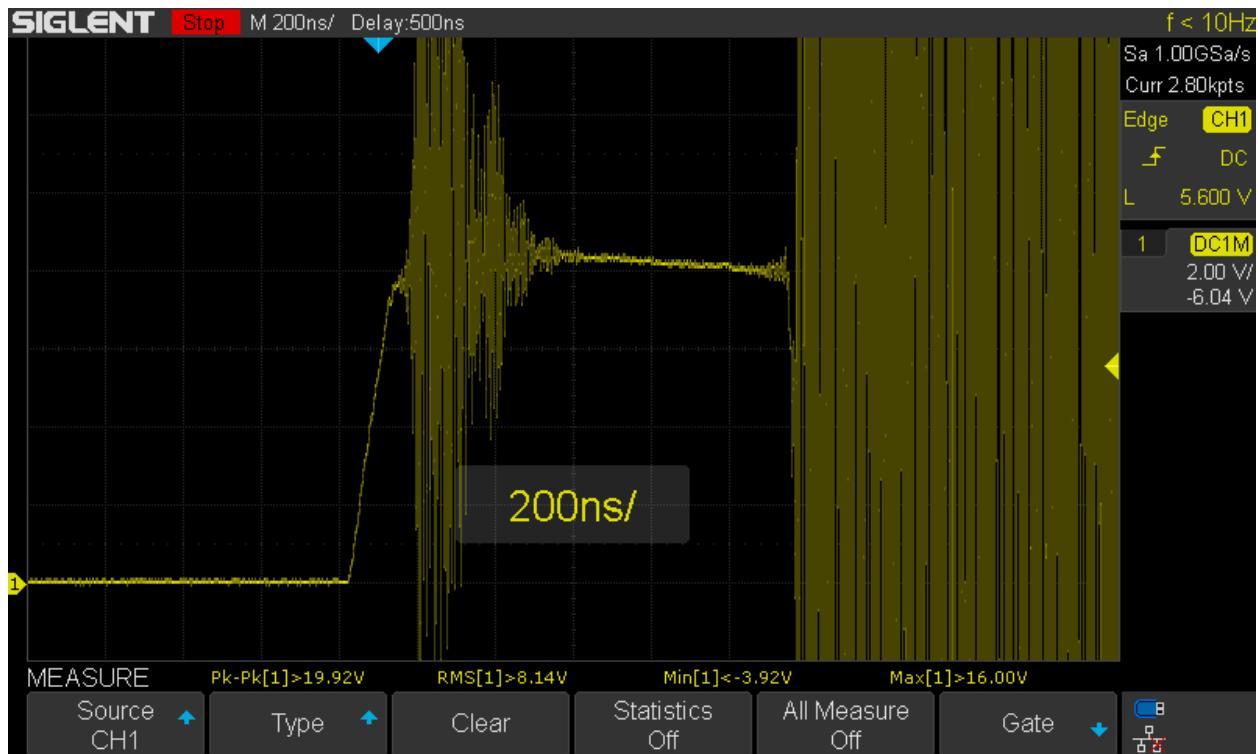
7 GATE: 10V? CAP ANODE: 45V SERIES RESISTOR: 2R DURATION: 1us



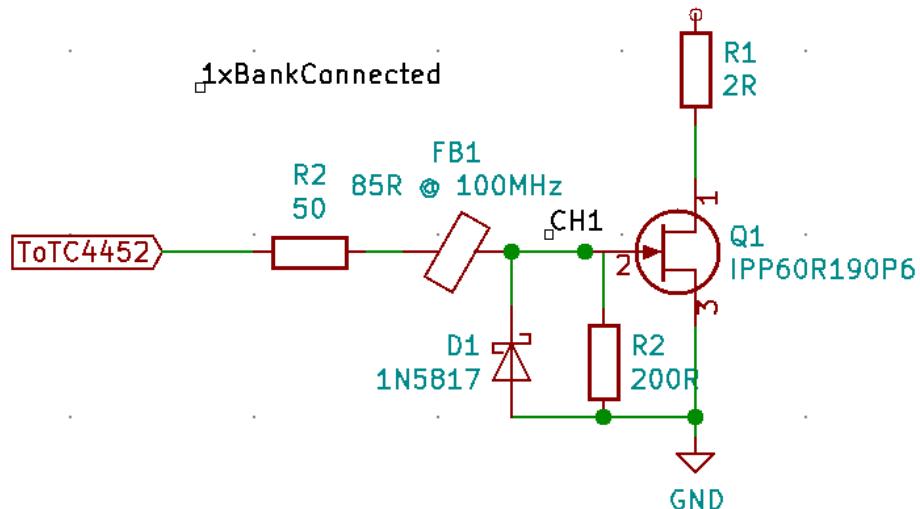
Changed gate resistor to 50R



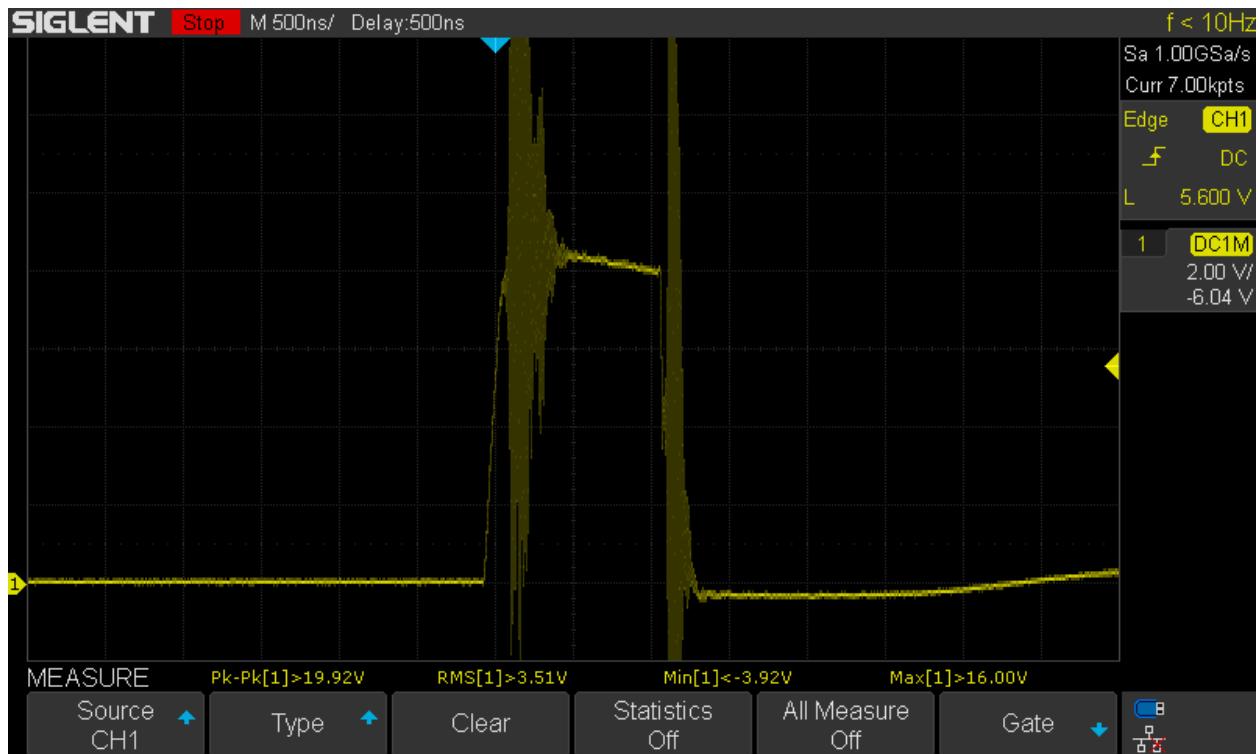
8 GATE: 10V? CAP ANODE: 90V SERIES RESISTOR: 2R DURATION: 1us



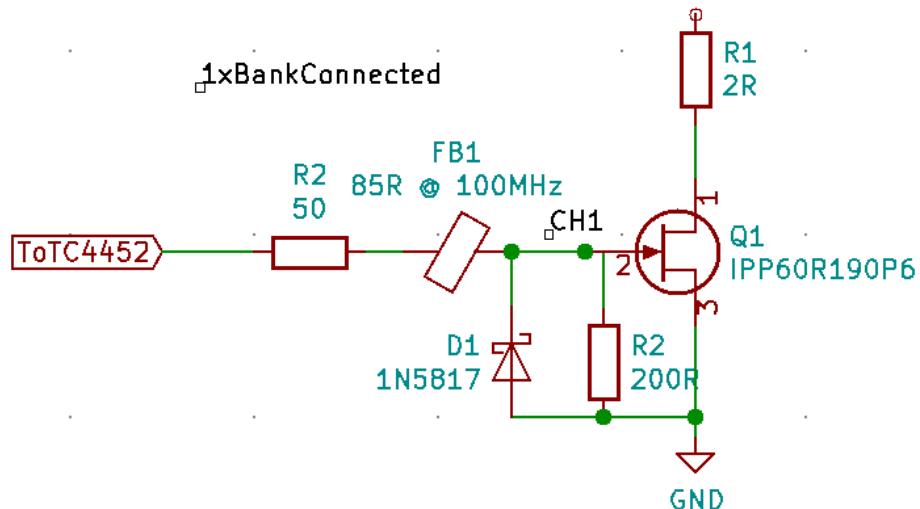
Increased Cap Anode to 90V



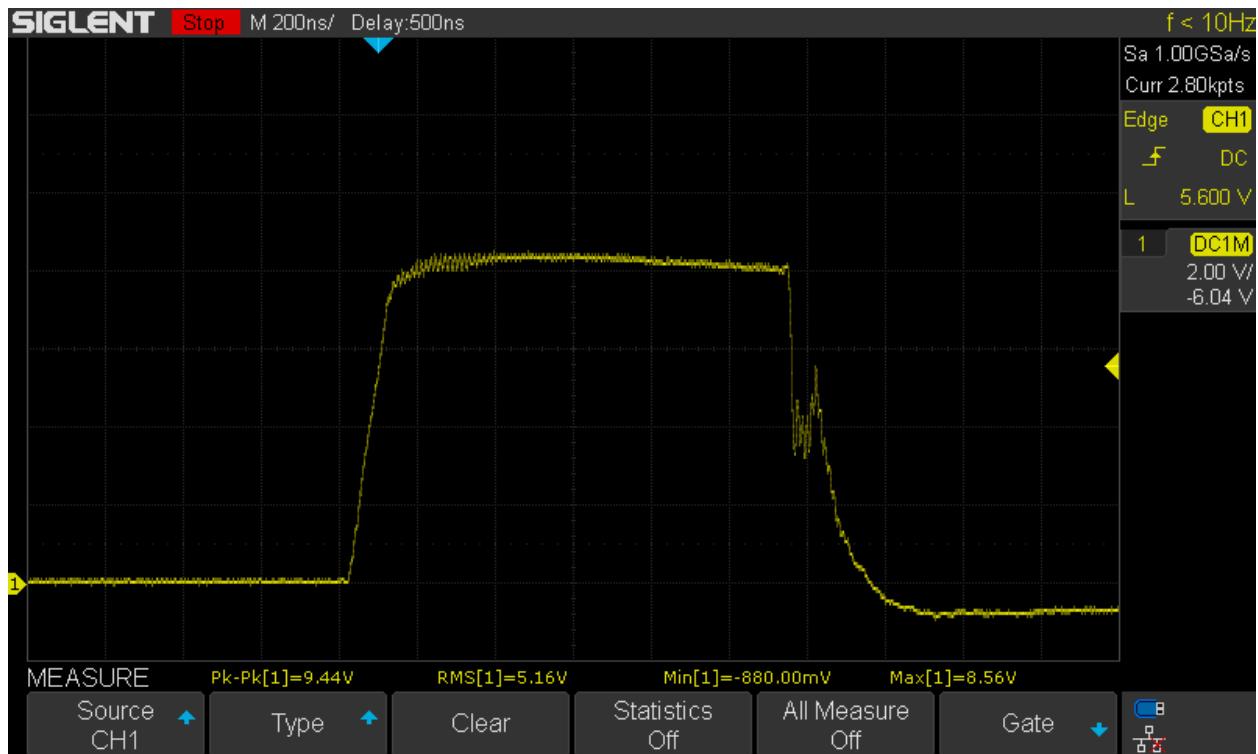
9 GATE: 10V? CAP ANODE: 90V SERIES RESISTOR: 2R DURATION: 1us



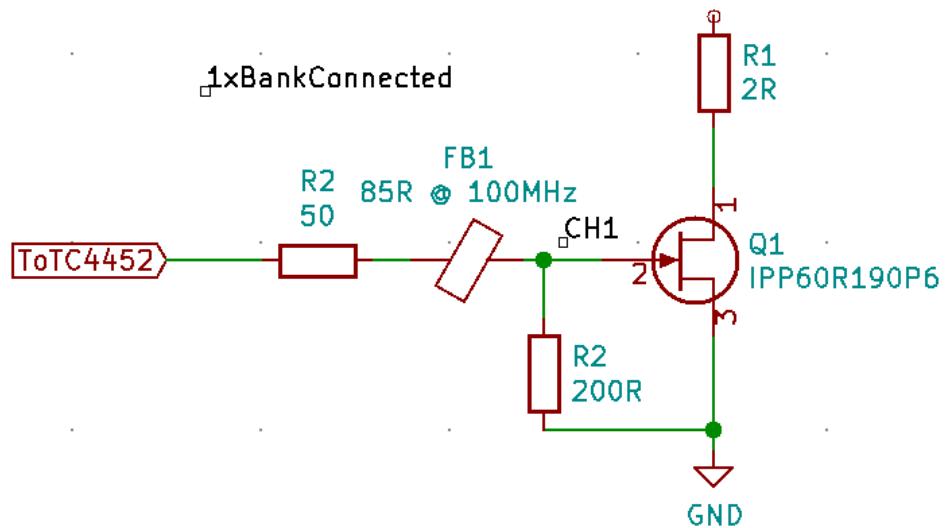
No Change



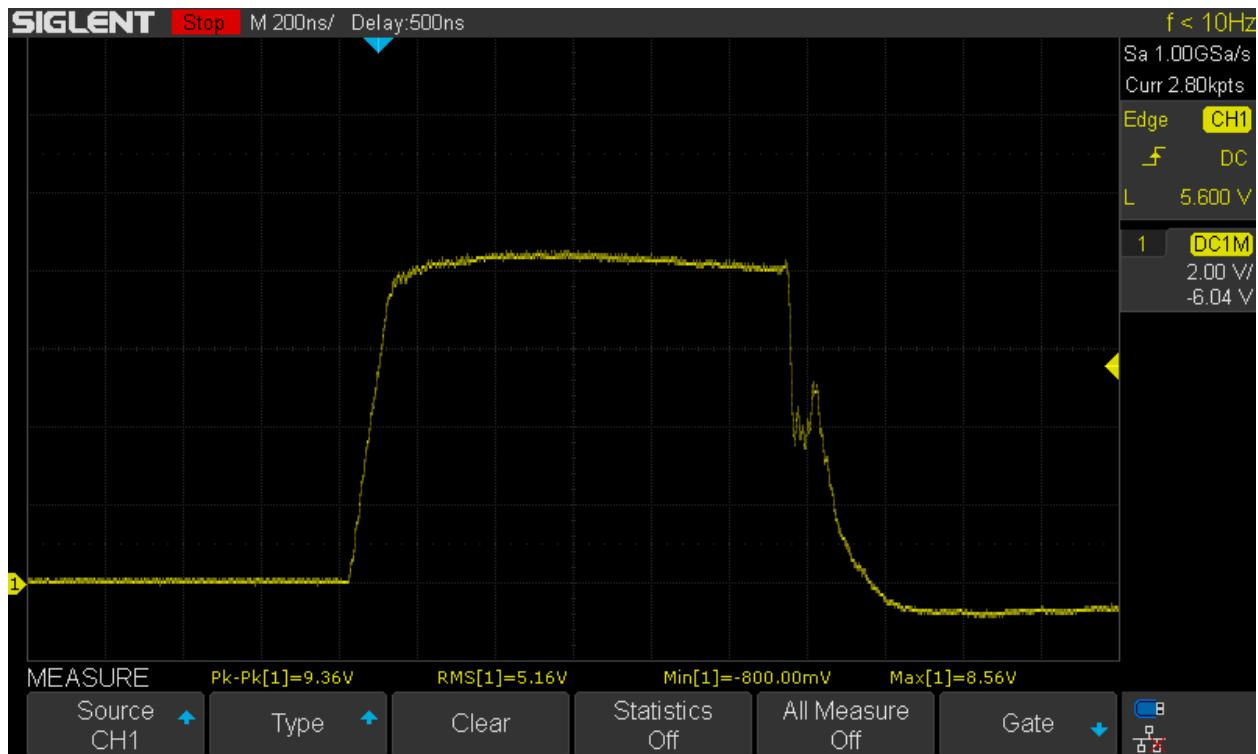
10 GATE: 10V? CAP ANODE: 90V SERIES RESISTOR: 2R DURATION: 1us



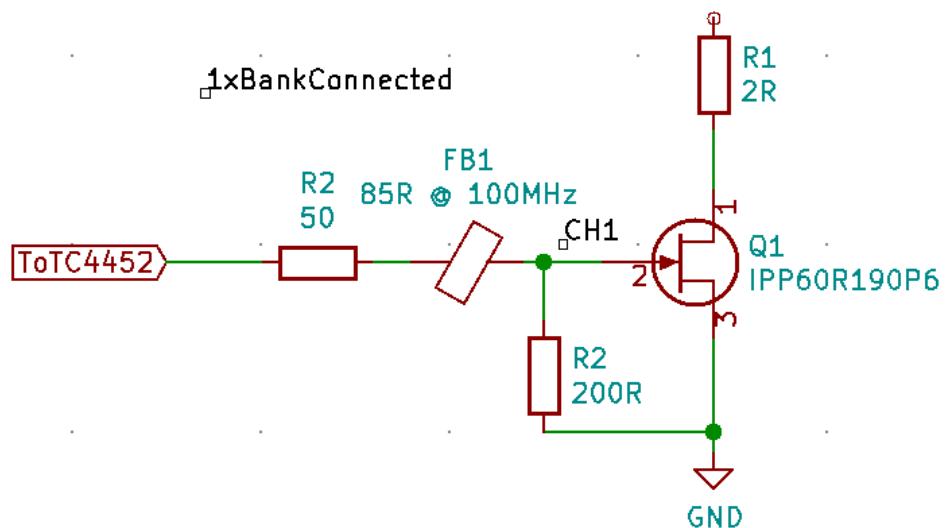
Removed Diode



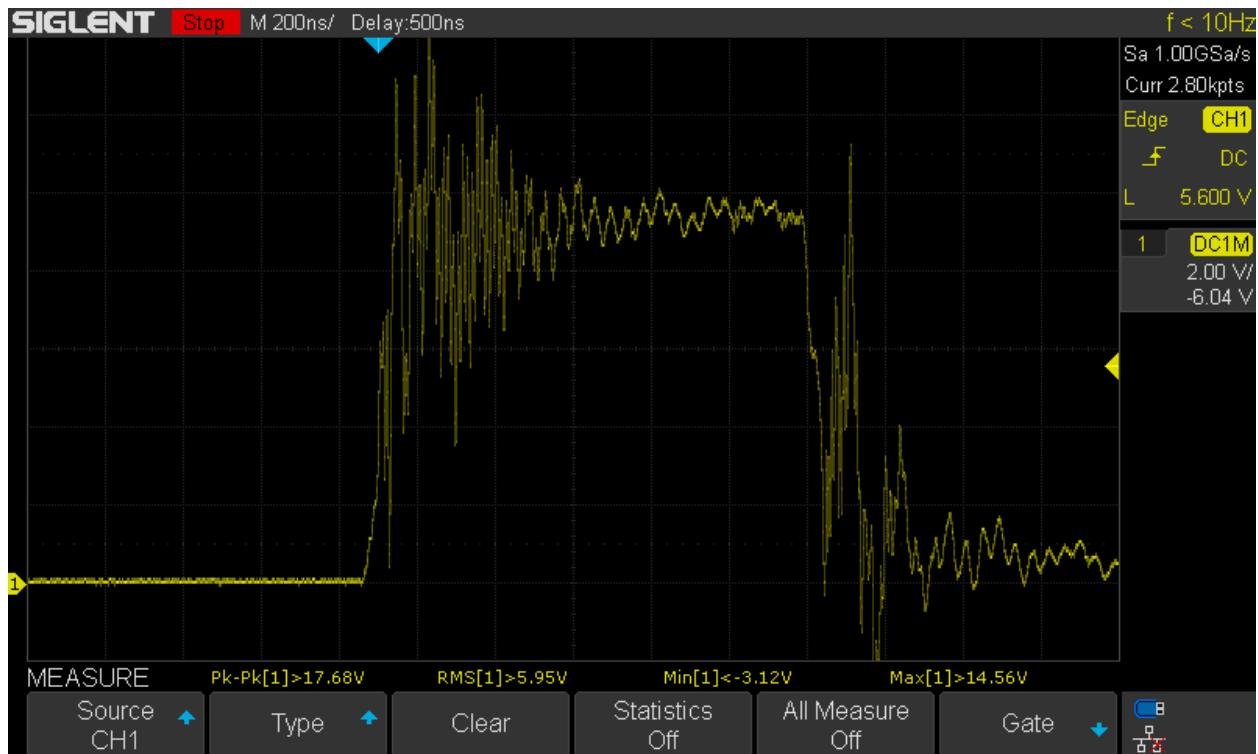
11, 12 (dup) GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



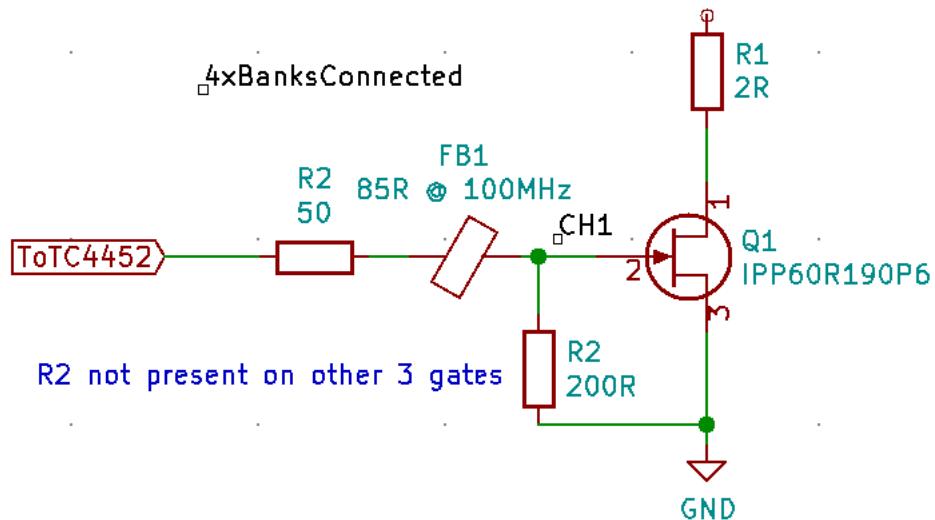
Increased Cap Anode to 120V



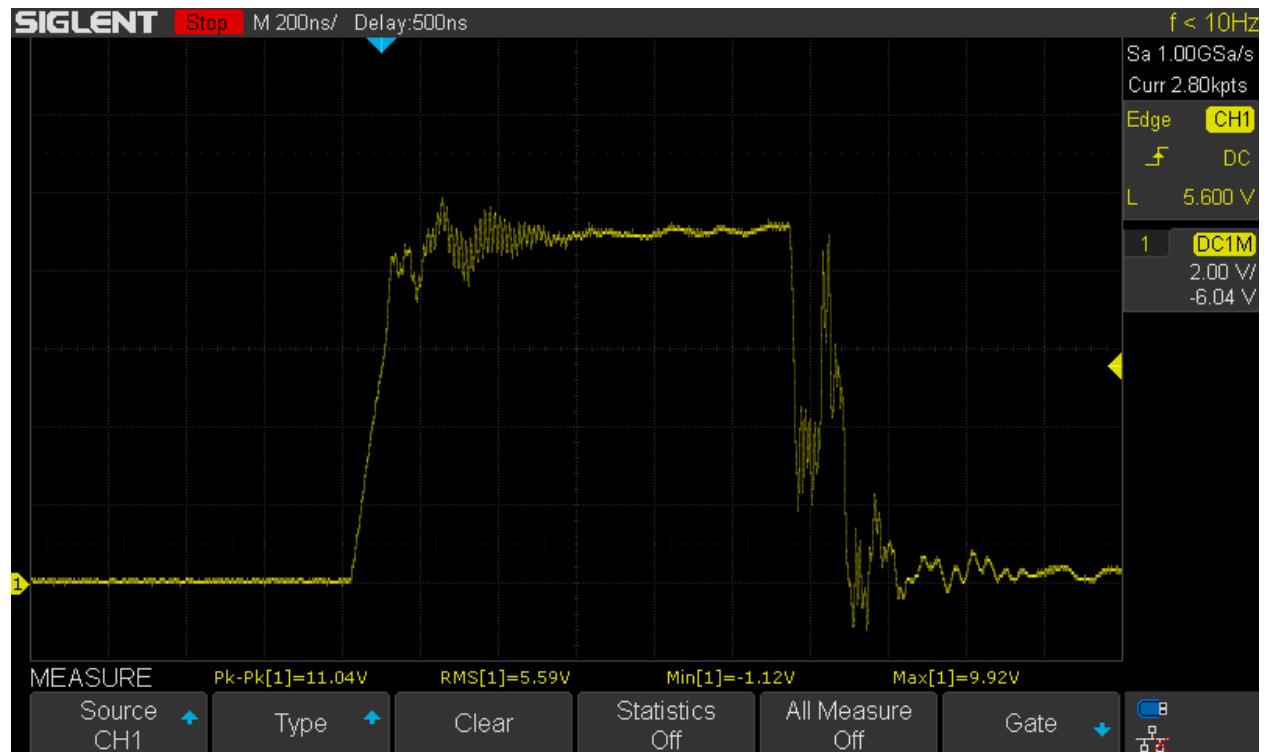
13 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



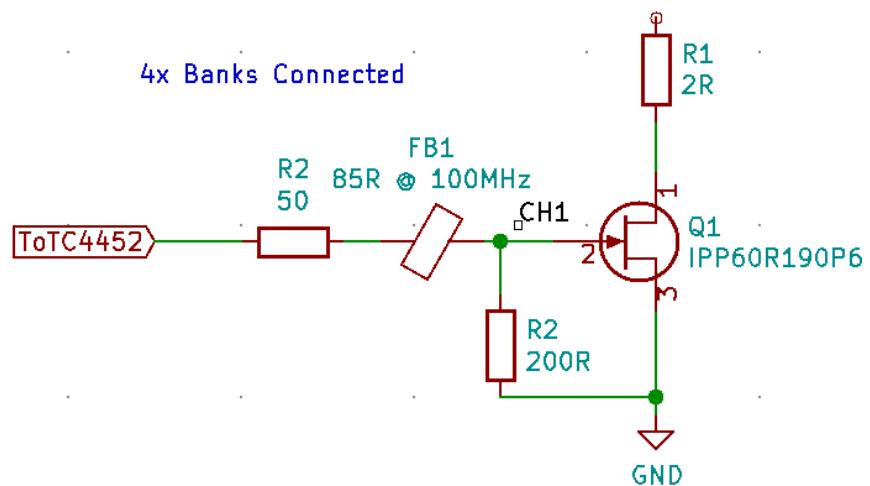
Connect all 4 LED Banks



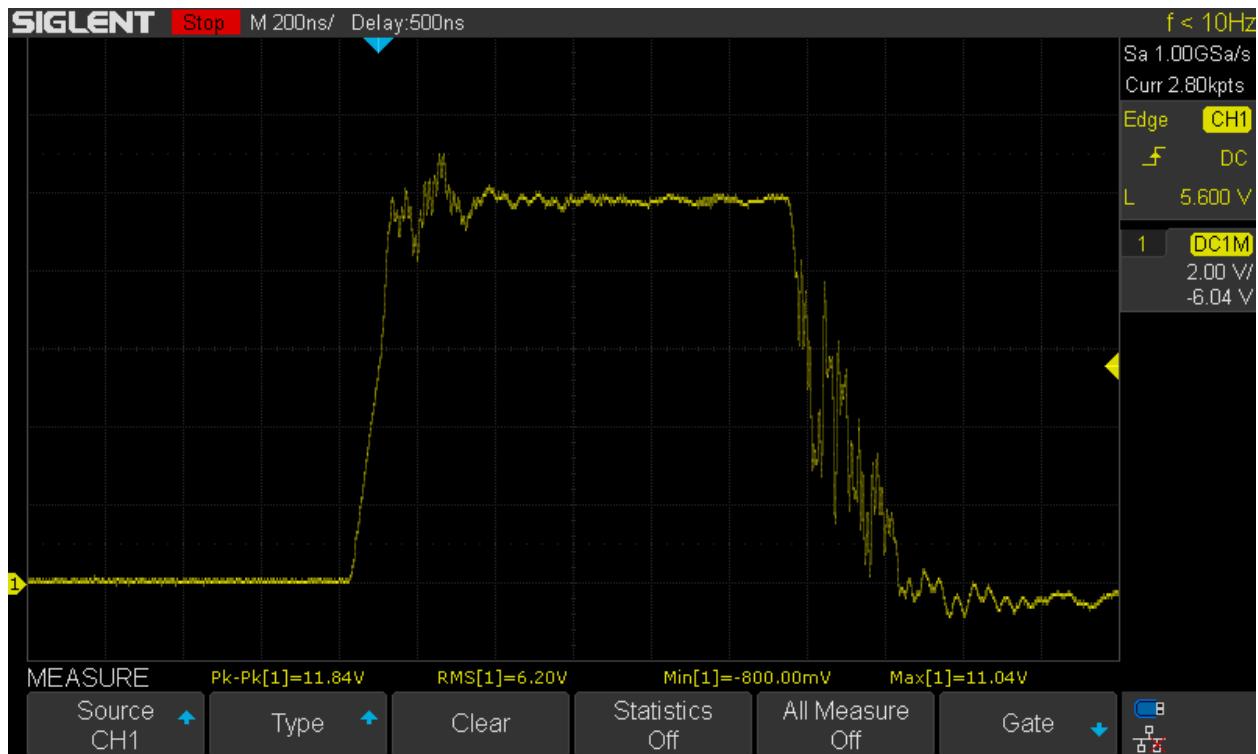
14 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



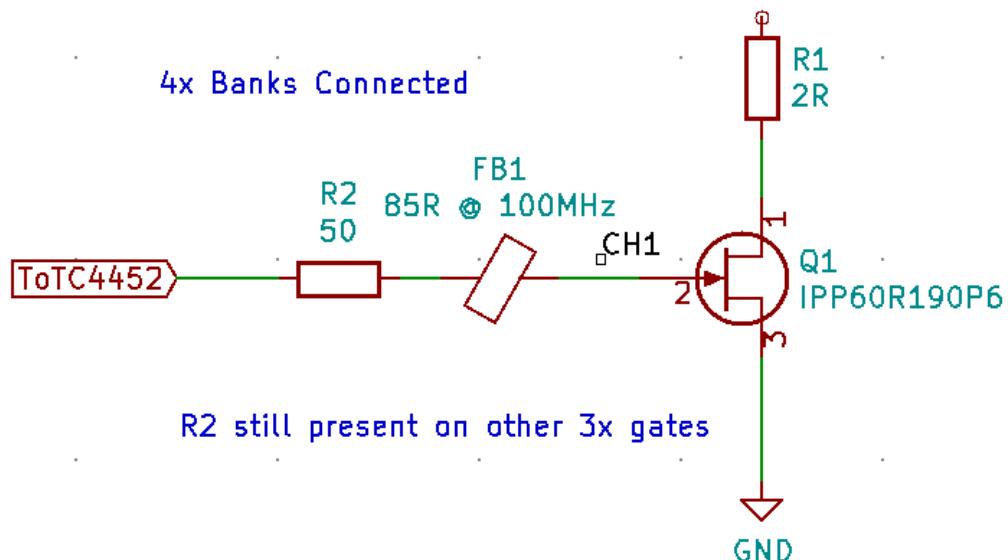
Added 50R gate resistor to all banks



15 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



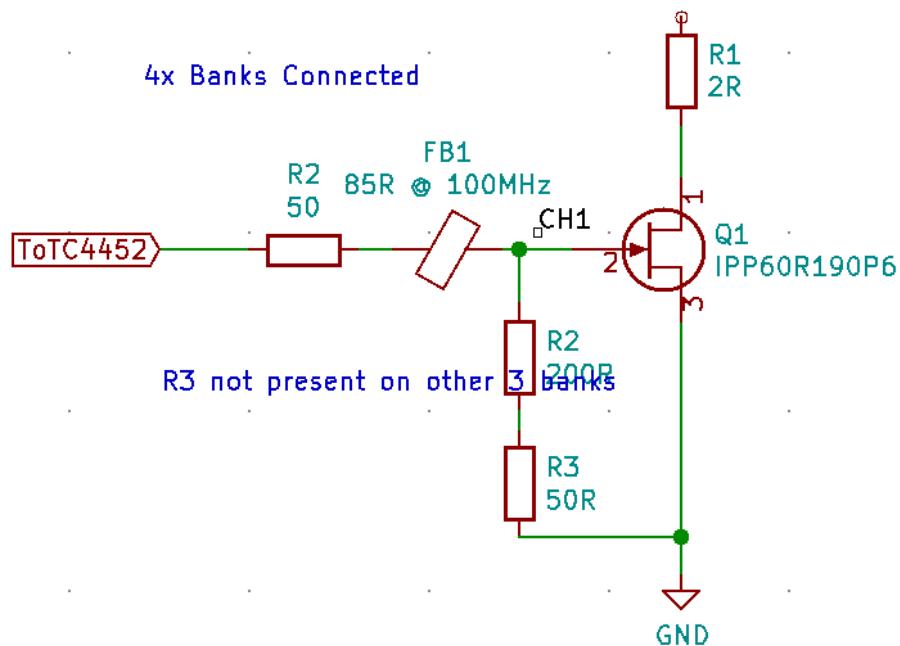
Removed 200R pull-down resistor



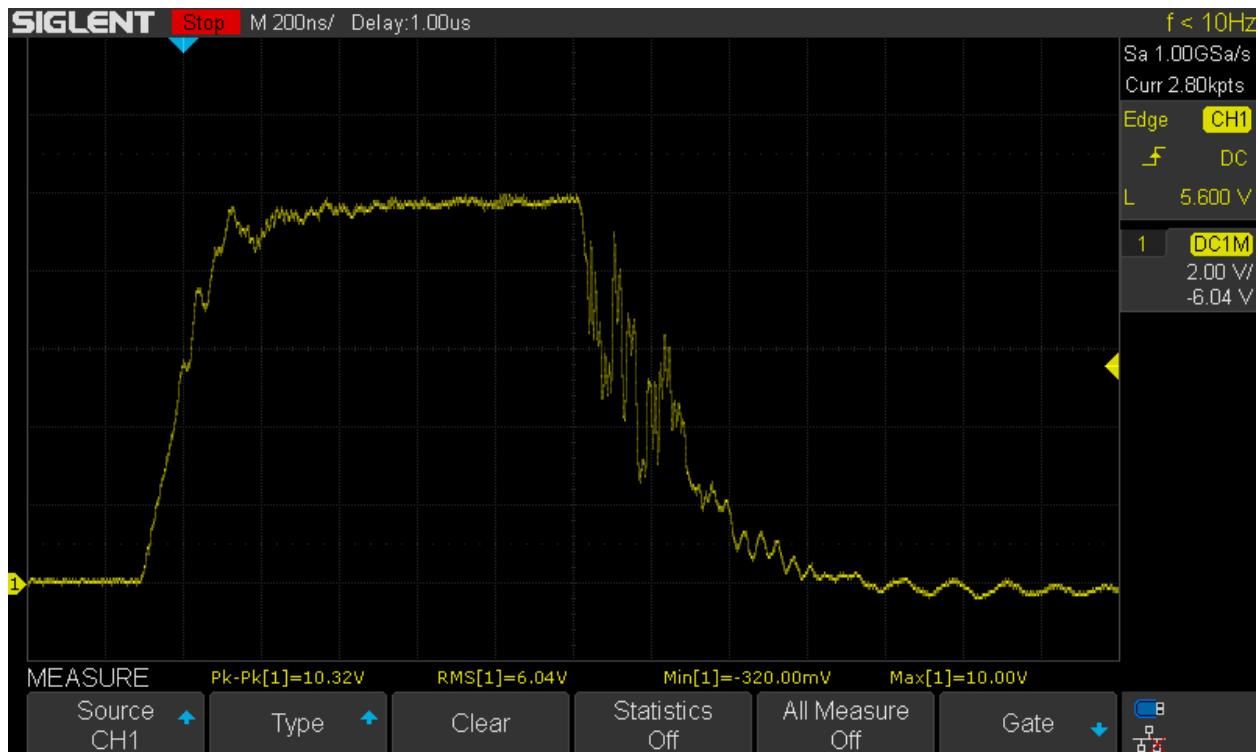
16 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



200R pull-down re-installed, 50R pull-down added in series (250R effective)

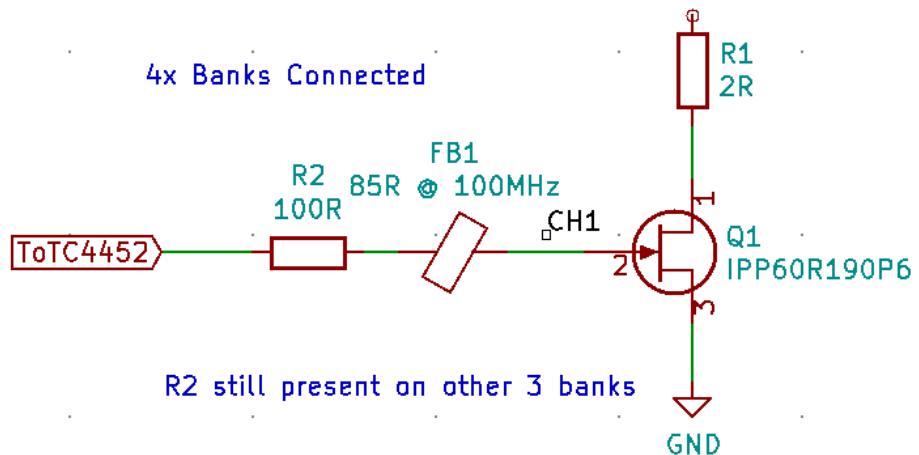


17 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Pull-Down removed

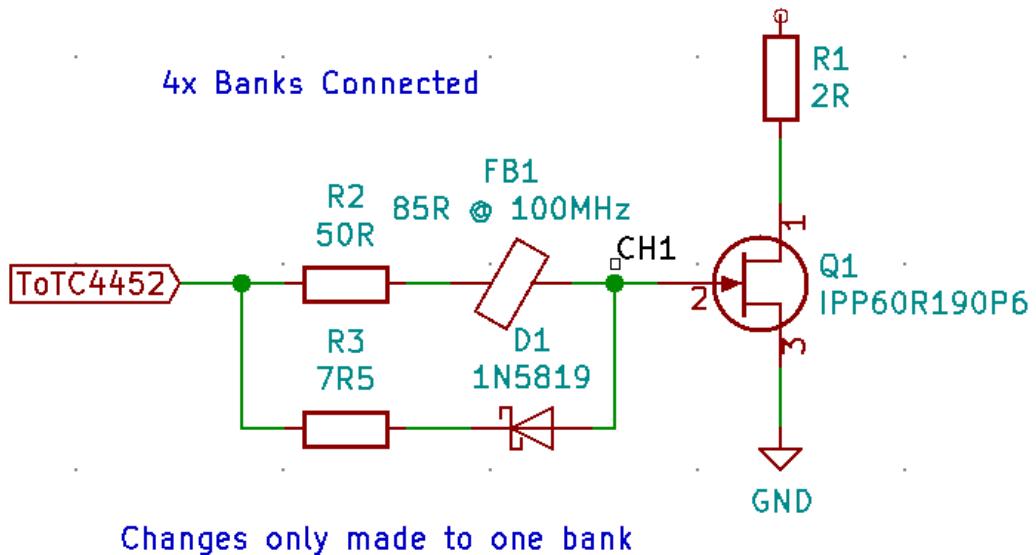
50R gate resistor replaced with 100R



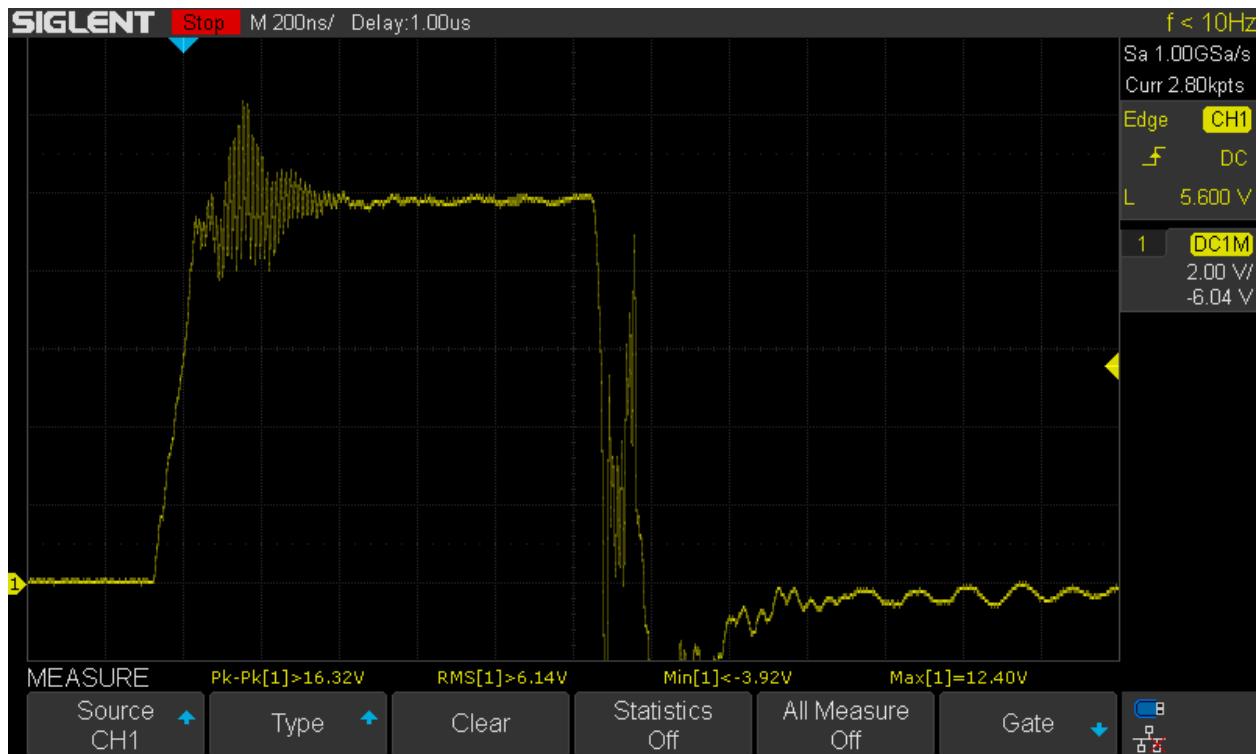
18 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



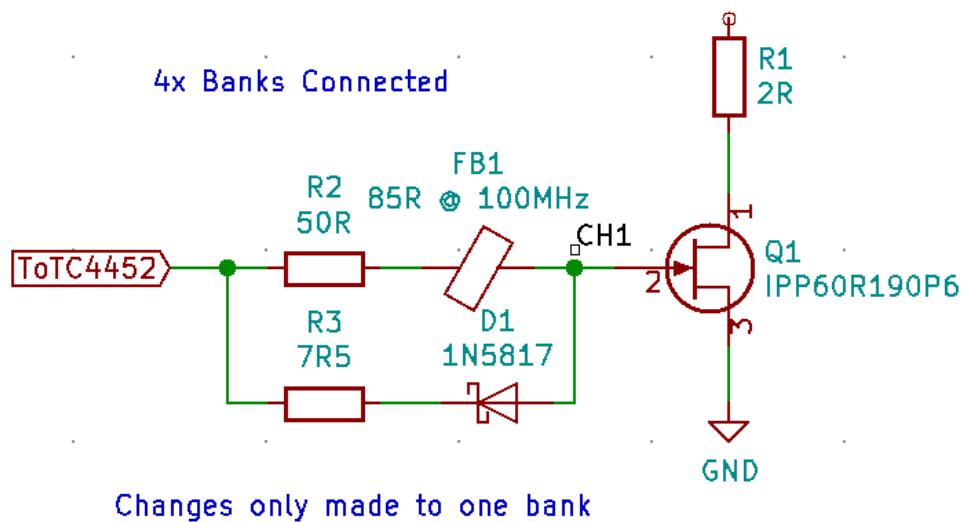
Diode added to gate with series resistor



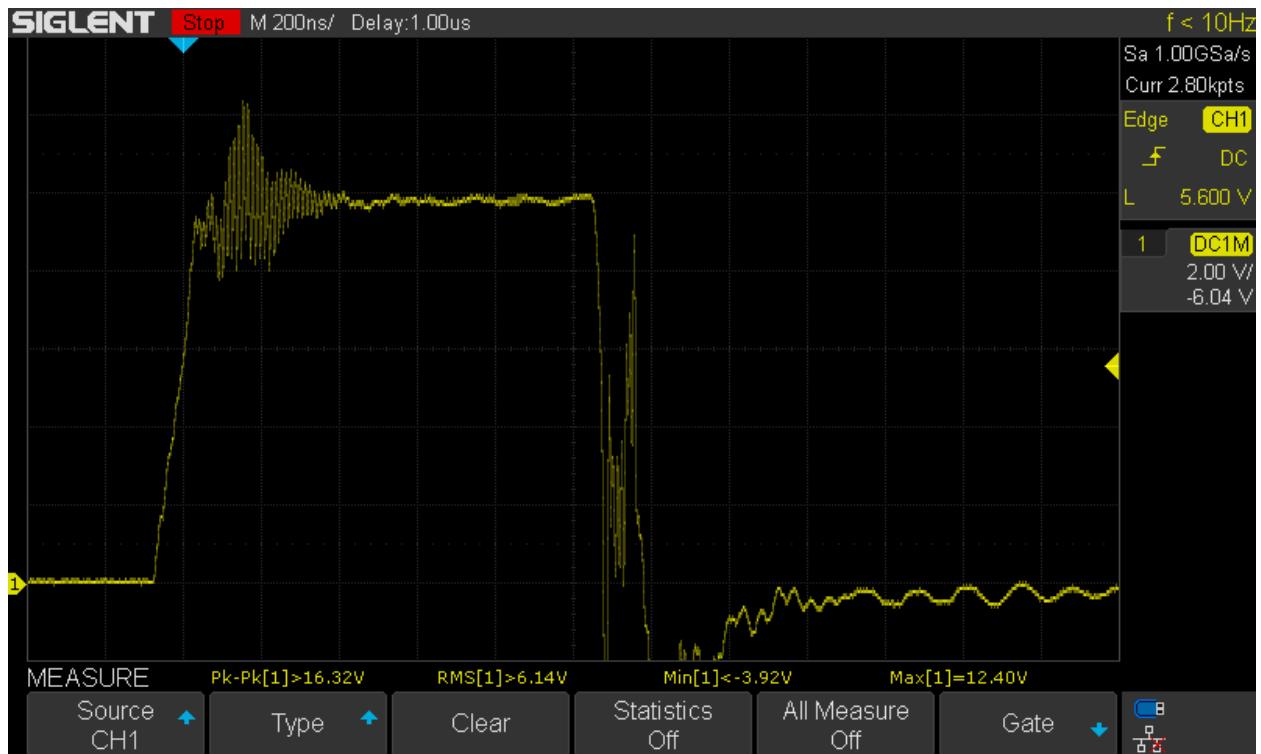
19 & 20 (dup) GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



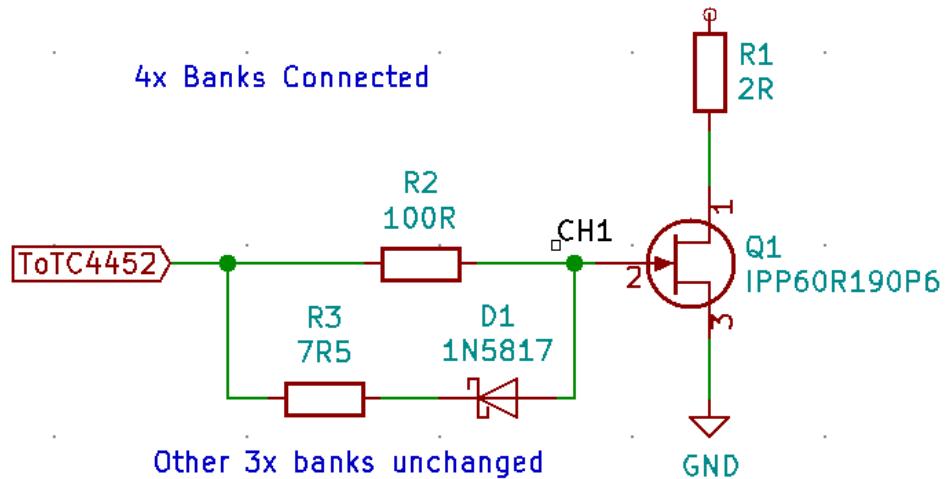
Replace 5819 with 5817



21 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Removed Ferrite Bead



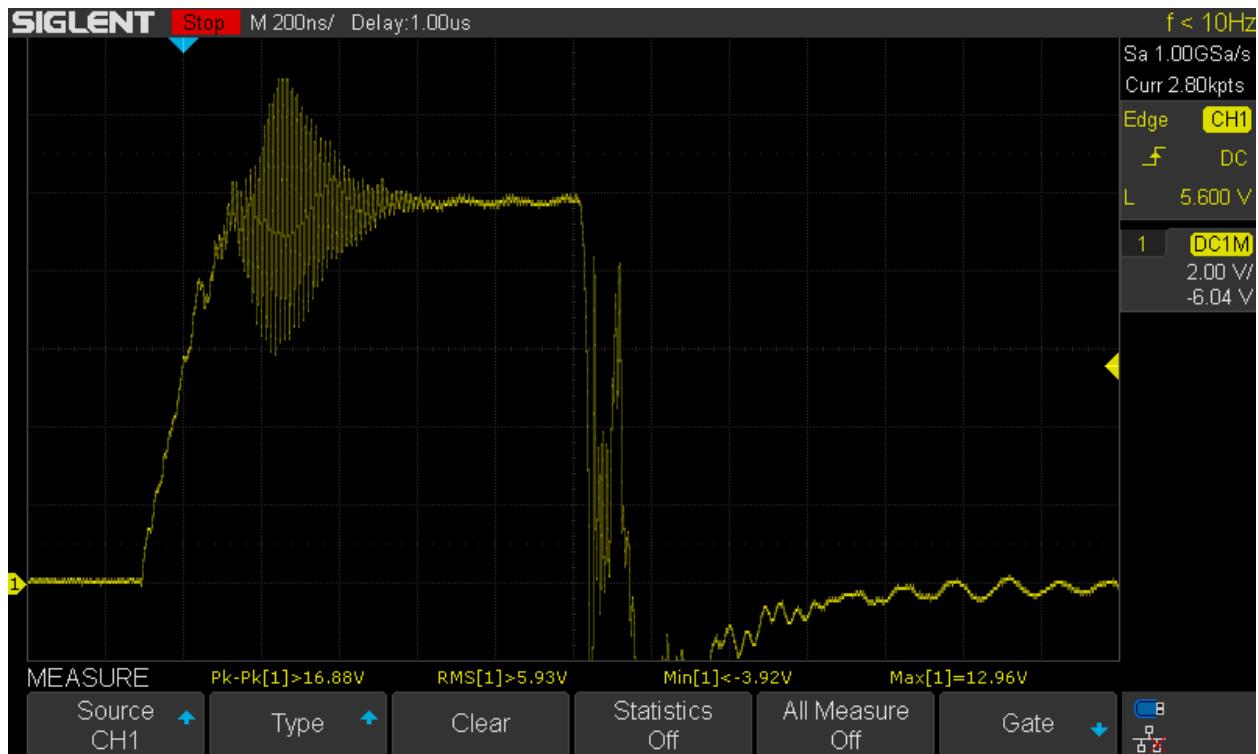
22

GATE: 10V?

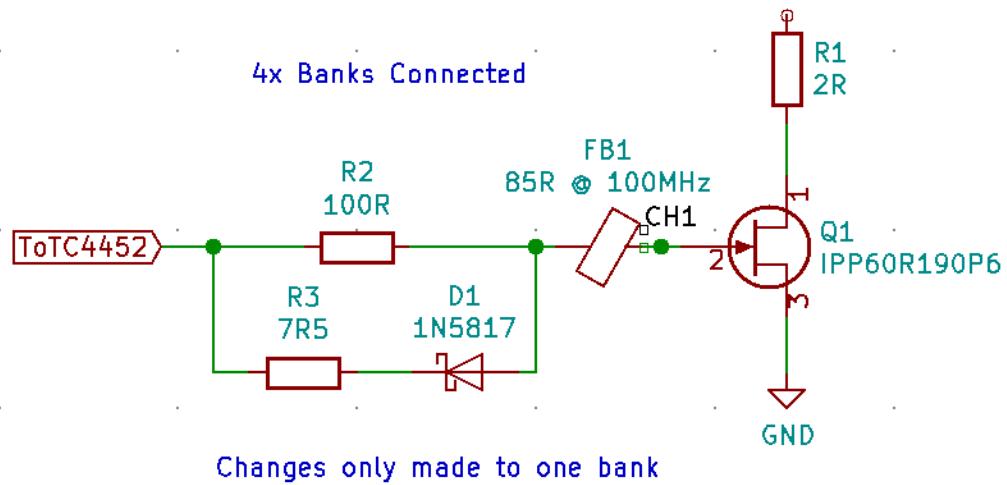
CAP ANODE: 120V

SERIES RESISTOR: 2R

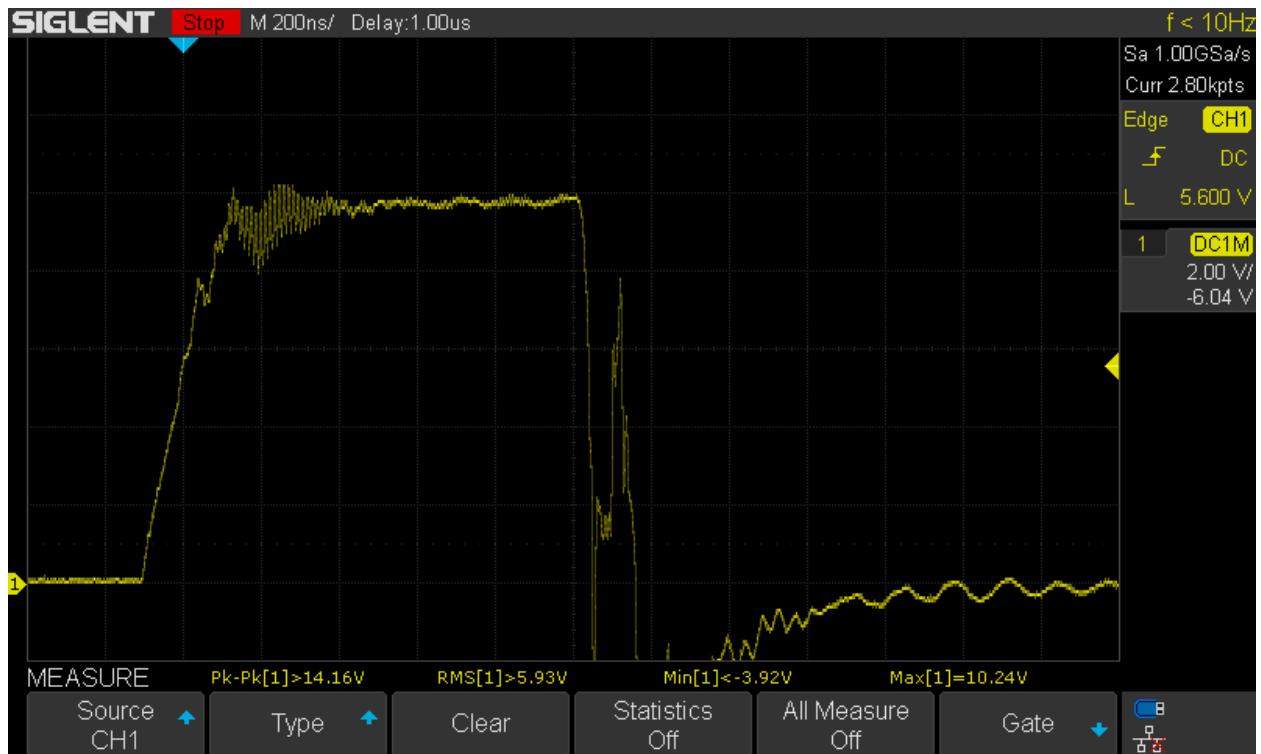
DURATION: 1us



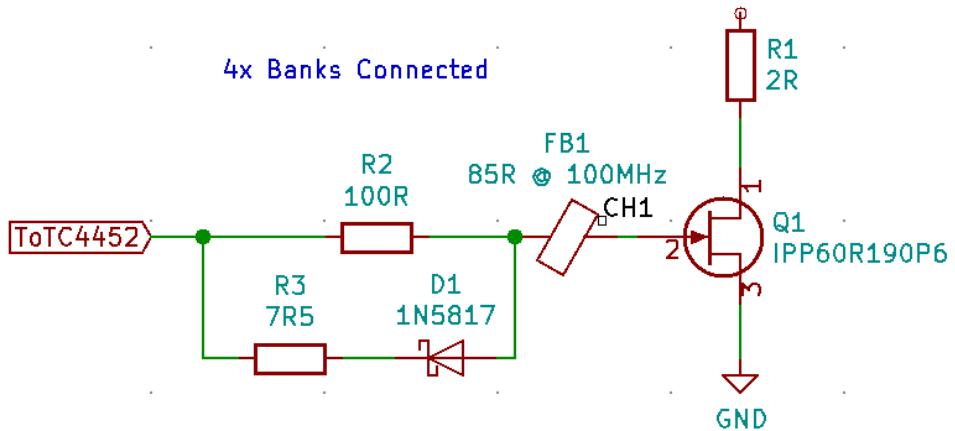
Moved ferrite bead to series with diode and 100R



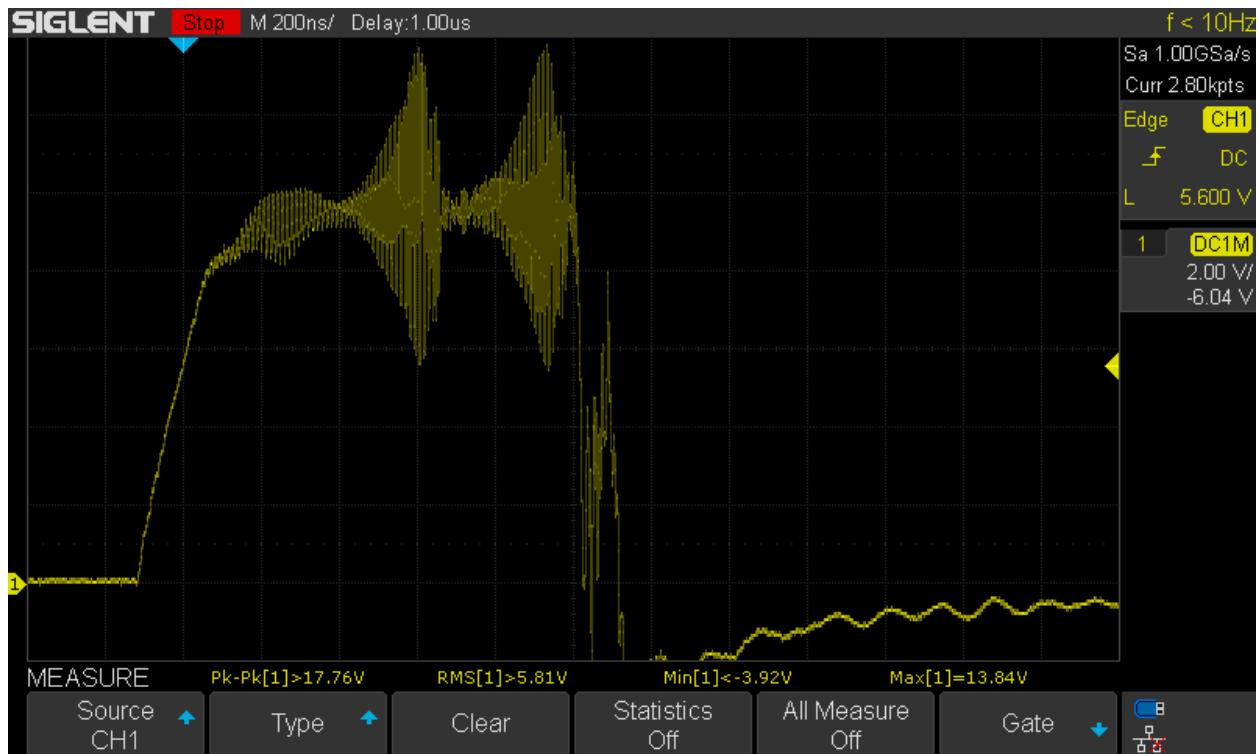
23 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Apply circuit to ALL banks

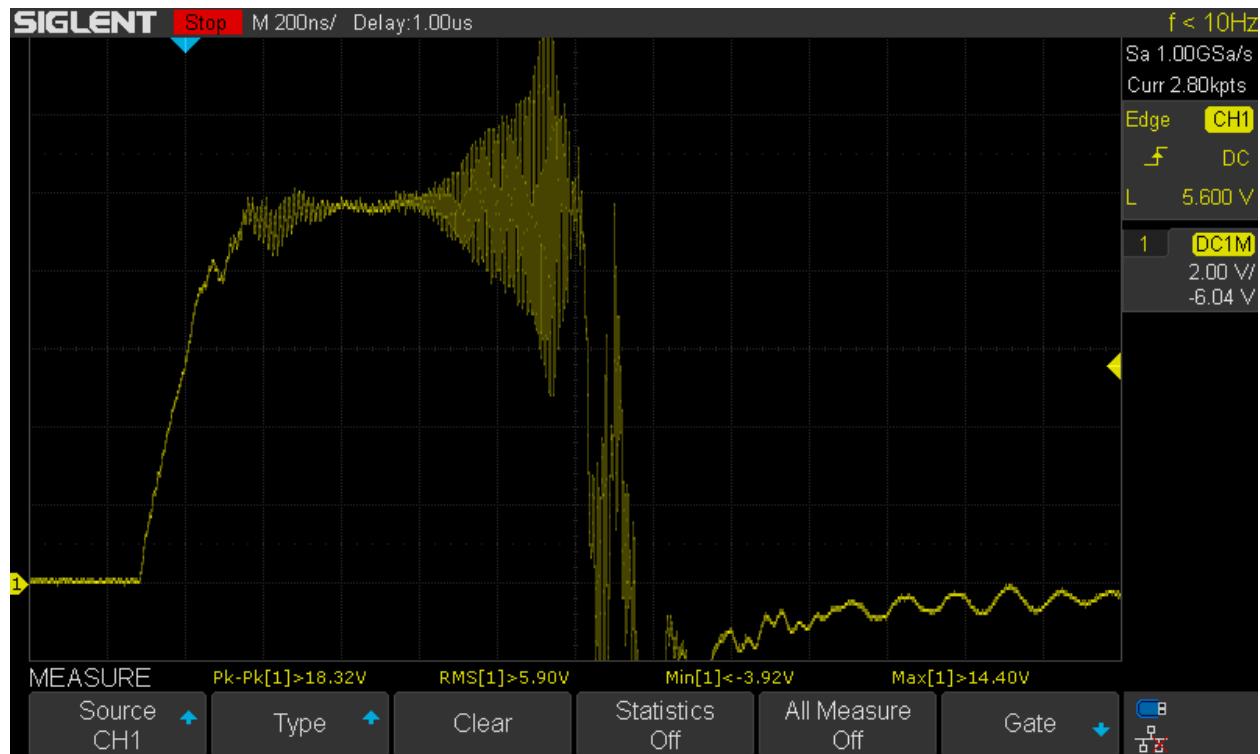


24 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



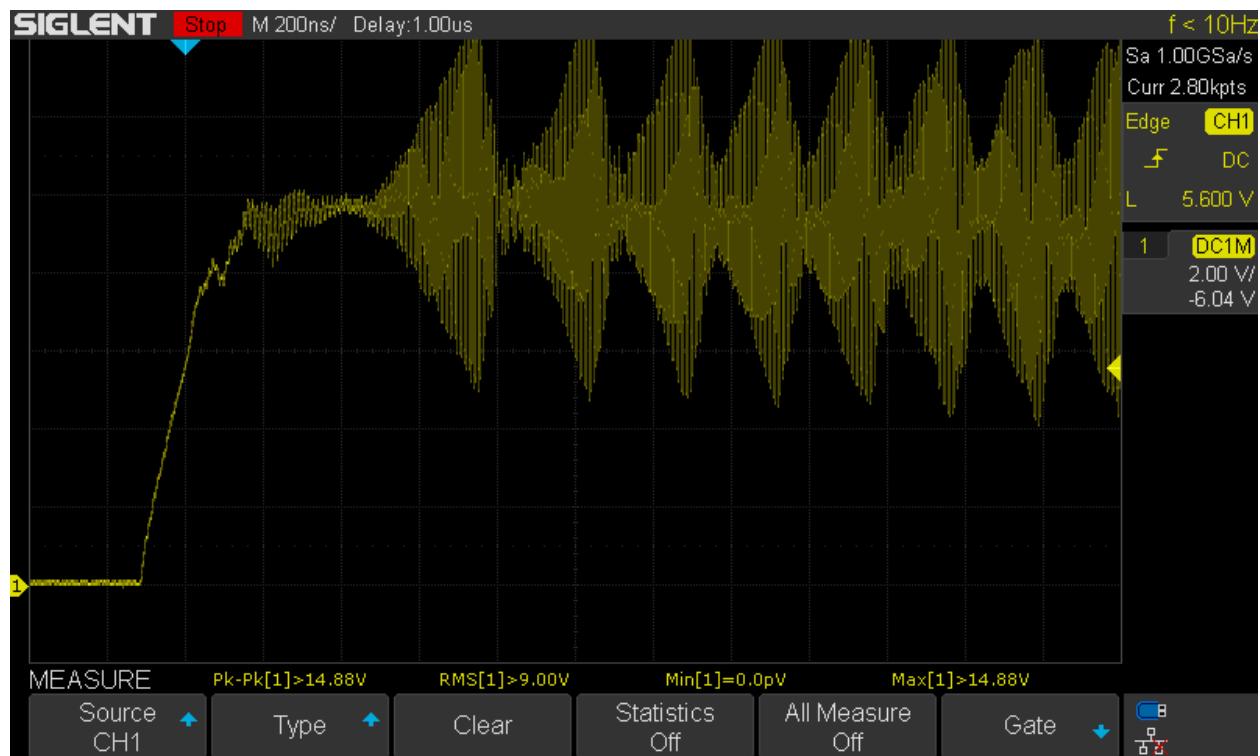
Removed errant capacitor in circuit...

25, 26 (dup) GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



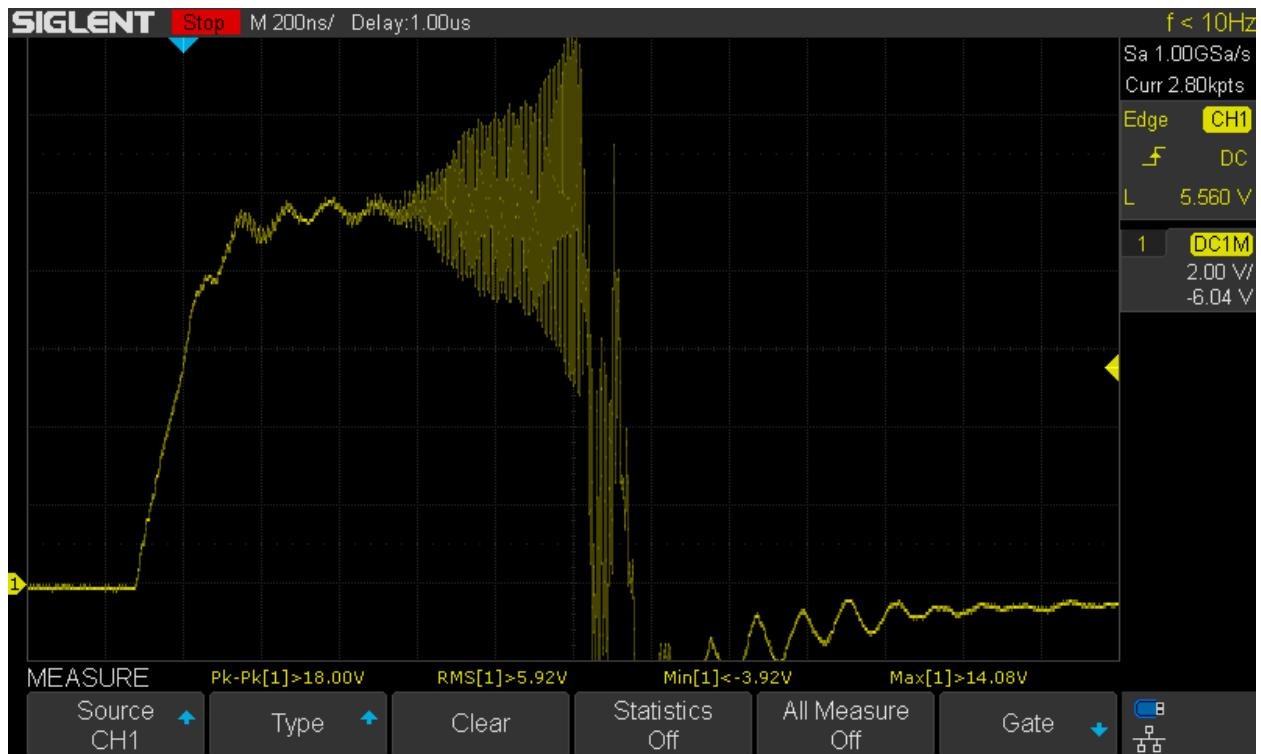
No Change

26 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 2us

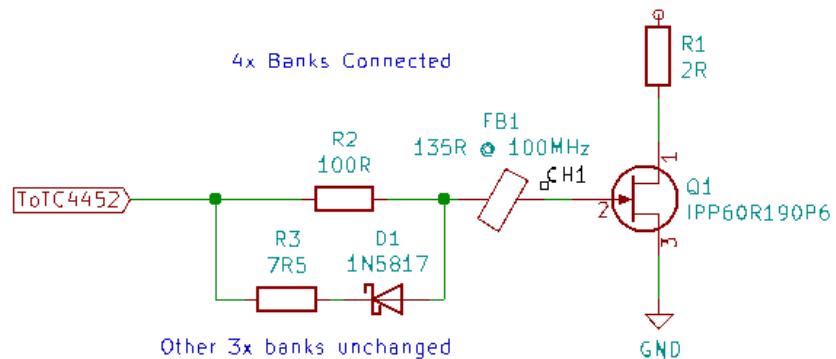


2microsecond Strobe

27 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Replaced ferrite bead with 135R @ 100MHz



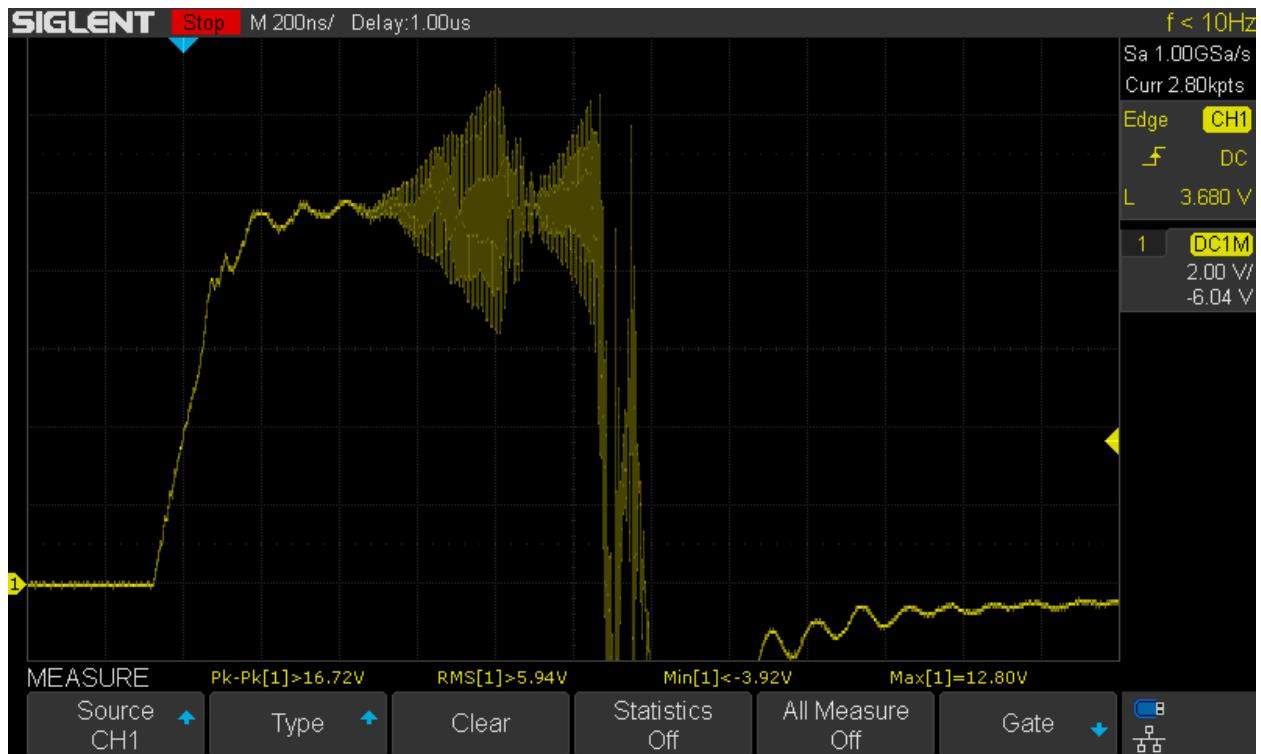
28

GATE: 10V?

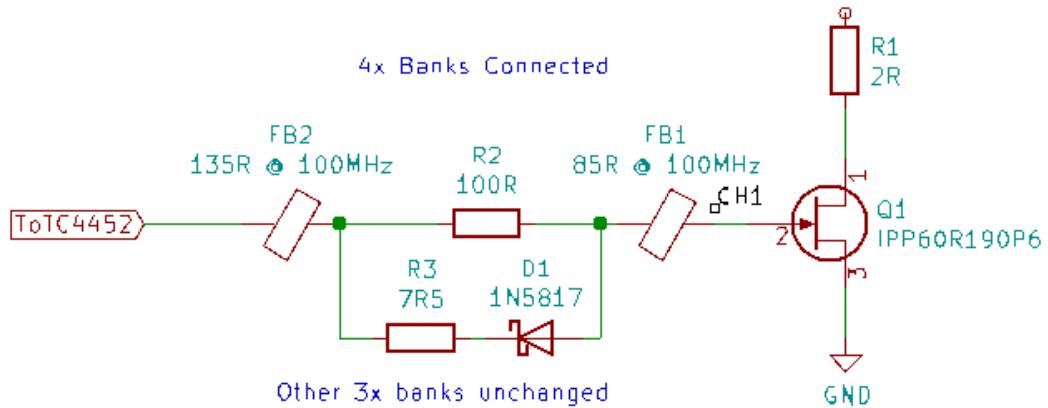
CAP ANODE: 120V

SERIES RESISTOR: 2R

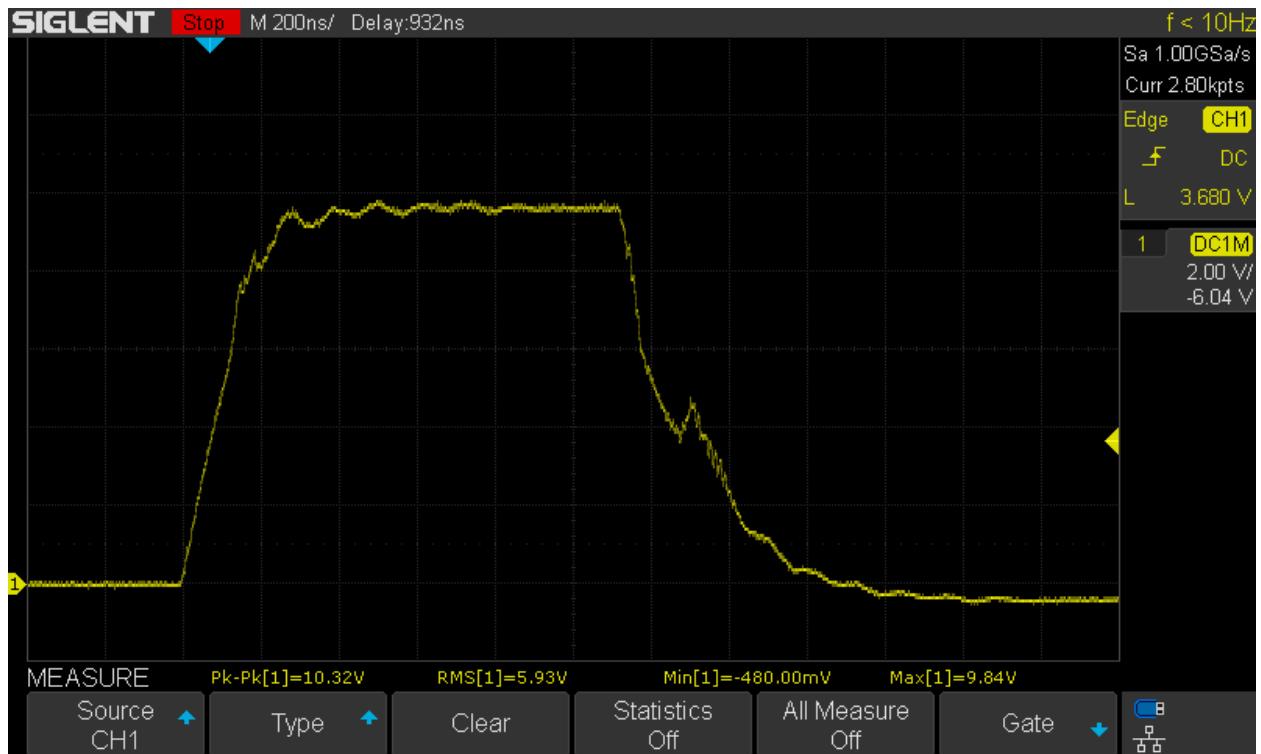
DURATION: 1us



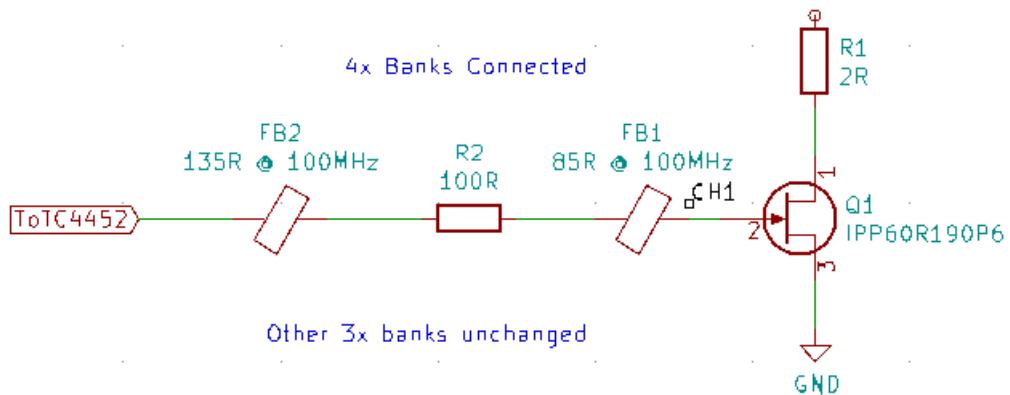
Added second ferrite beads, moved 135R ferrite bead



29 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



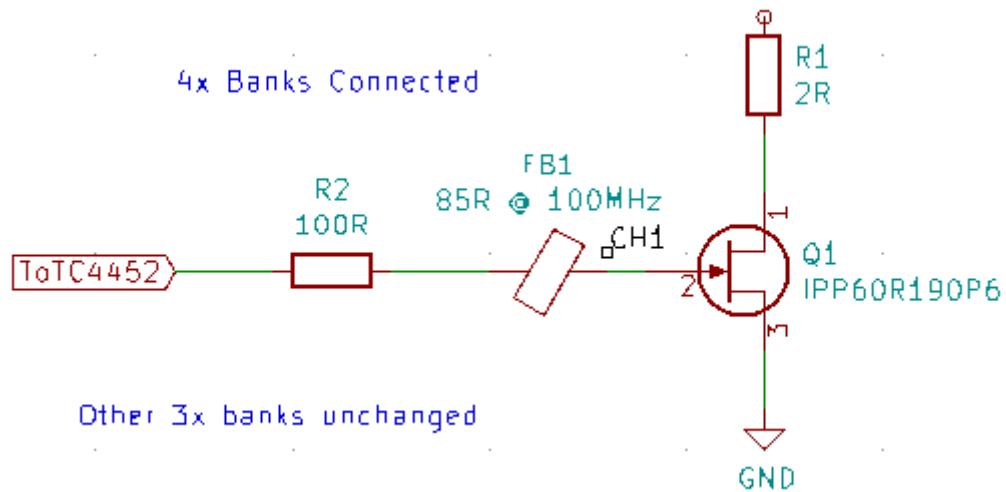
Removed diode-resistor circuit



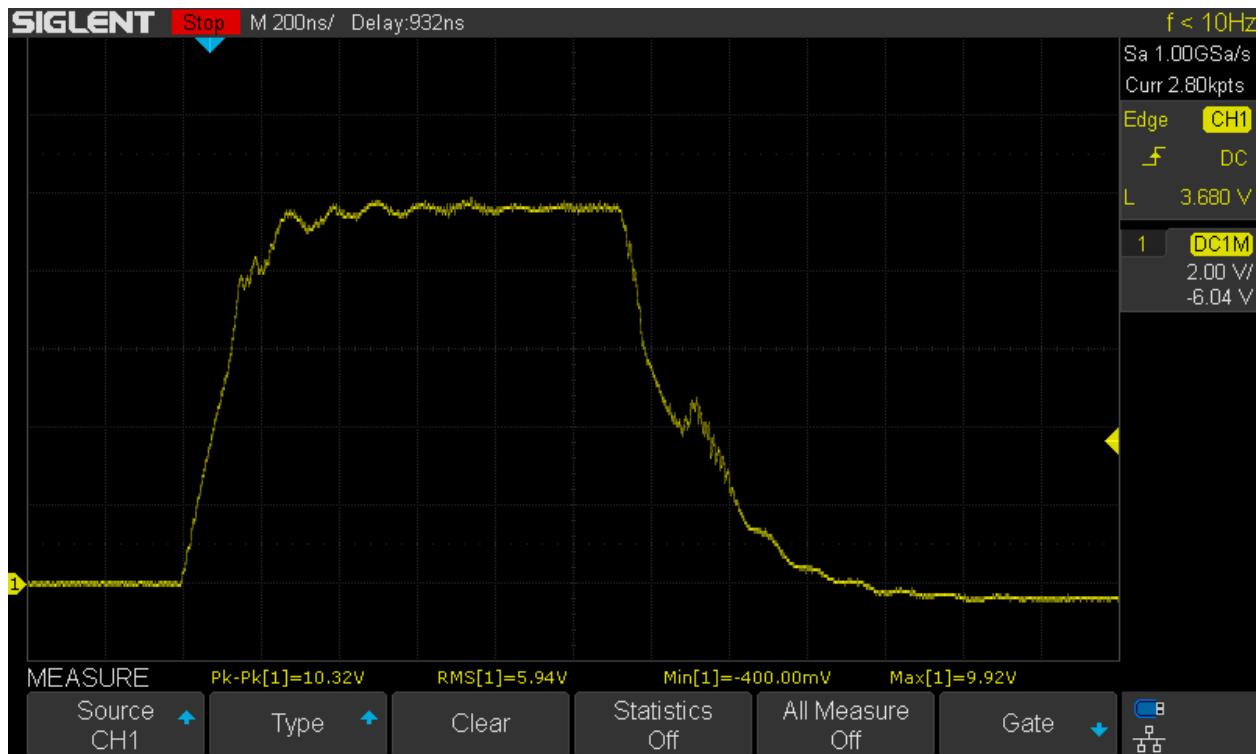
30 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



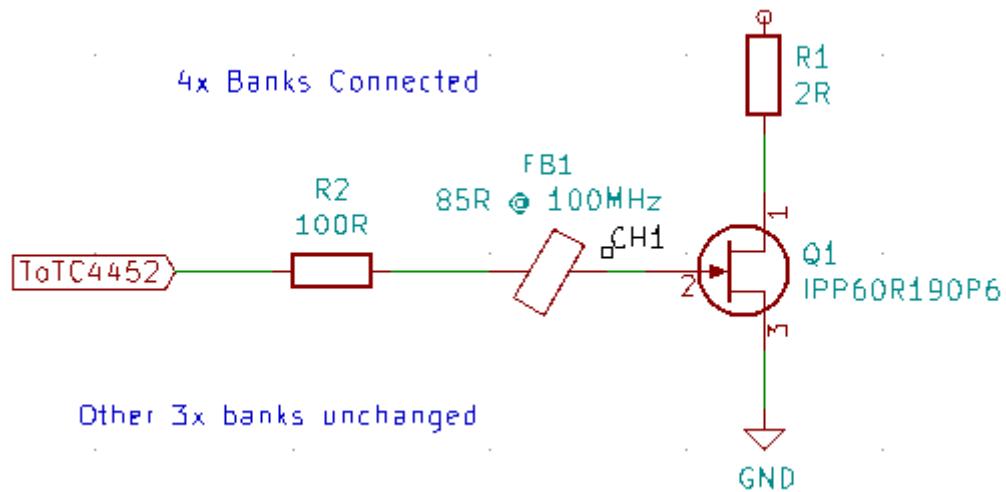
Removed 135R ferrite bead



31 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



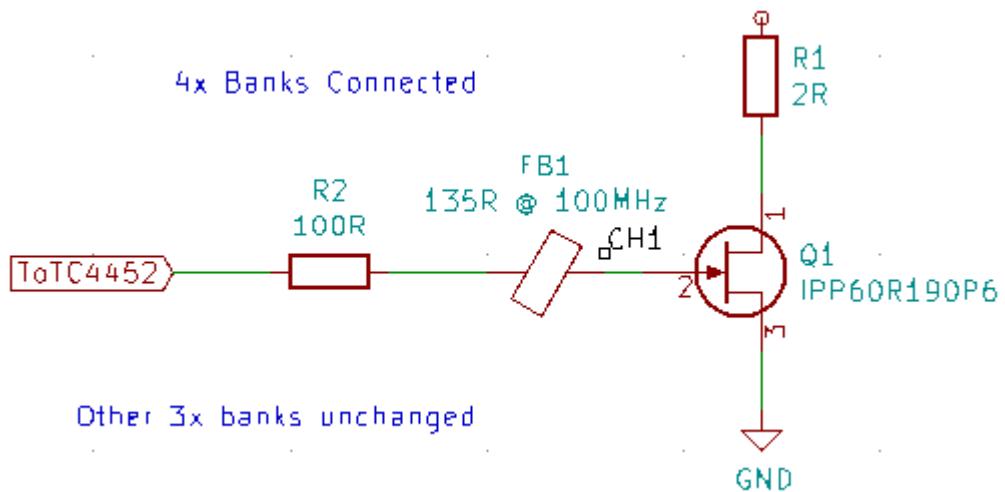
Trimmed leads



32 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



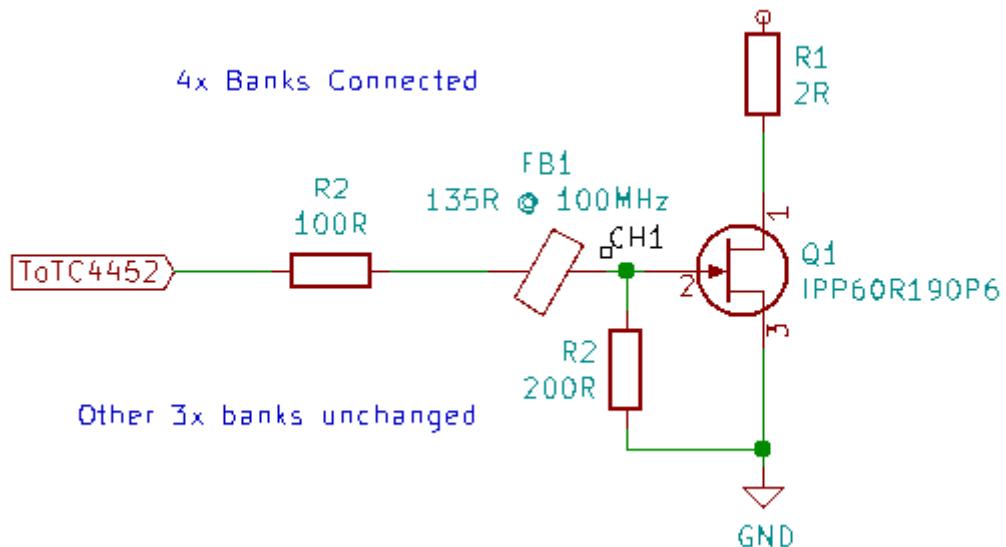
Replaced 85R ferrite bead with 135R ferrite bead



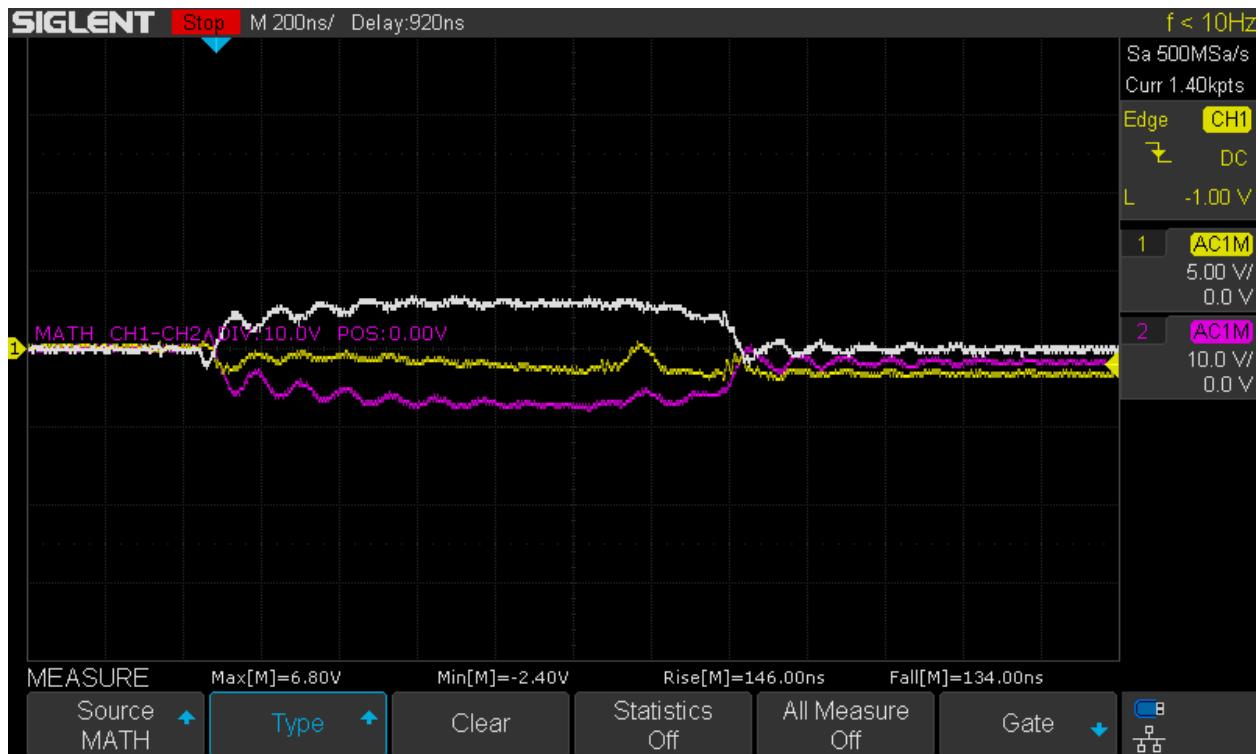
33 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Added 200R pull-down resistor

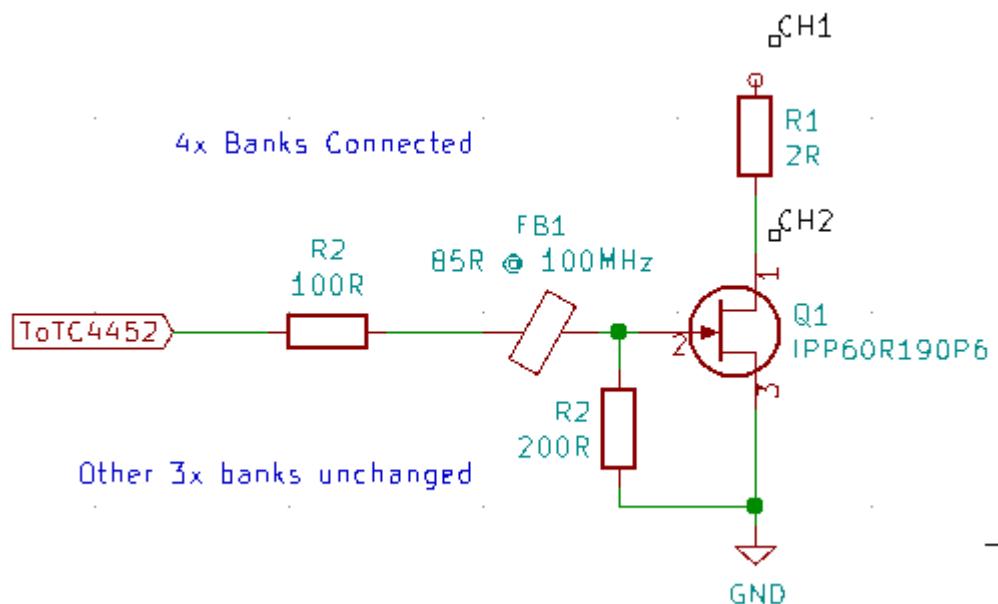


34, 35 (dup) GATE: 10V? CAP ANODE: 50V SERIES RESISTOR: 2R DURATION: 1us

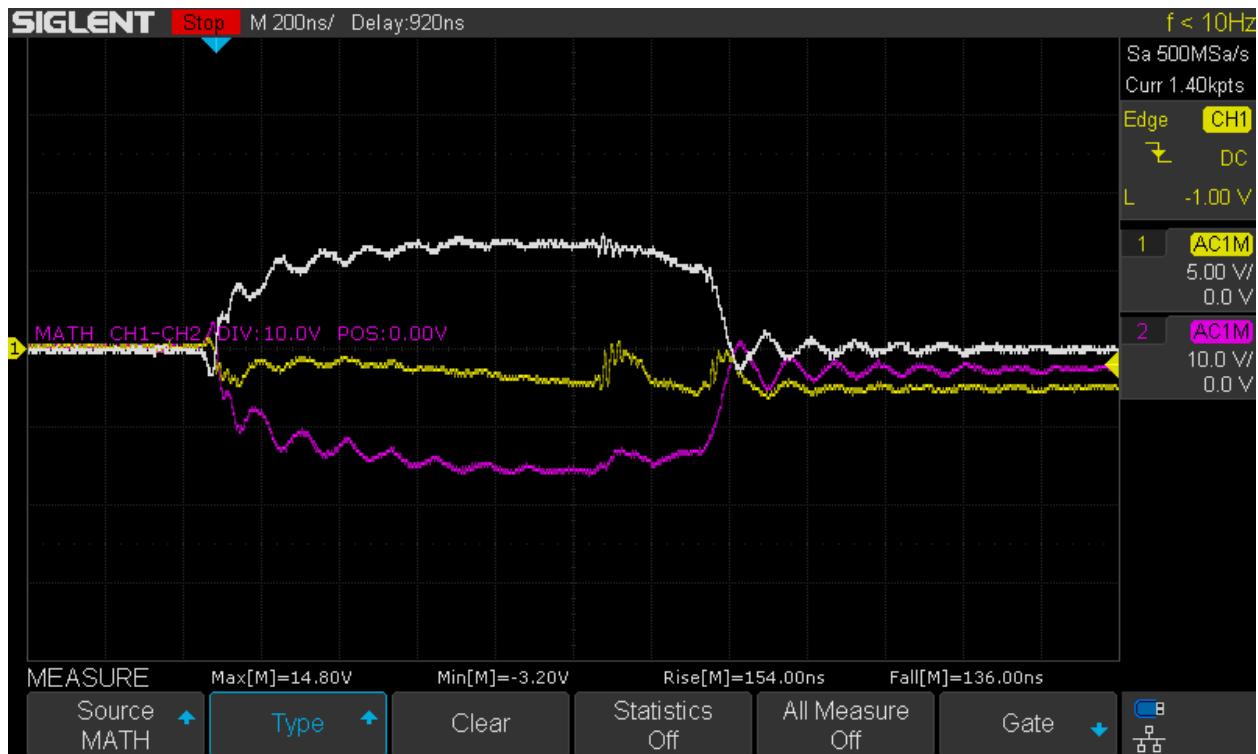


Measuring Current

50V Cap Anode

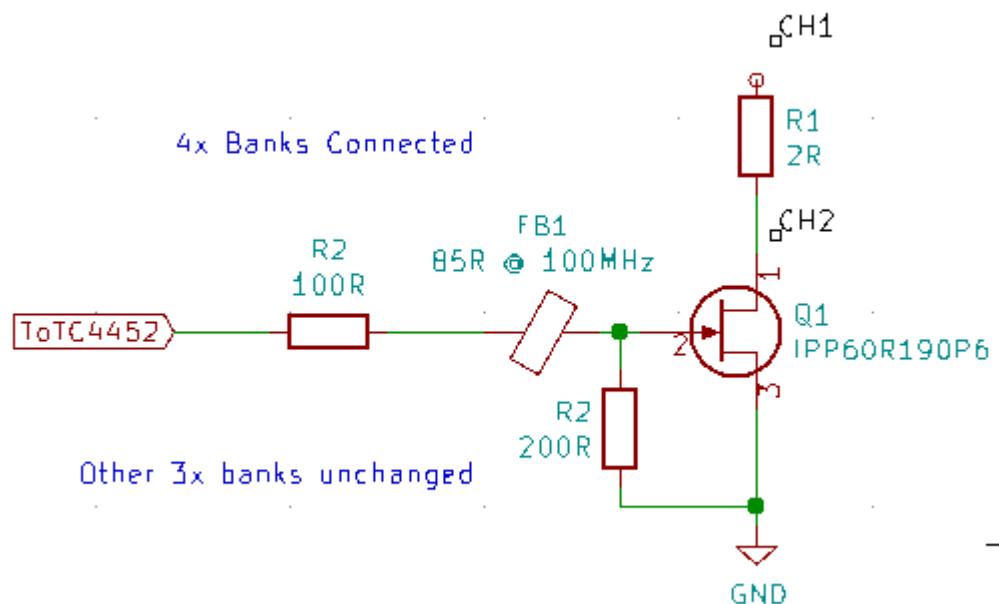


36 GATE: 10V? CAP ANODE: 70V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

70V Cap Anode



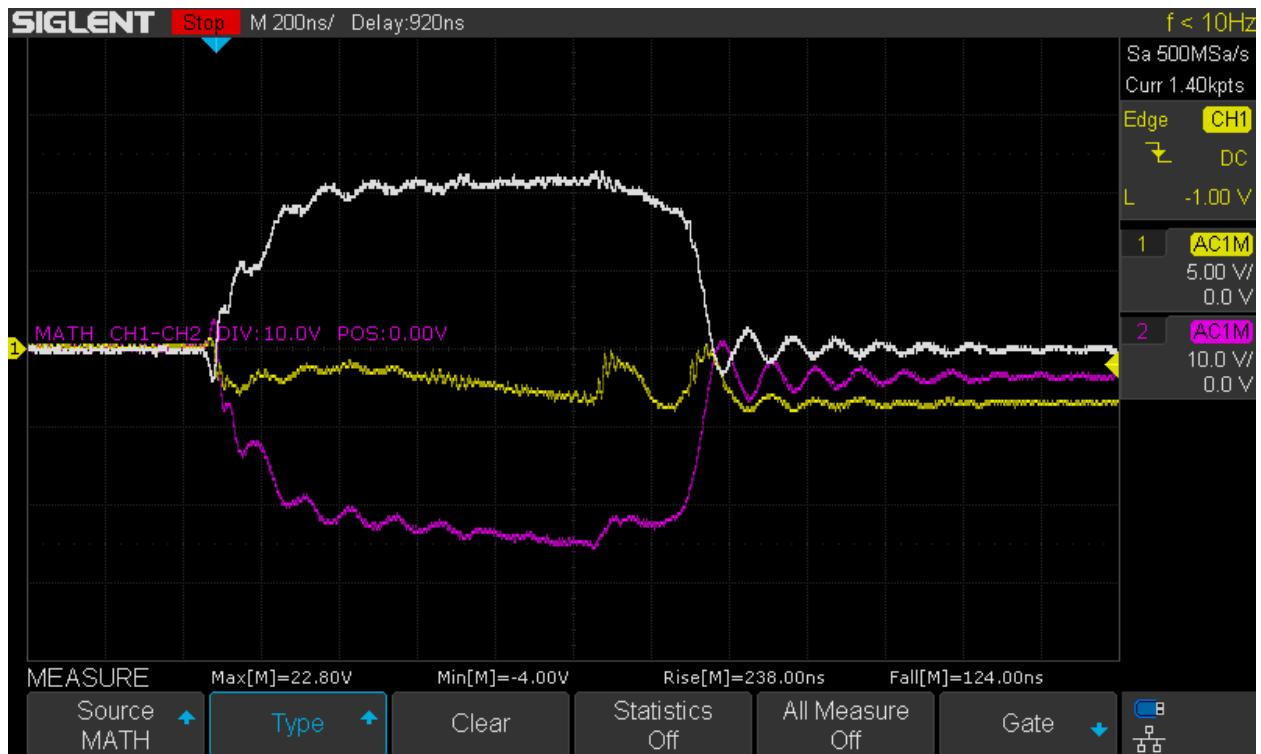
37 GATE: 10V? CAP ANODE: 80V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

80V Cap Anode

38 GATE: 10V? CAP ANODE: 90V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

90V Cap Anode

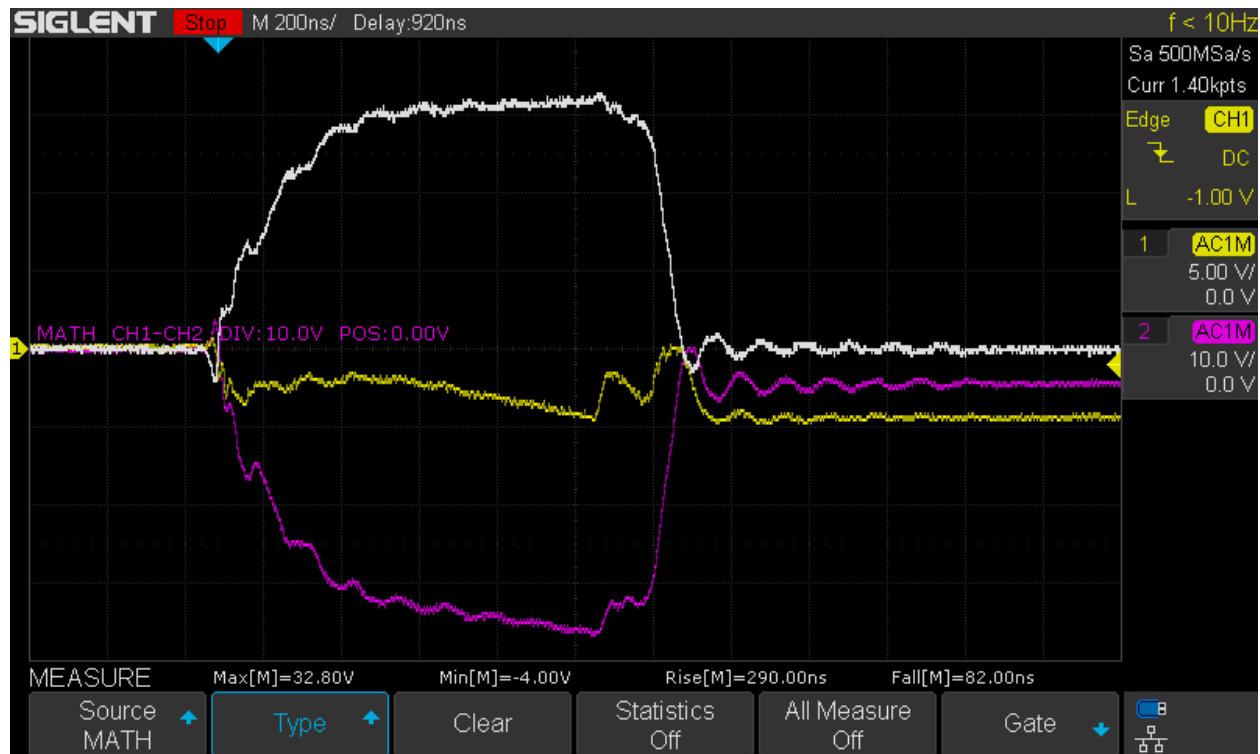
39, 40 (duplicate)

GATE: 10V?

CAP ANODE: 50V

SERIES RESISTOR: 2R

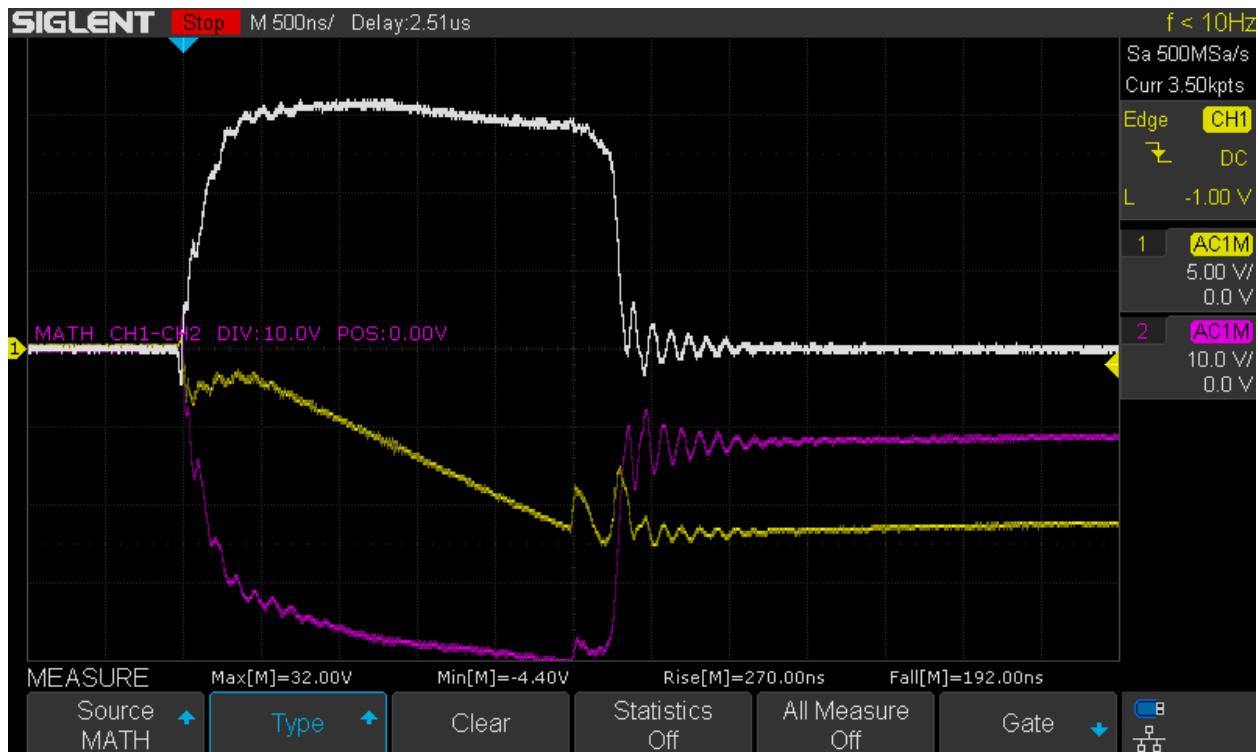
DURATION: 1us



Measuring Current

50V Cap Anode

41 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

120V Cap Anode

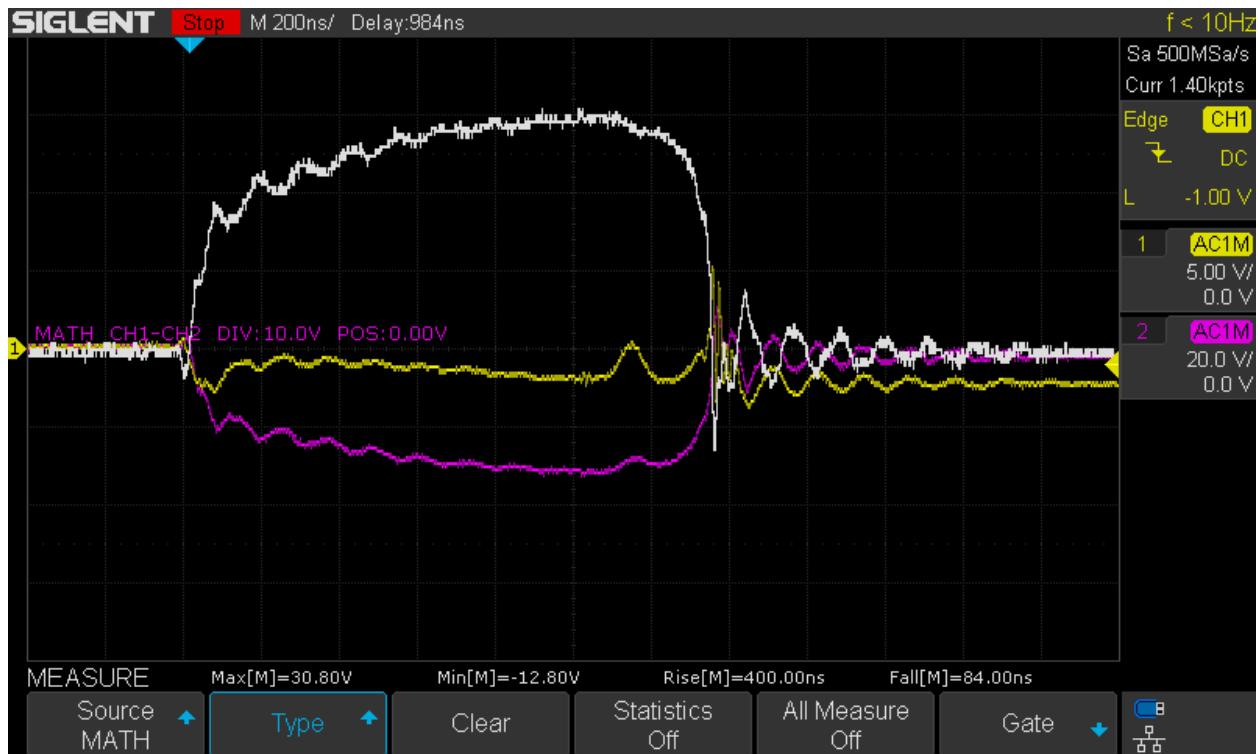
42, 43 (duplicate)

GATE: 10V?

CAP ANODE: 50V

SERIES RESISTOR: 2R

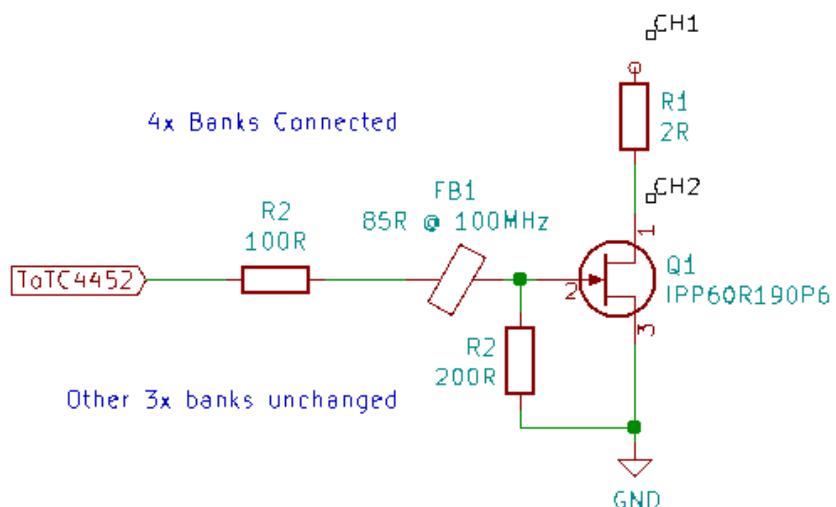
DURATION: 1us



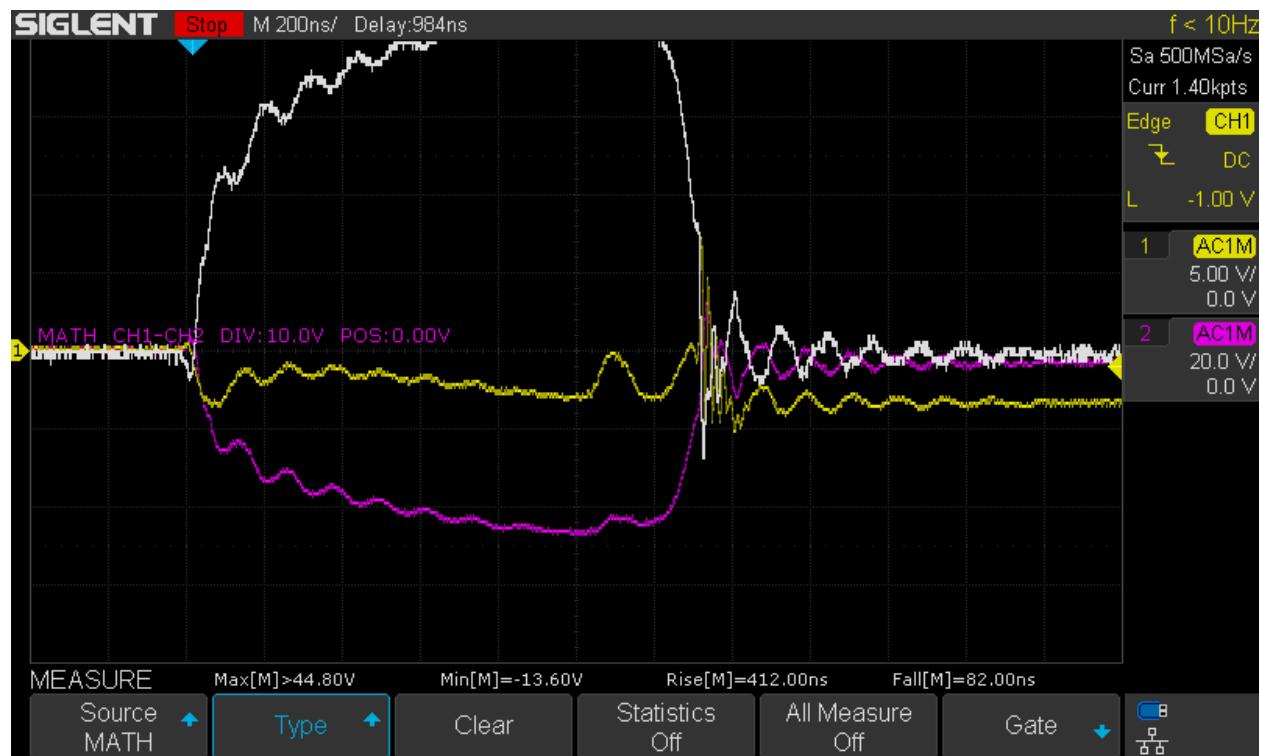
Measuring Current

50V Cap Anode

Changed ferrite bead and pull-down resistor changed

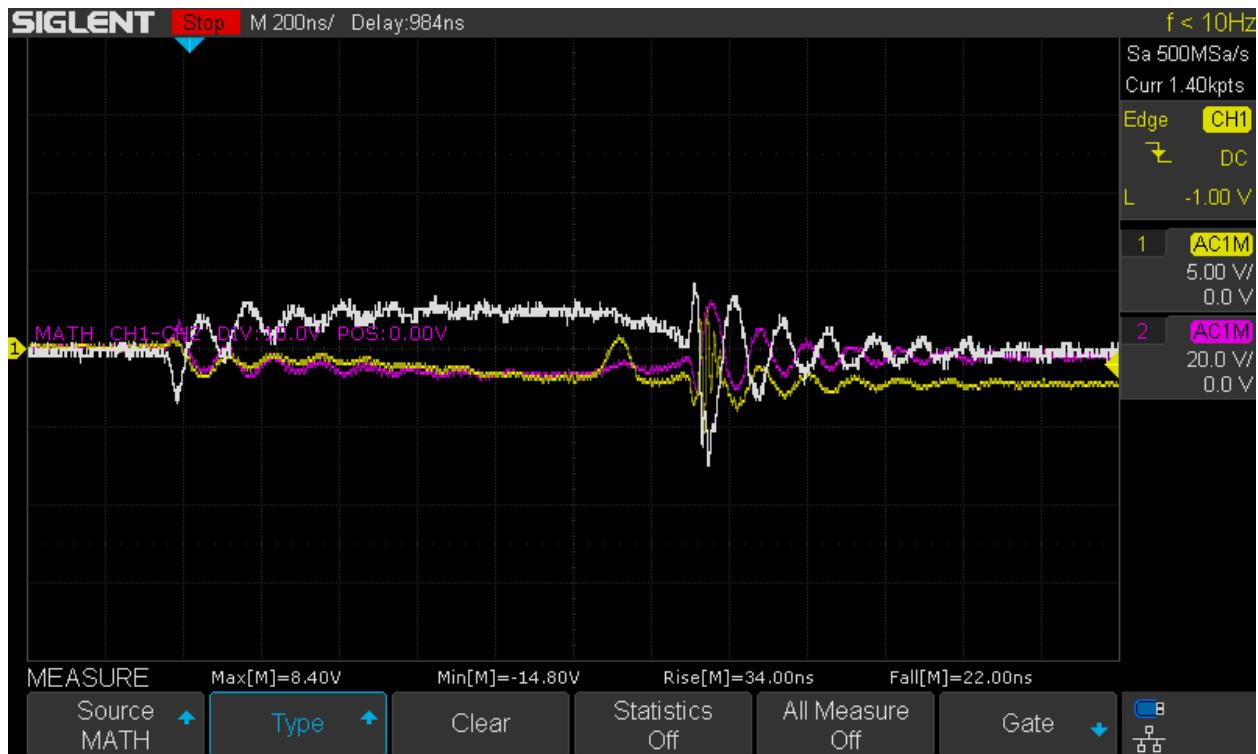


44 GATE: 10V? CAP ANODE: 70V SERIES RESISTOR: 2R DURATION: 1us



70V Cap Anode

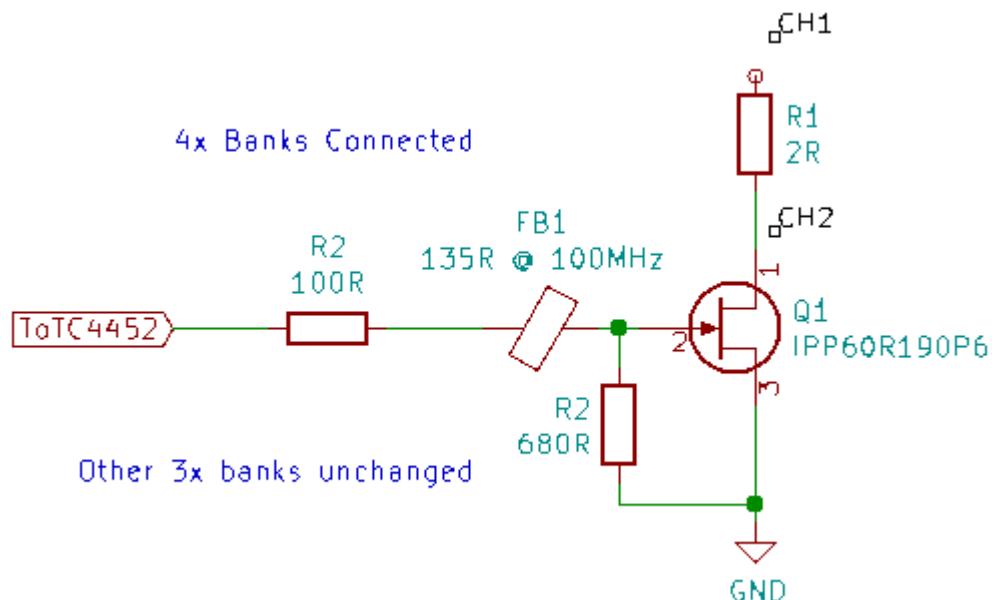
45 GATE: 10V? CAP ANODE: 50V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

50V Cap Anode

Changed ferrite bead and pull-down resistor changed



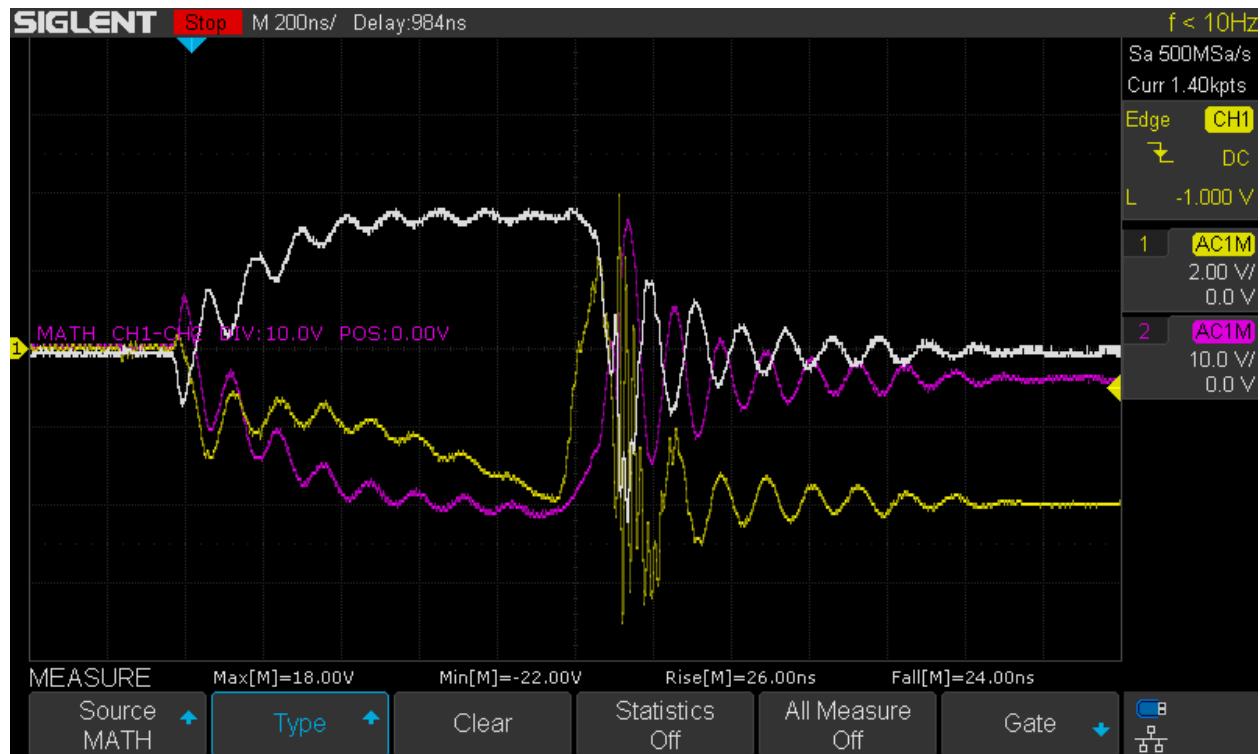
46, 47 (duplicate)

GATE: 10V?

CAP ANODE: 90V

SERIES RESISTOR: 2R

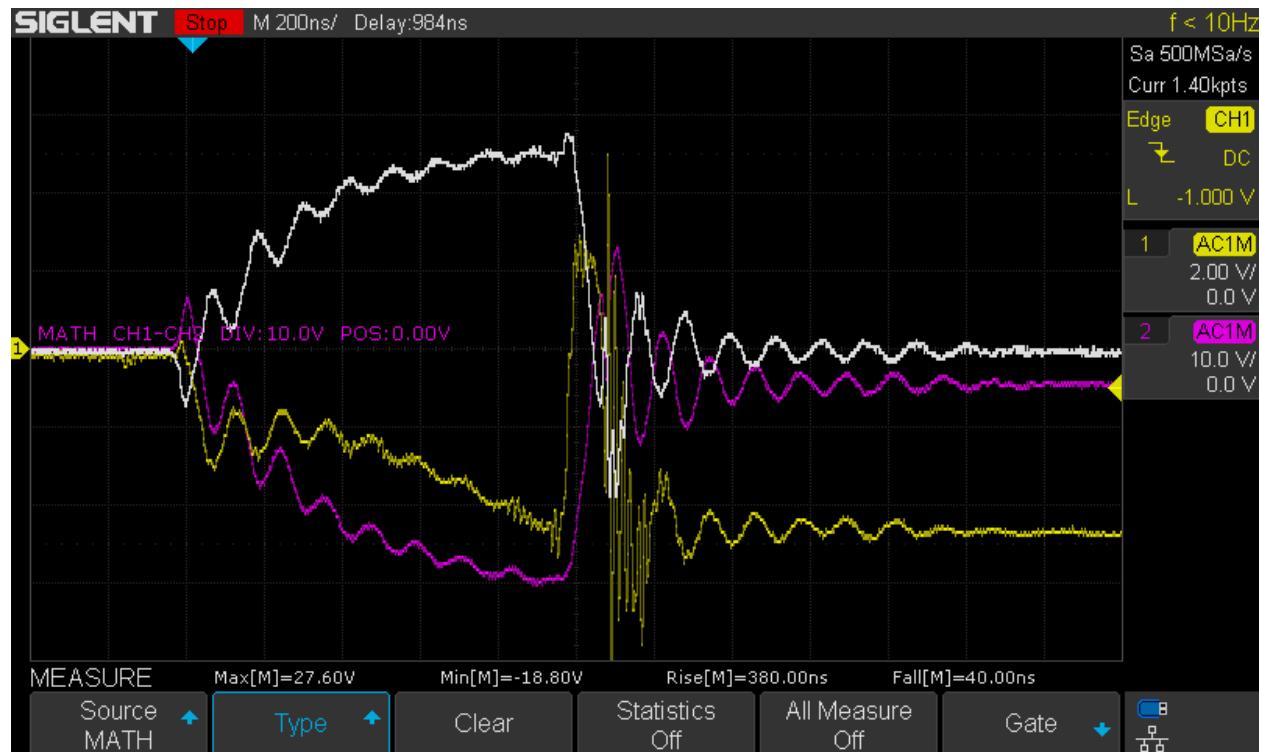
DURATION: 1us



Measuring Current

90V Cap Anode

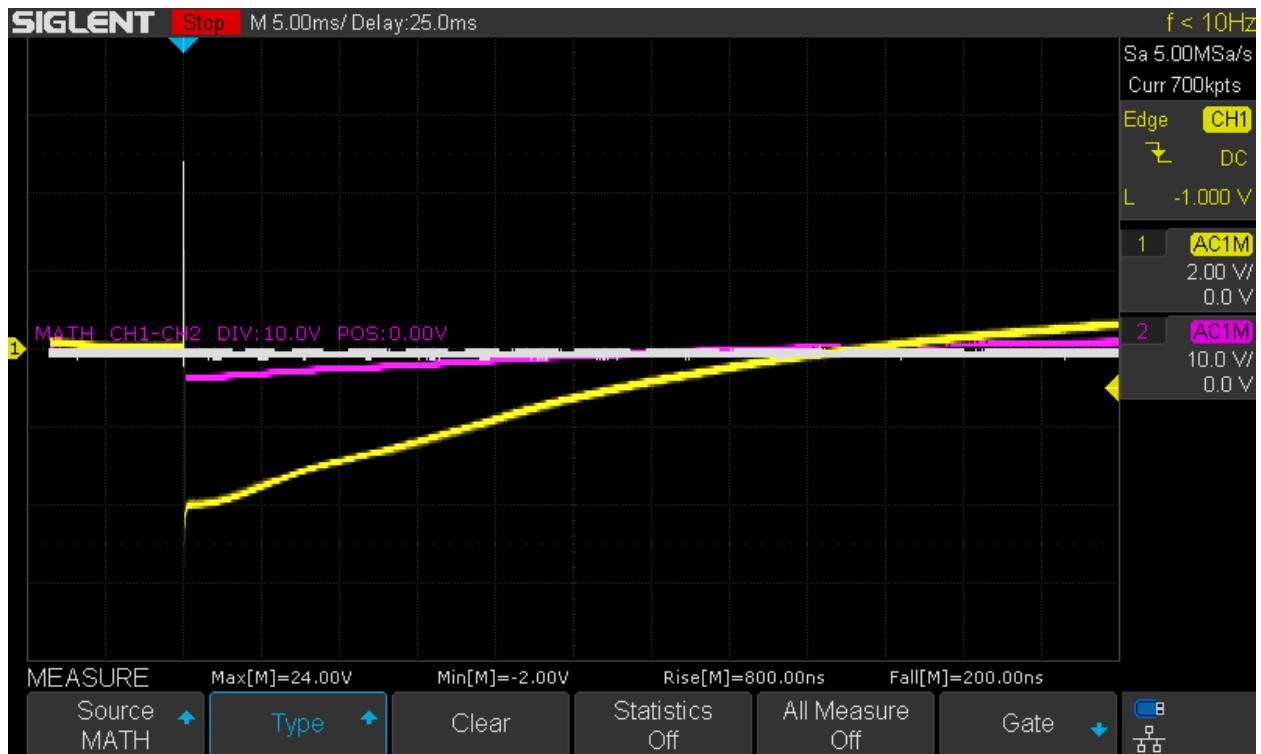
48 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

120V Cap Anode

49 GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Measuring Current

120V Cap Anode

Series 2 – TC4452 Gate Driver Output

Overview:

Purpose: To improve the gate driver circuit

Equipment:

- E2 Prototype with four banks of LED's in various states of damage
 - IPPR60 MOSFET's

Results:

- Adding capacitance to the TC4452 output exacerbates the ringing
- Adding a 10R series resistor with 10nF capacitor to GND to the TC4452 output slows the gate rise and fall significantly (~400ns rise/fall time)
- Adding a 1R5 series resistor with 10nF capacitor to GND to the TC4452 output improves ringing, overshoot @ gates slightly without affecting rise/fall times
-

Test Data:

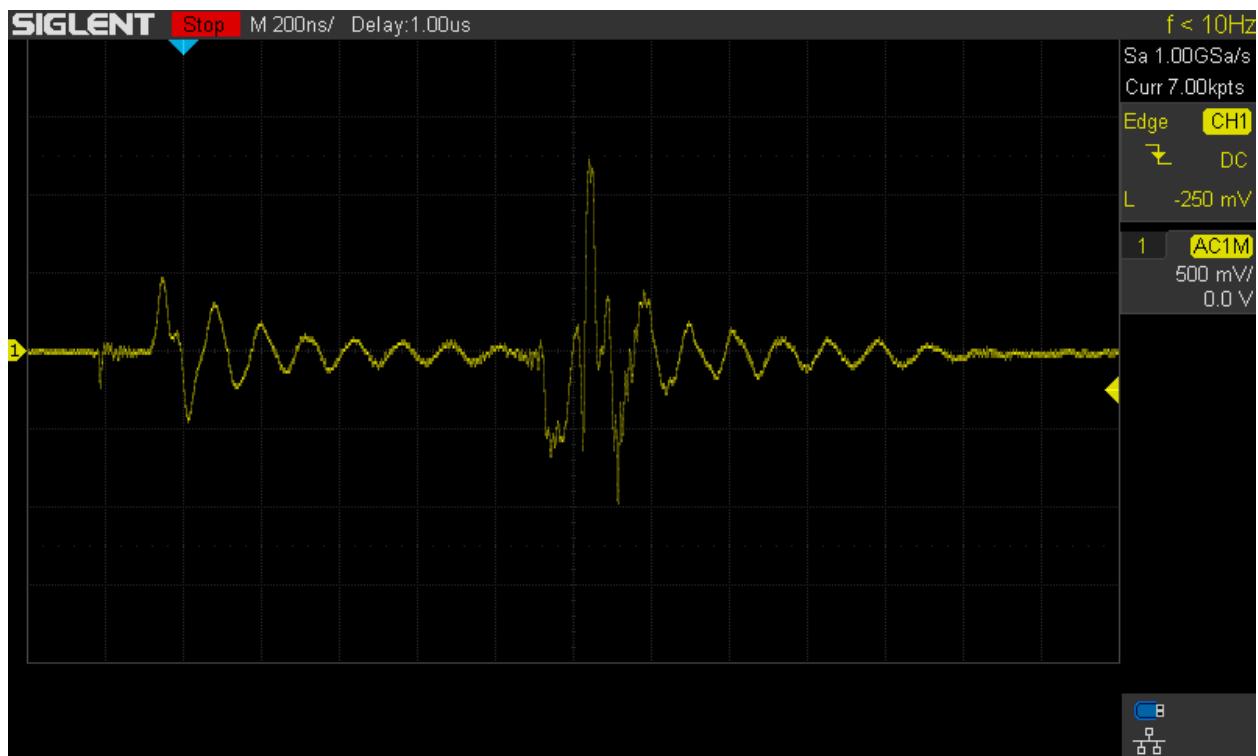
1

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



TC4452 Input Voltage

1us pulse, 4x gates connected

2x 10uF capacitors (ceramic) supplying

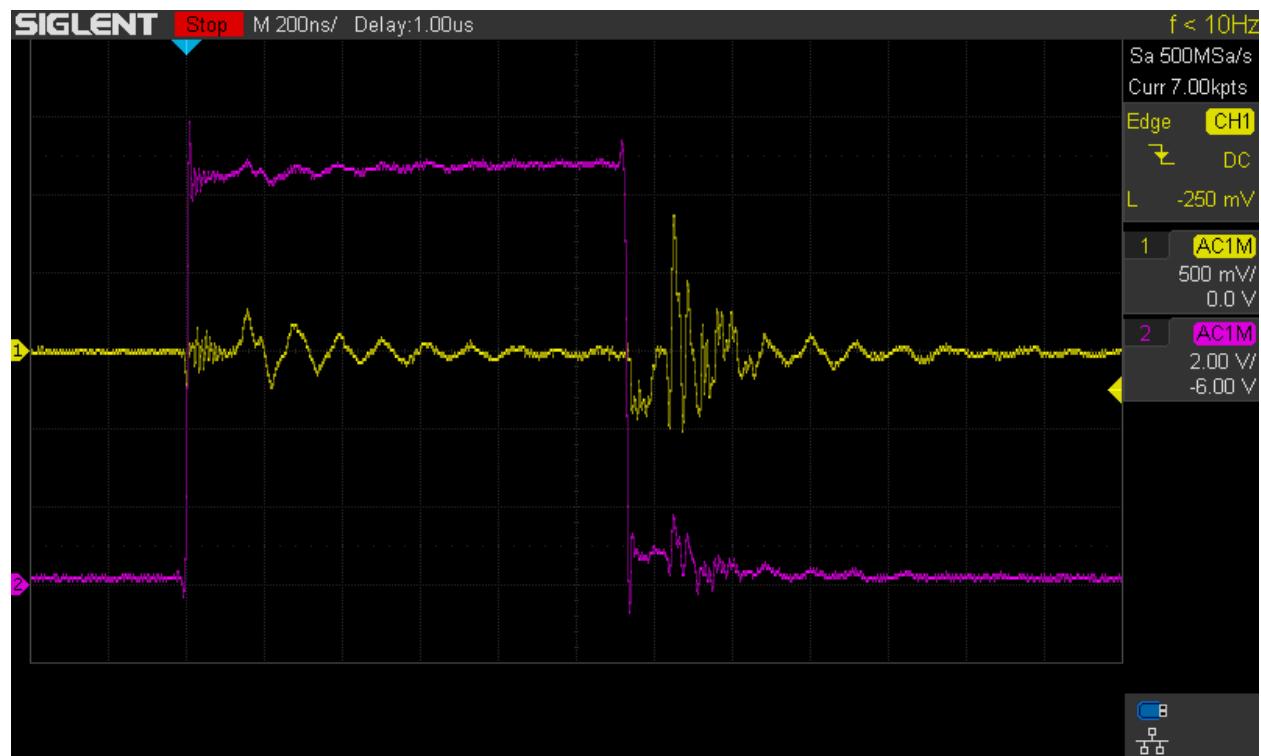
2

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



CH1 – TC4452 Input

CH2 – TC4452 Output

1us pulse

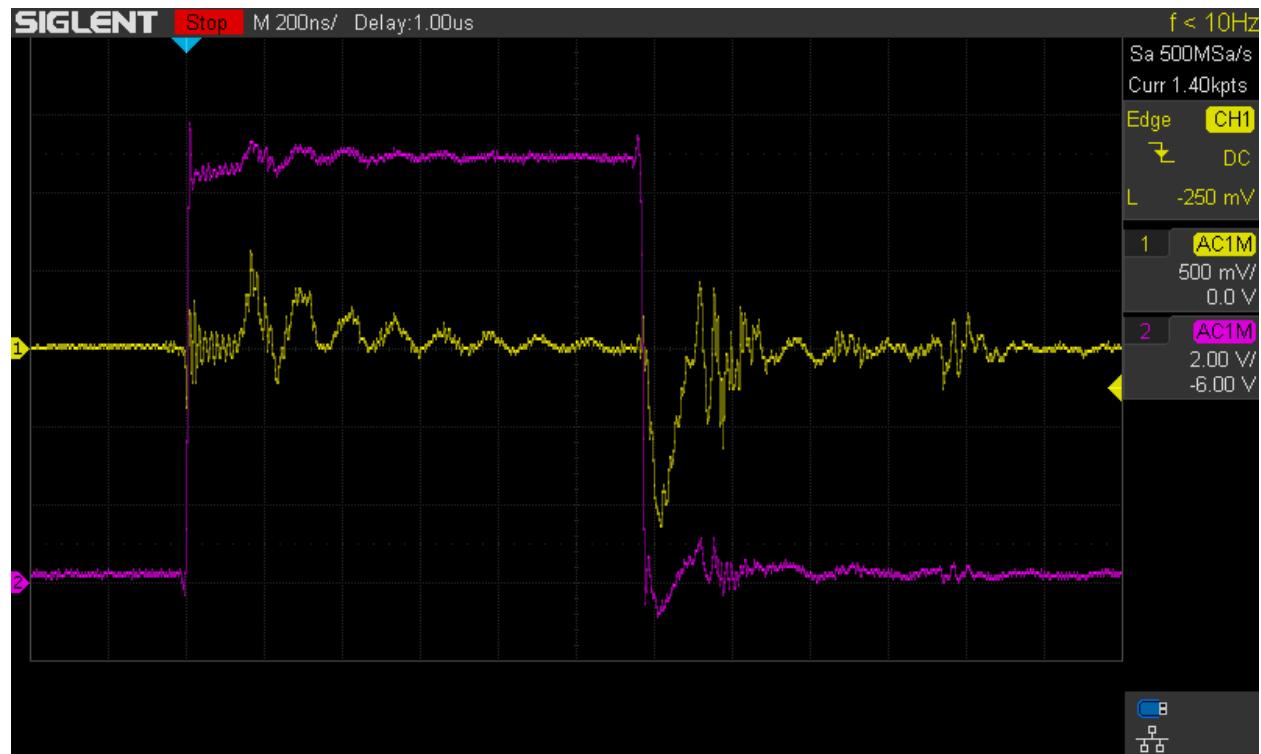
3

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Added 10nF cap @ TC4452 input

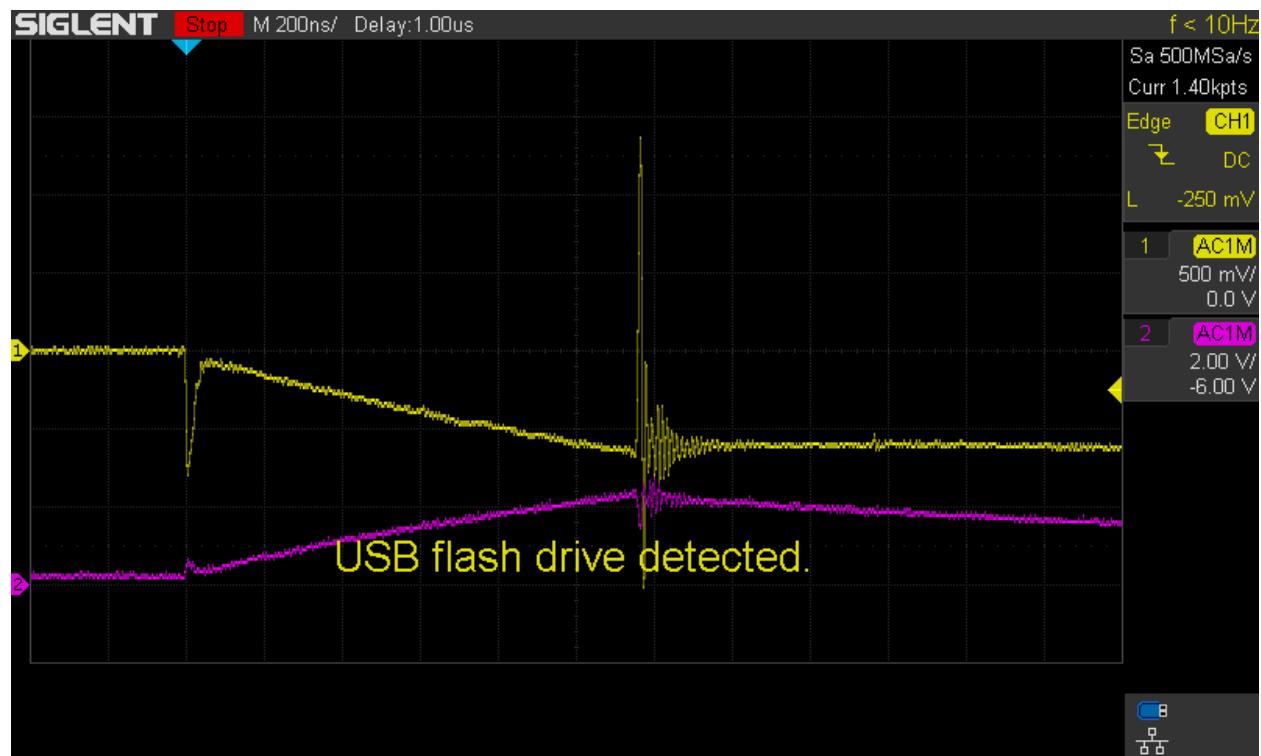
4

GATE: 10V?

CAP ANODE: 120V

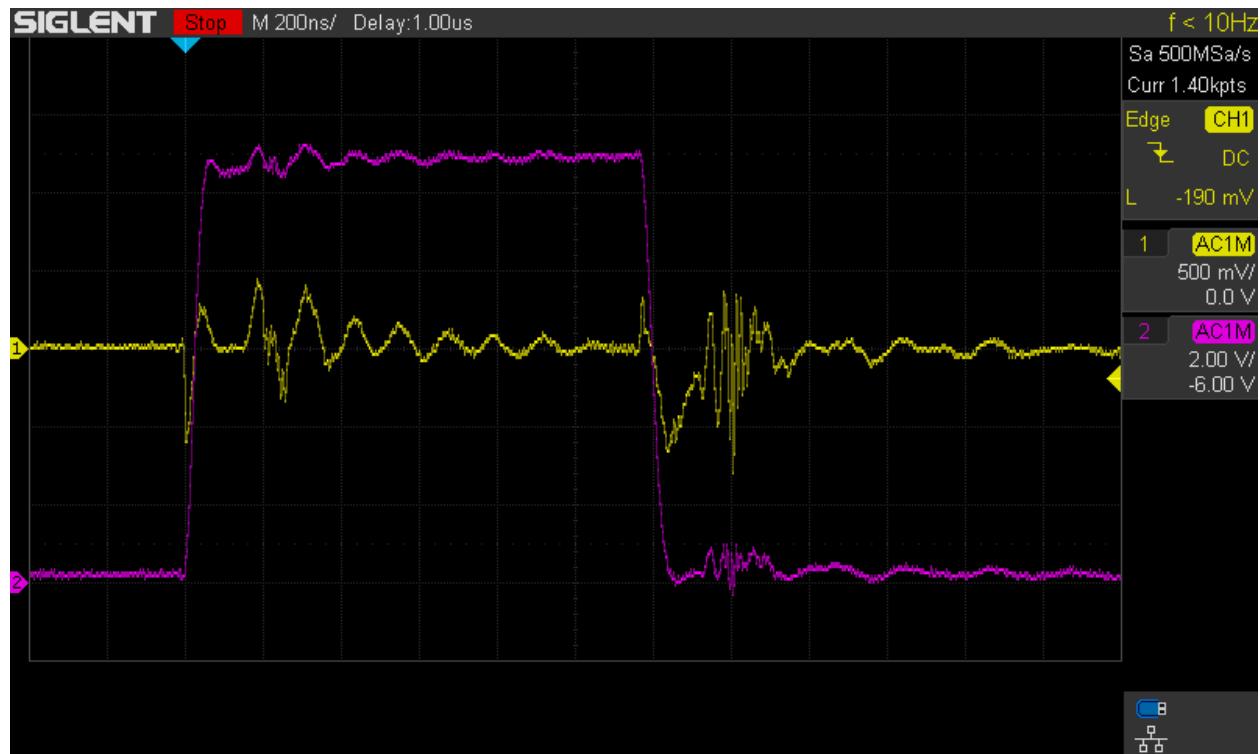
SERIES RESISTOR: 2R

DURATION: 1us



Added 2.2uF capacitor on TC4452 output

5, 6 (duplicate) GATE: 10V? CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



Replaced 2.2uF with 10nF on output

7

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



CH1 – MOSFET Gate

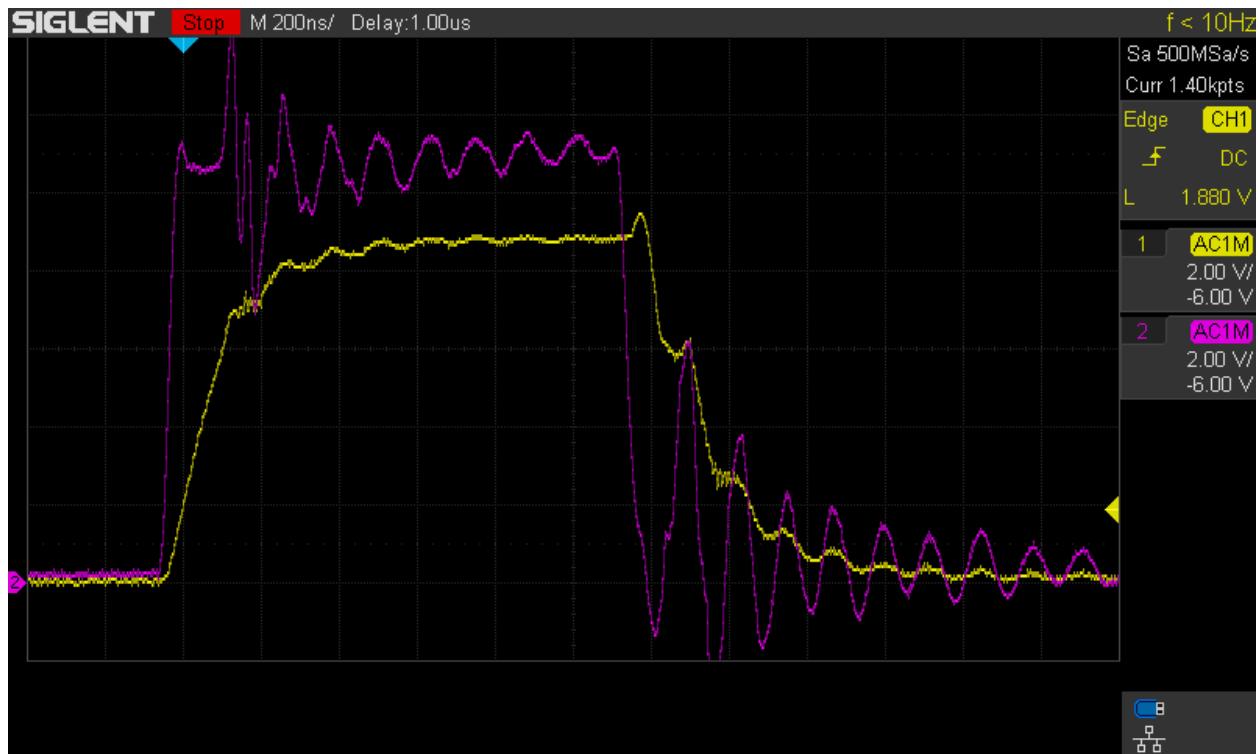
8

GATE: 10V?

CAP ANODE: 120V

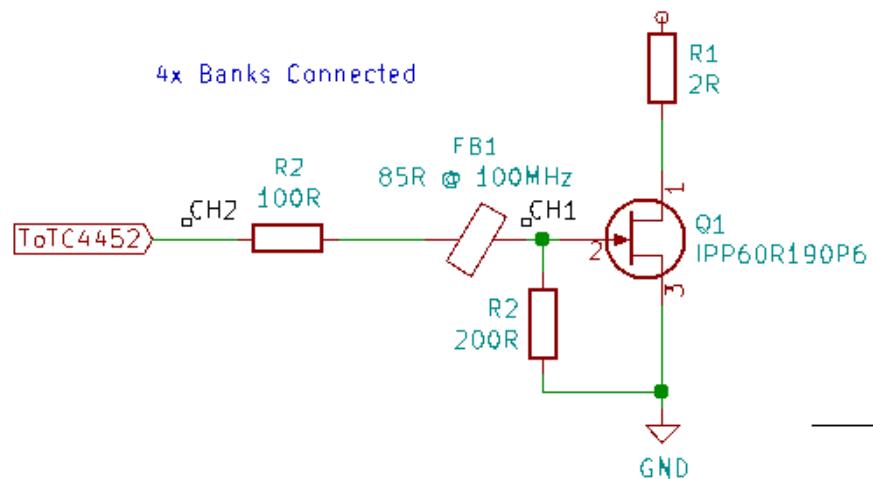
SERIES RESISTOR: 2R

DURATION: 1us



CH1 – MOSFET Gate voltage

CH2 -



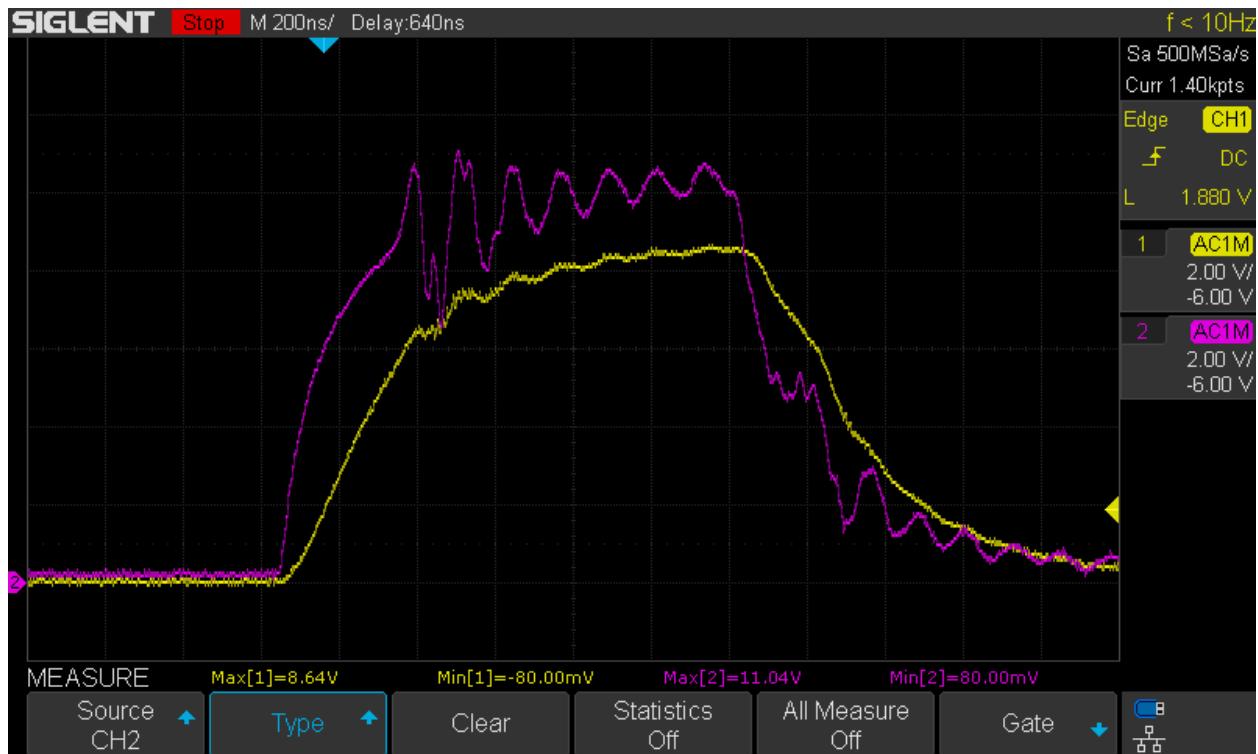
9

GATE: 10V?

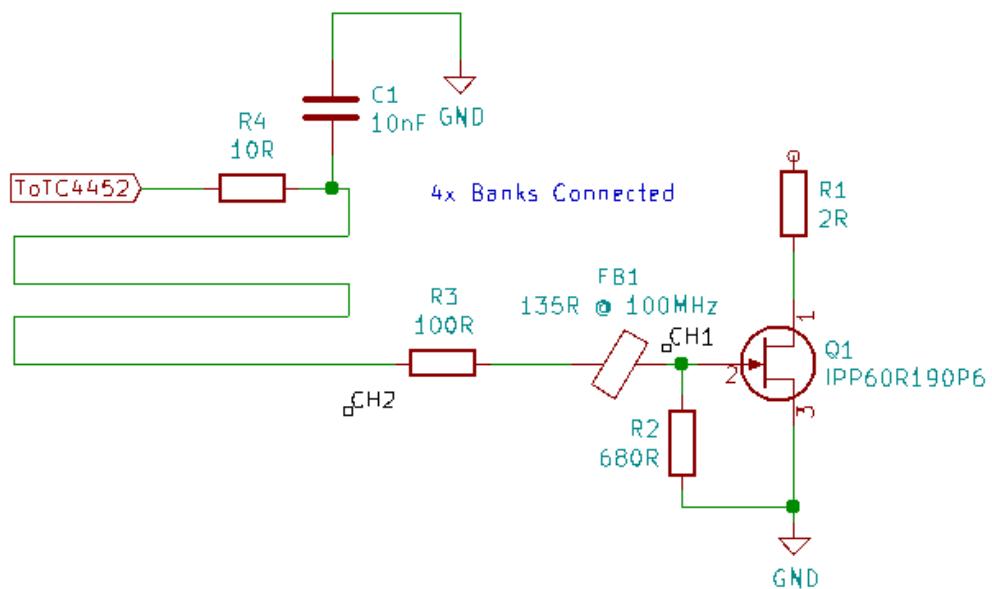
CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Added 10R resistor on TC4452 output



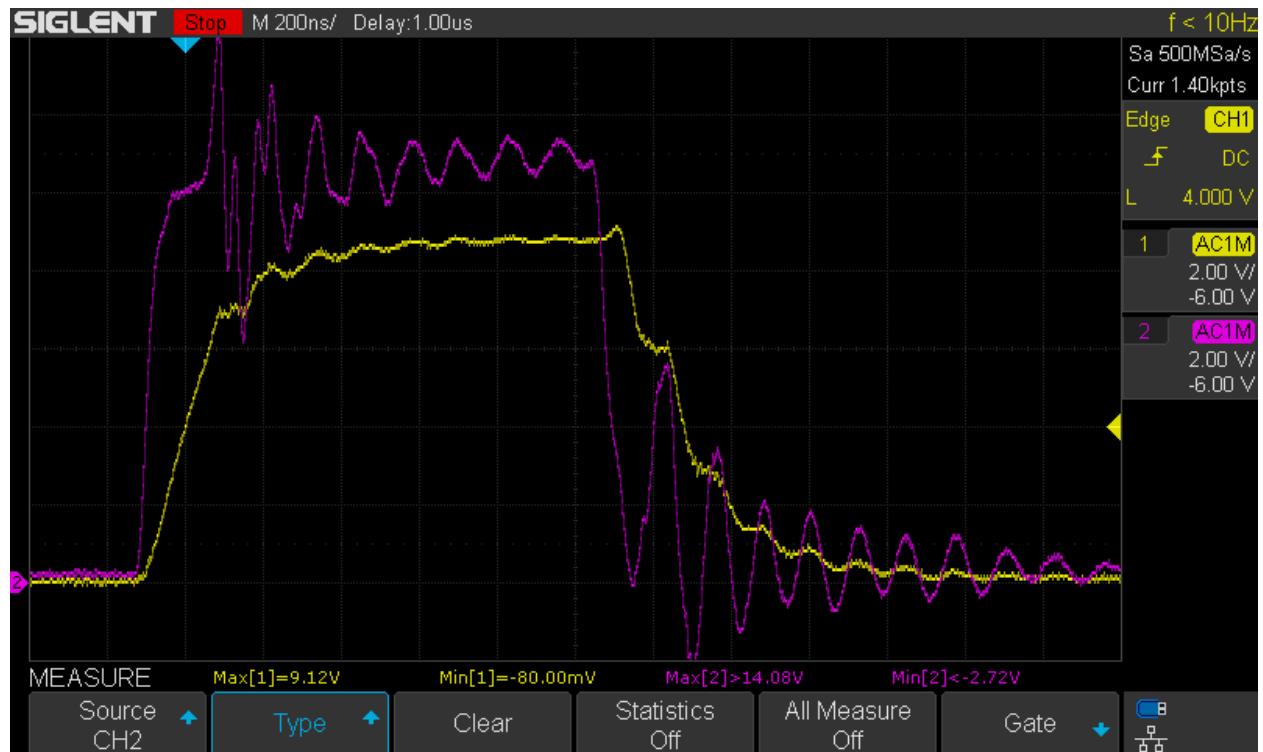
10

GATE: 10V?

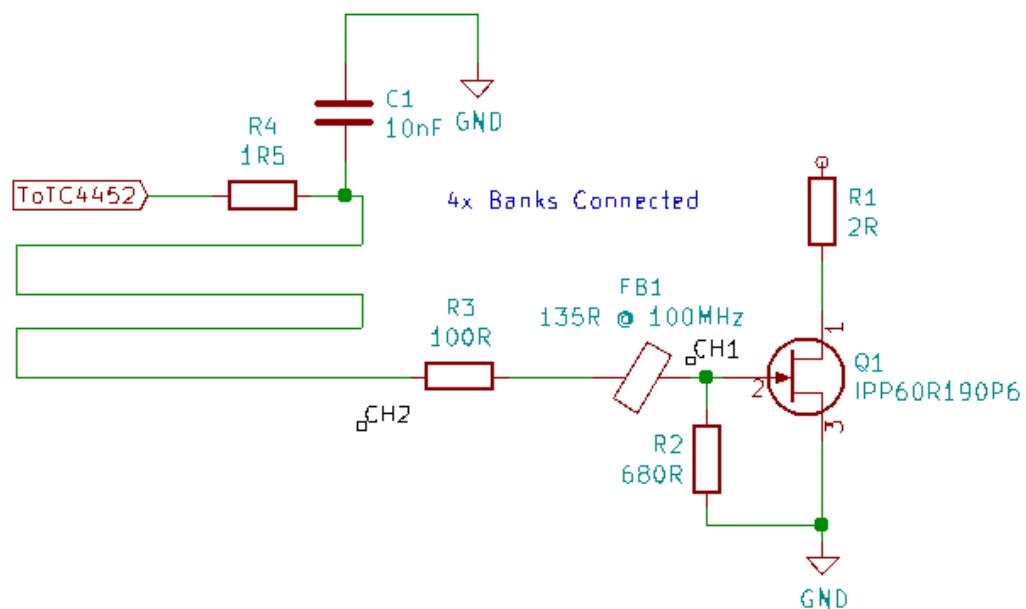
CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Changed TC4452 output resistor to 1R5



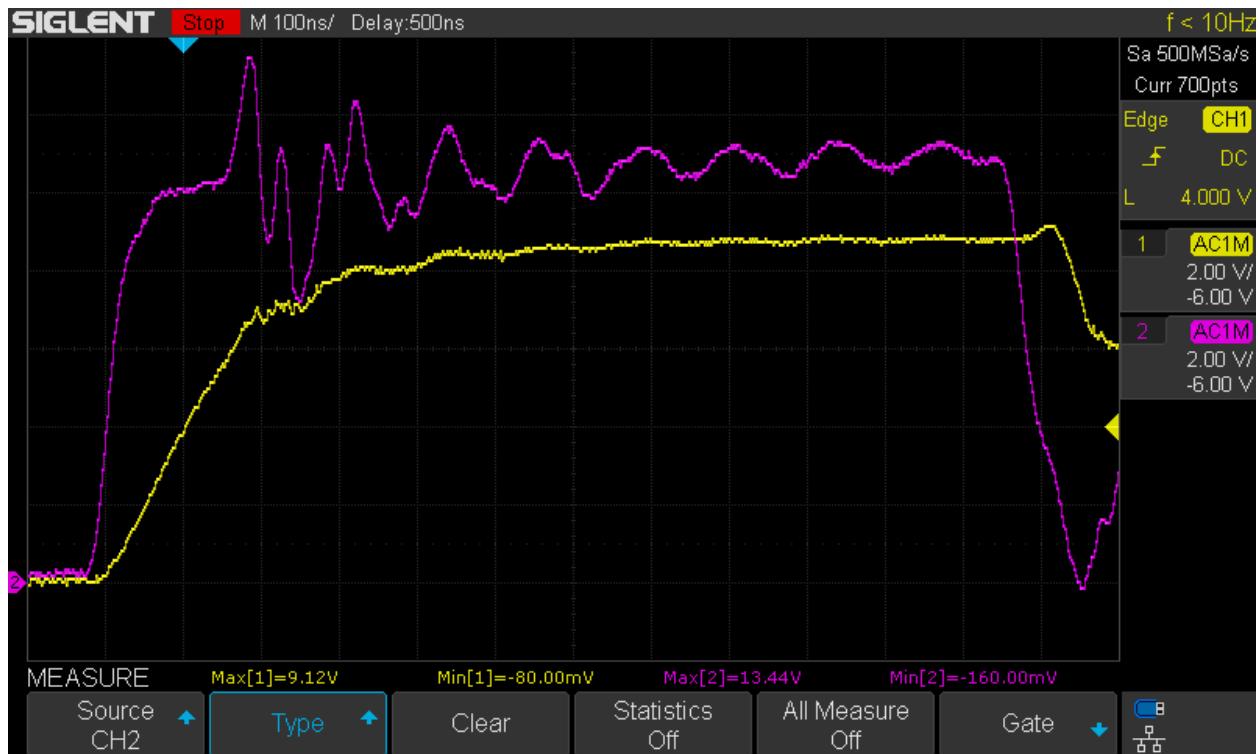
11

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



No Change

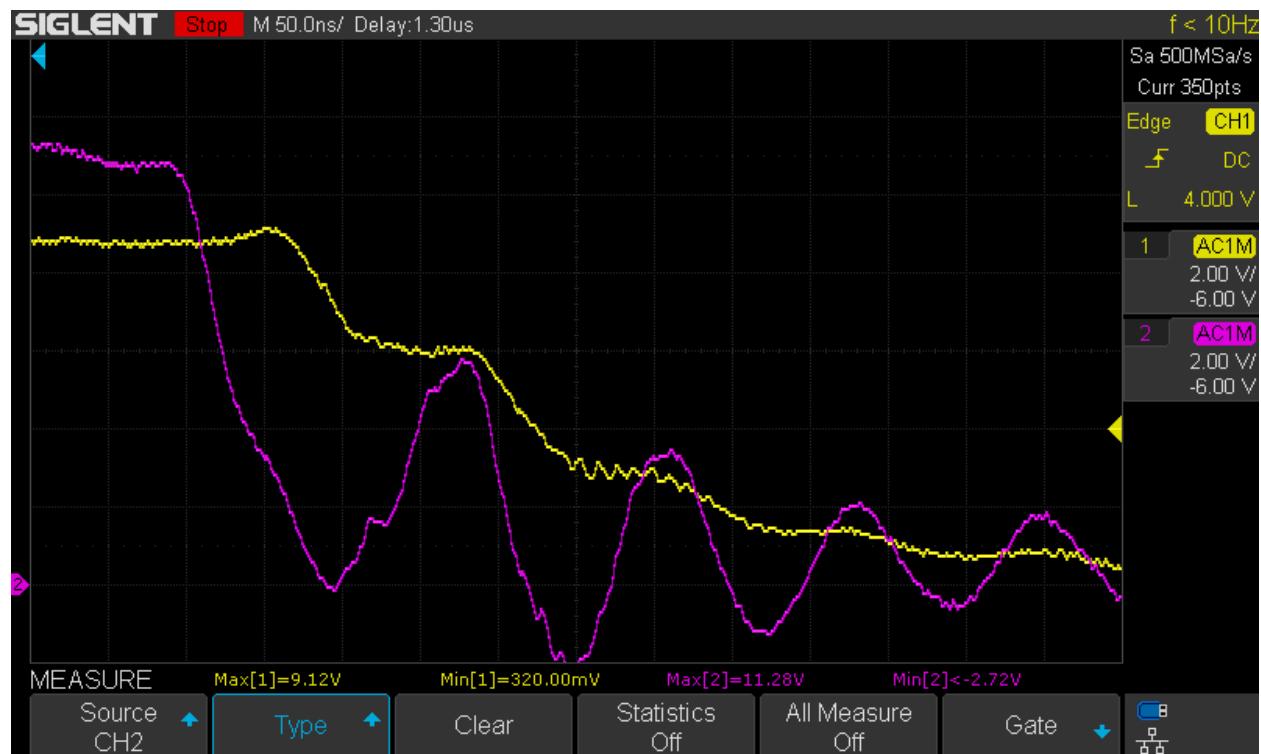
12

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



No Change

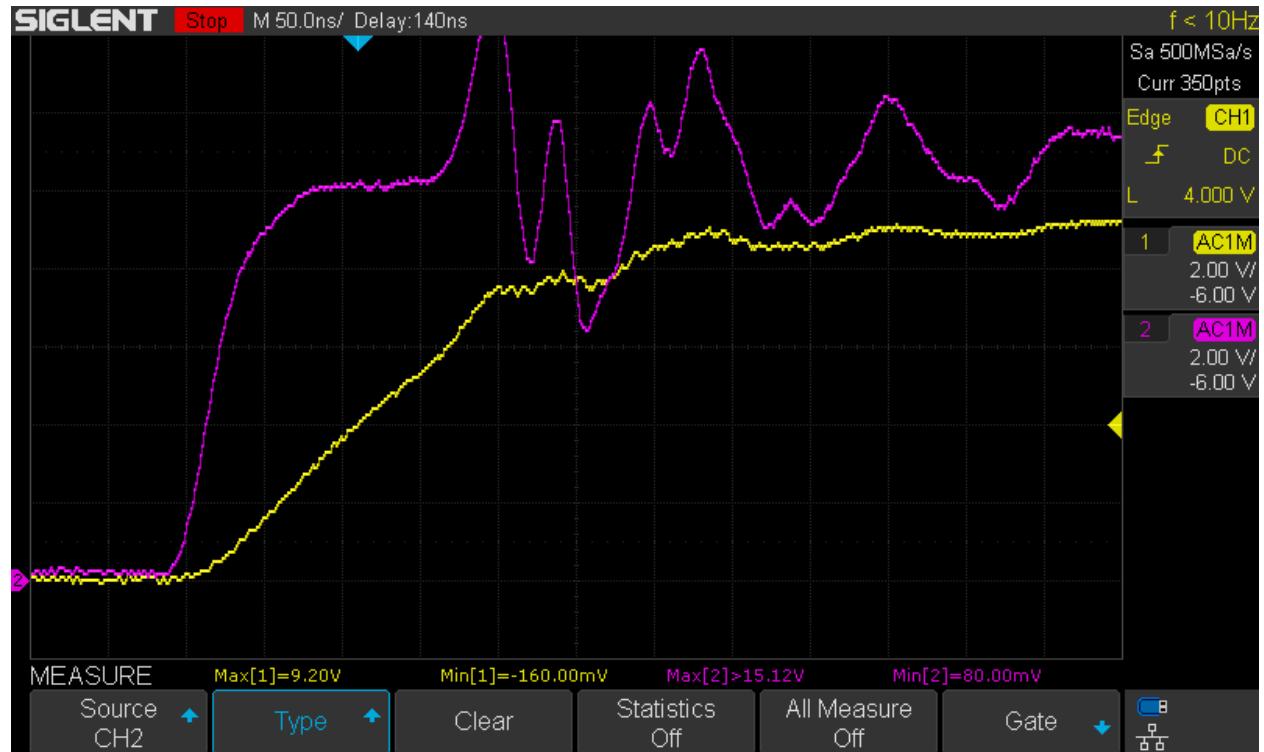
13

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Moved probes to furthest gate (longest leads), was on nearest gate (shortest leads)

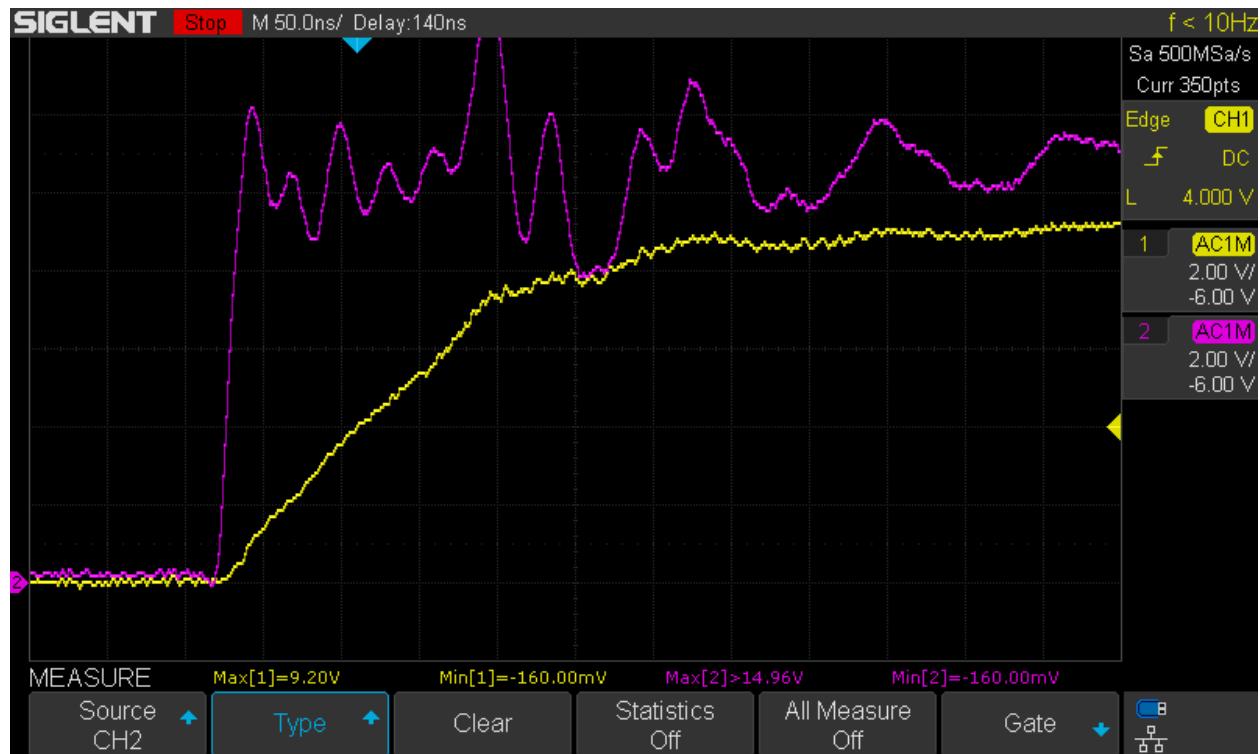
14

GATE: 10V?

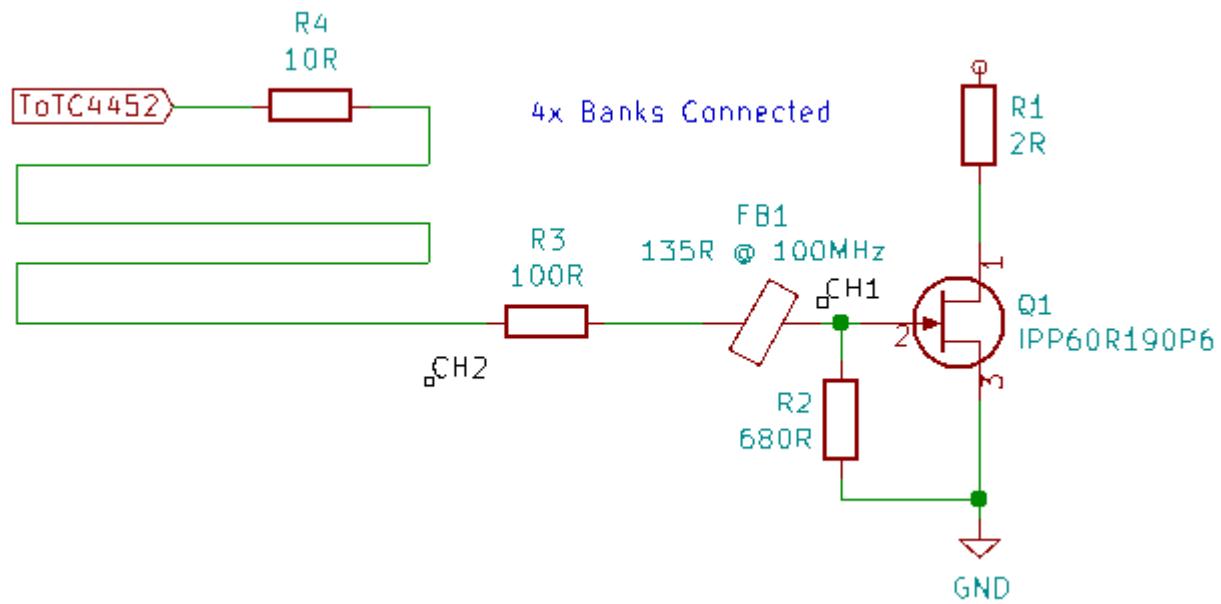
CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Removed capacitor @ TC4452



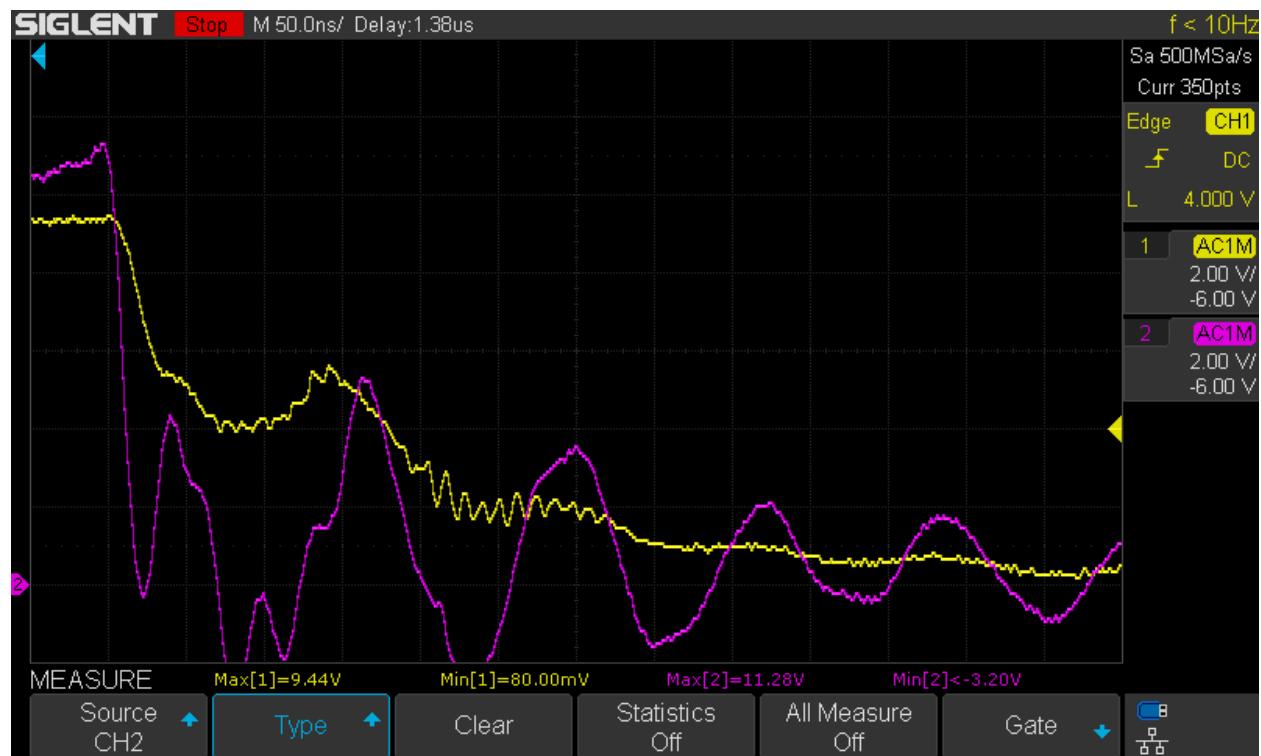
15

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



No Change

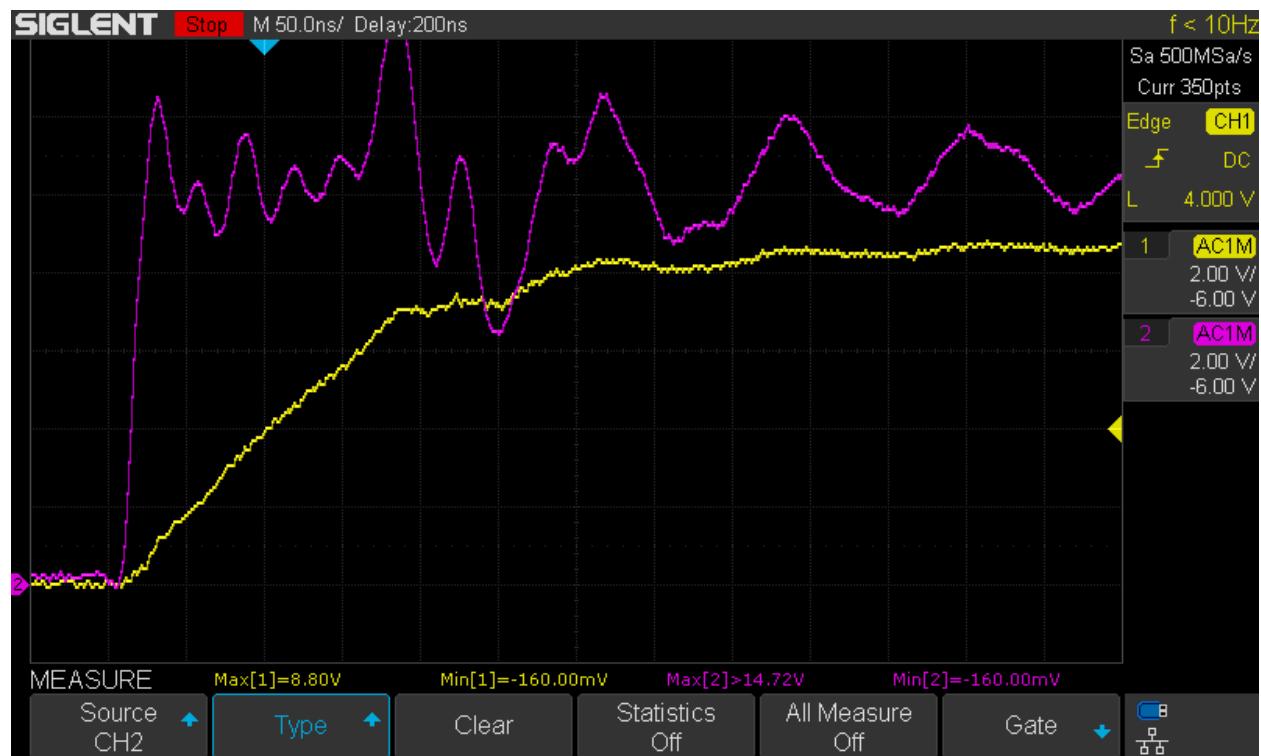
16

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Moved probes to nearest bank

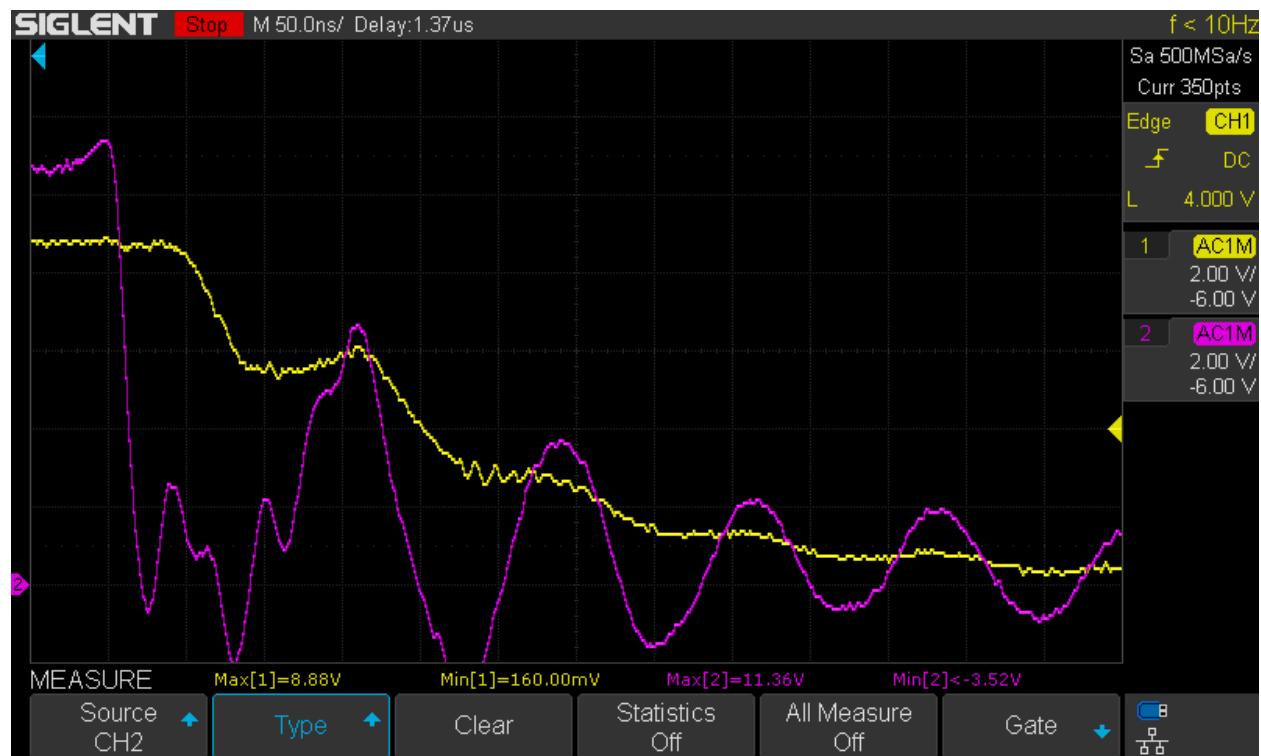
17

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



No Change

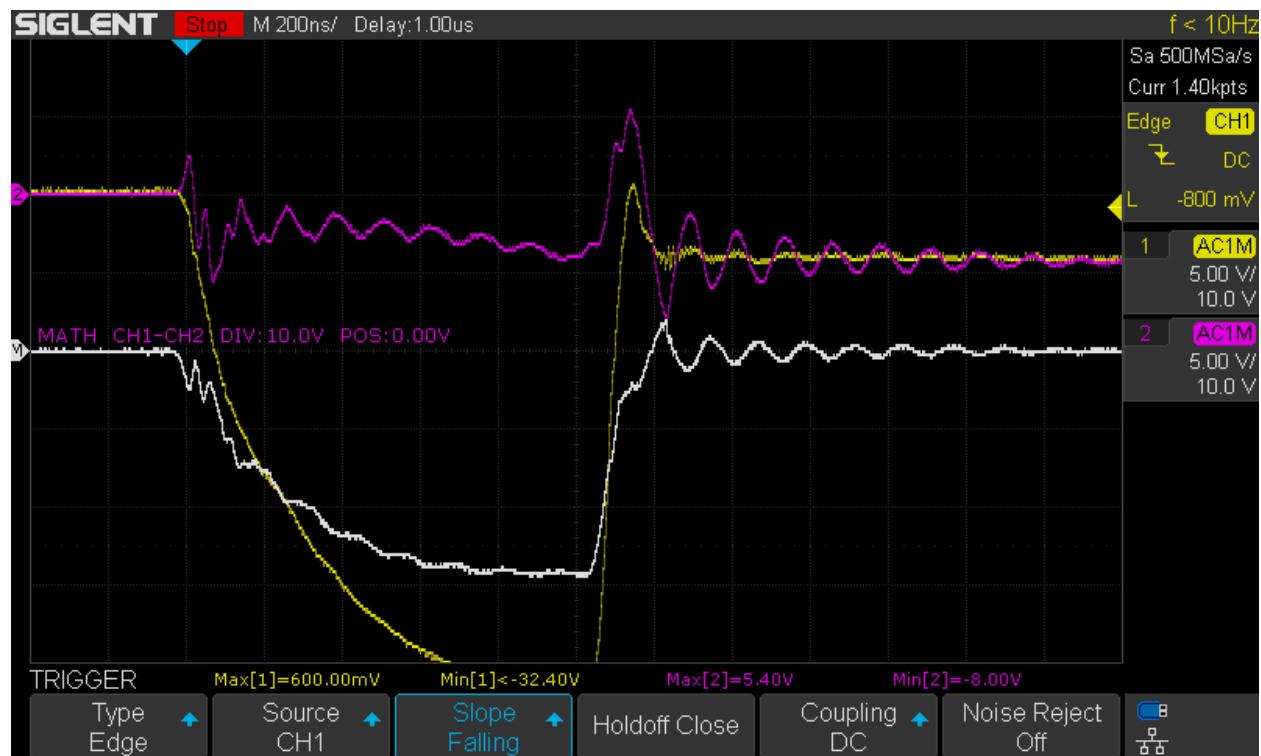
18, 19 (duplicate)

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



Measuring current across 2R LED resistor

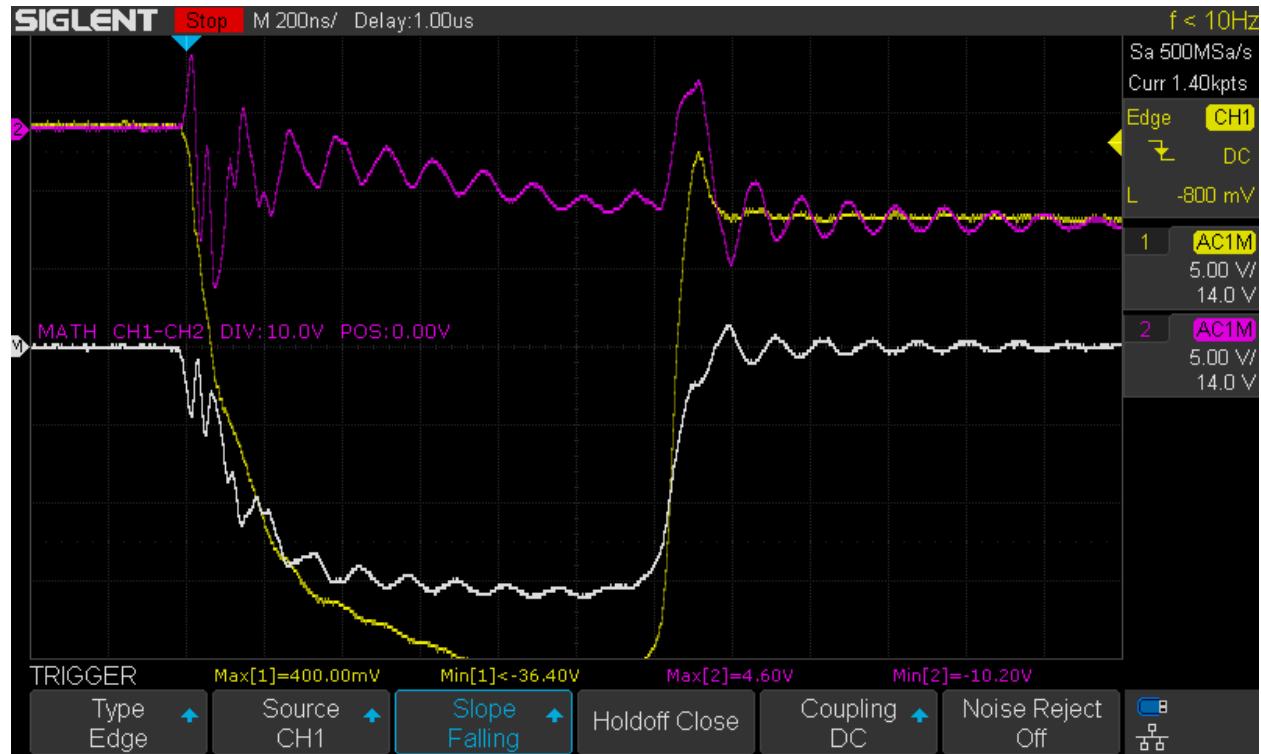
20

GATE: 10V?

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



No Change

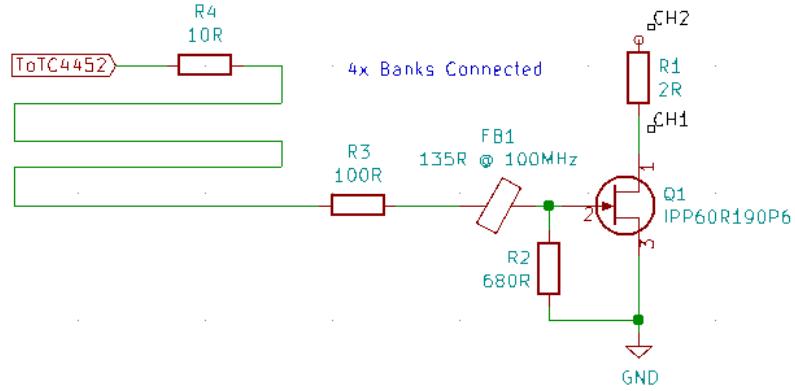
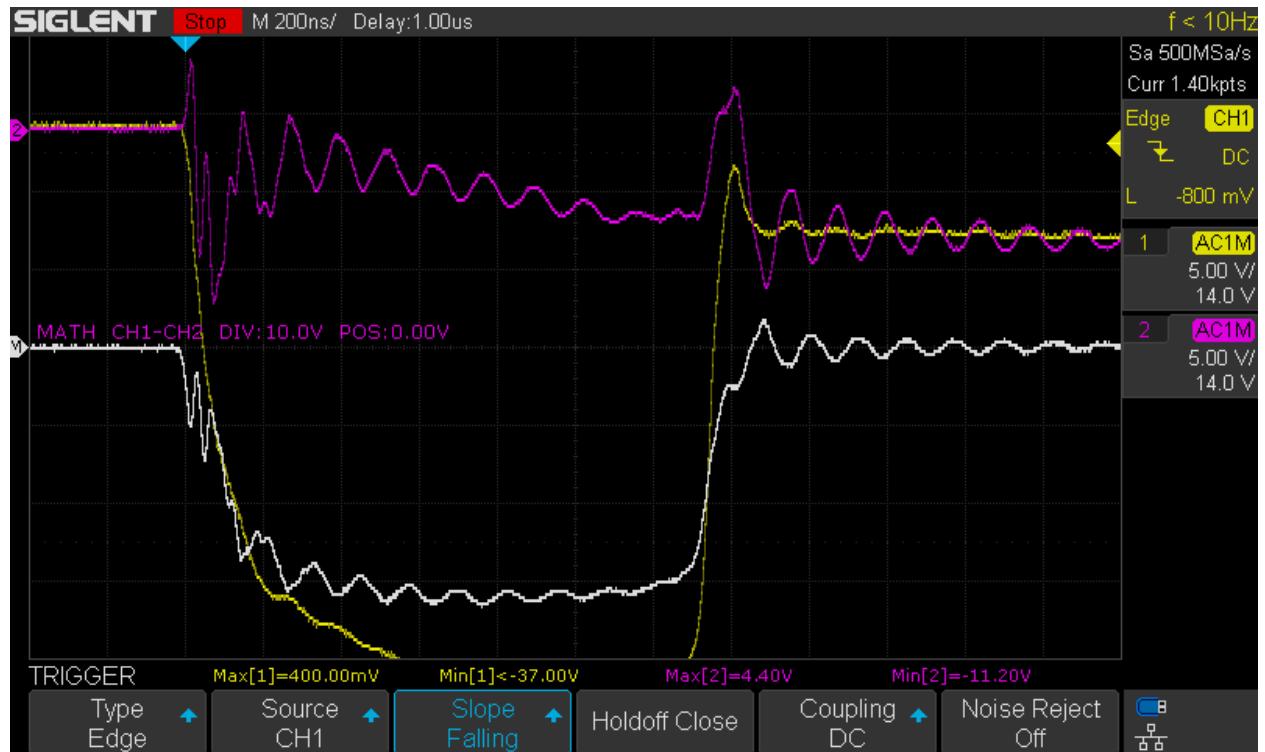
DRAFT 2020-08-23

E2 Flash Development Testing.odt

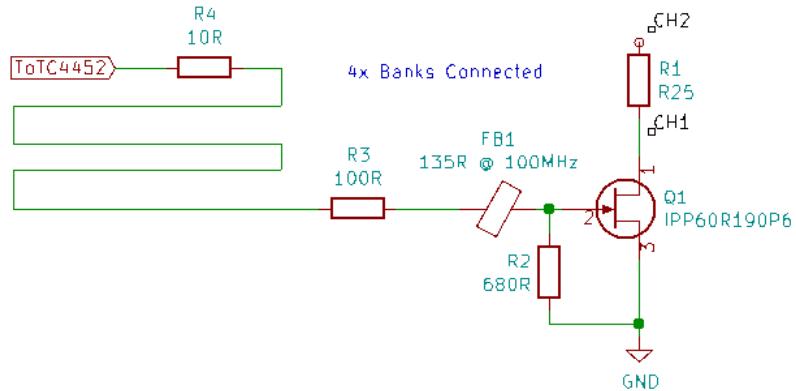
21

GATE: 11.4V CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us

Changed TC4452 input voltage to 11.4V

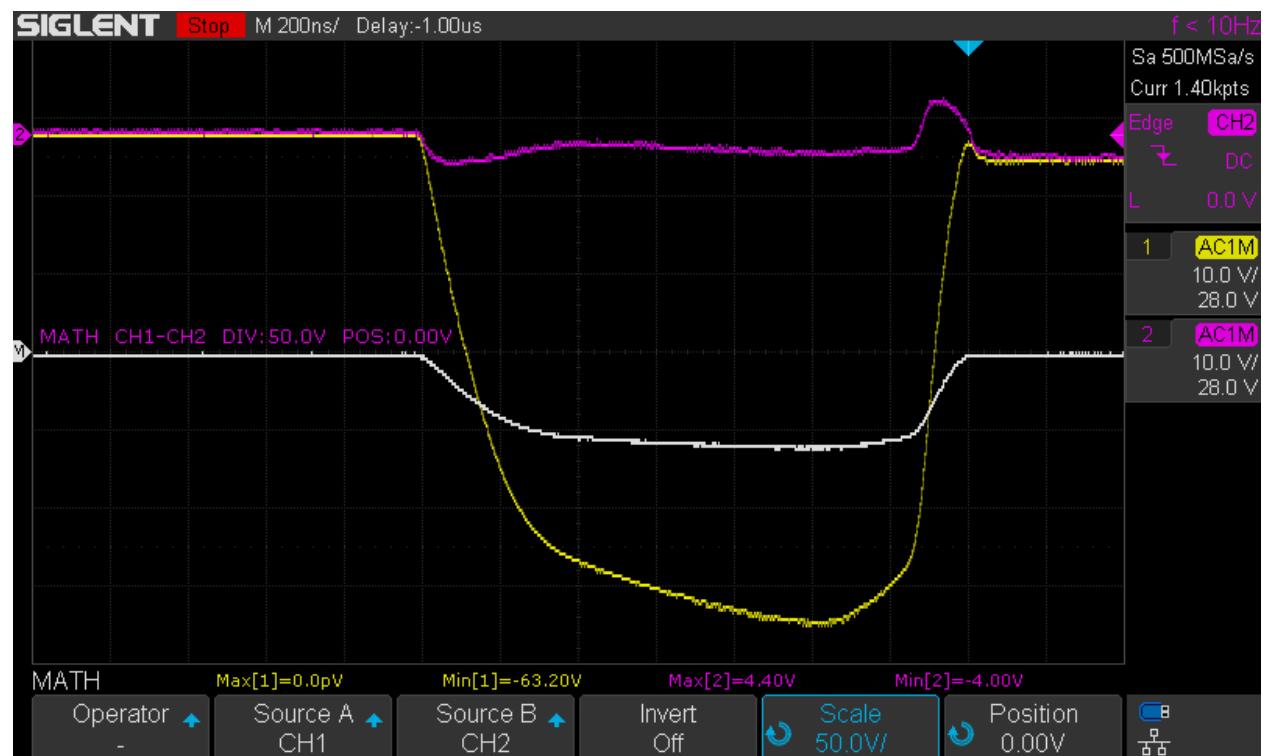


R25 Circuit:



Test Data:

23 GATE: 9V CAP ANODE: 60V SERIES RESISTOR: 2R DURATION: 1us



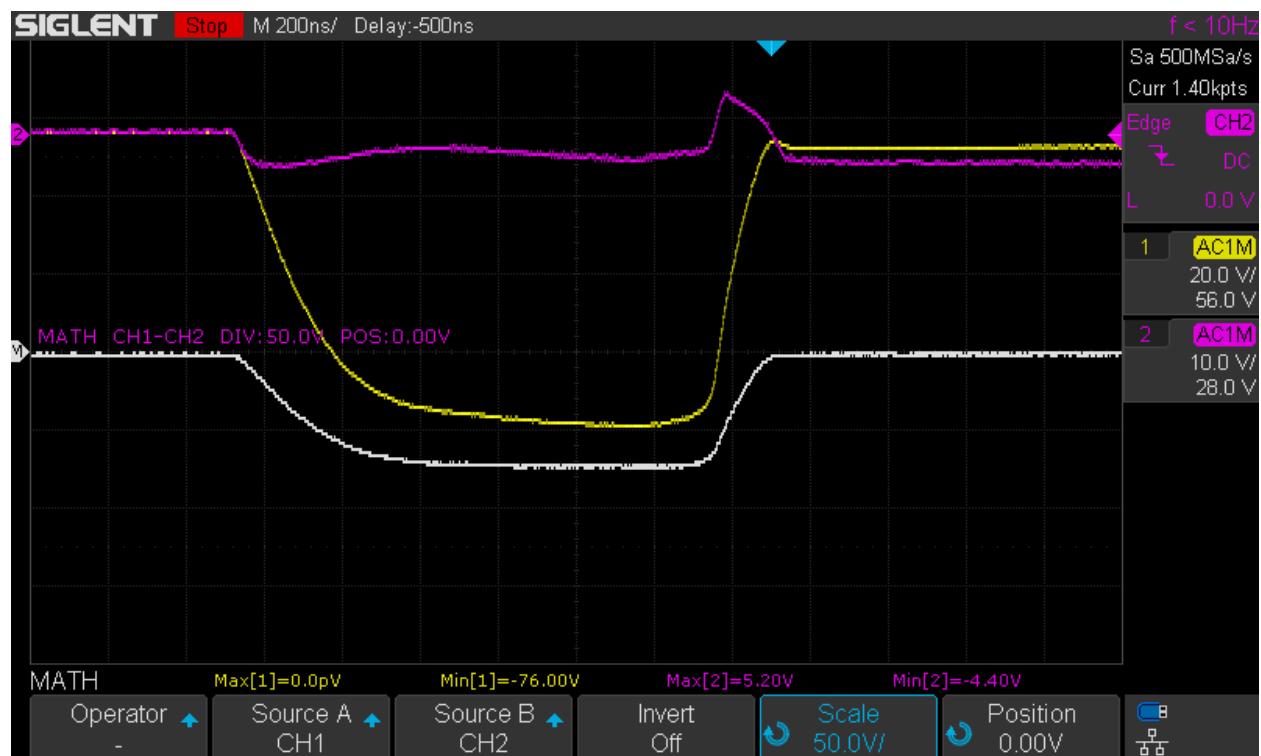
24

GATE: 9V

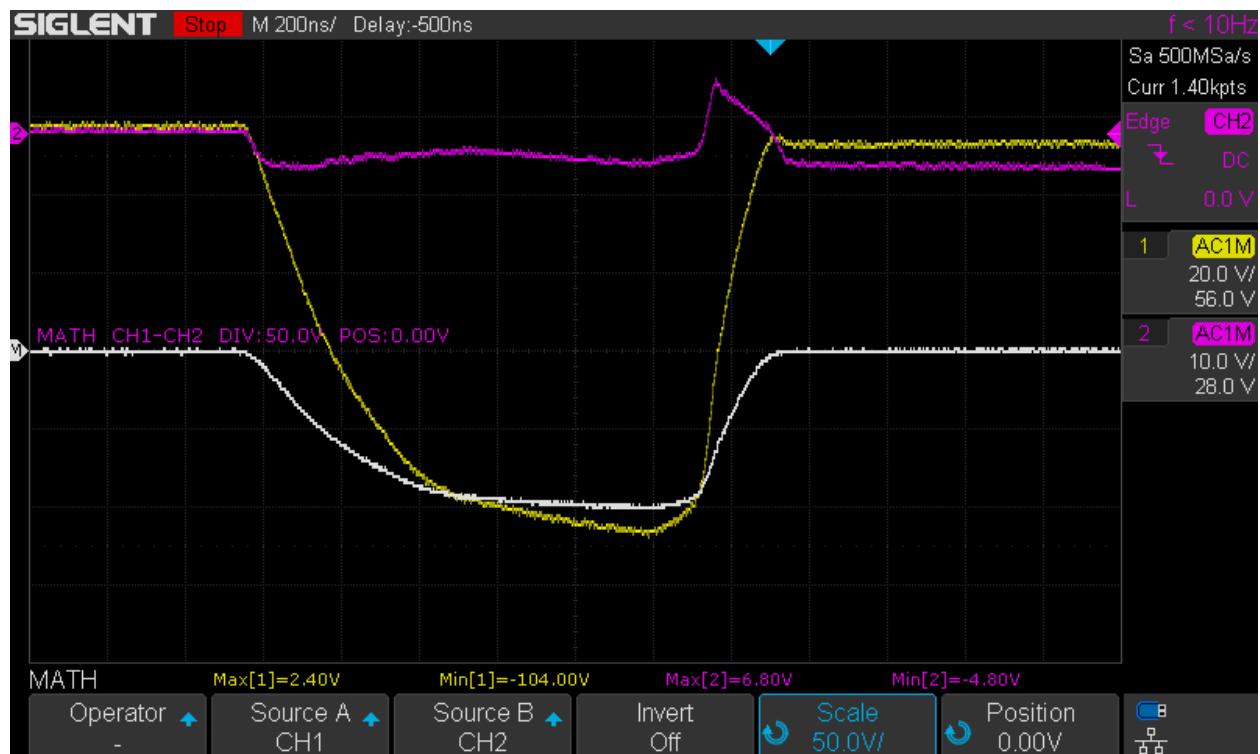
CAP ANODE: 80V

SERIES RESISTOR: 2R

DURATION: 1us



25, 26 (dup) GATE: 9V CAP ANODE: 100V SERIES RESISTOR: 2R DURATION: 1us



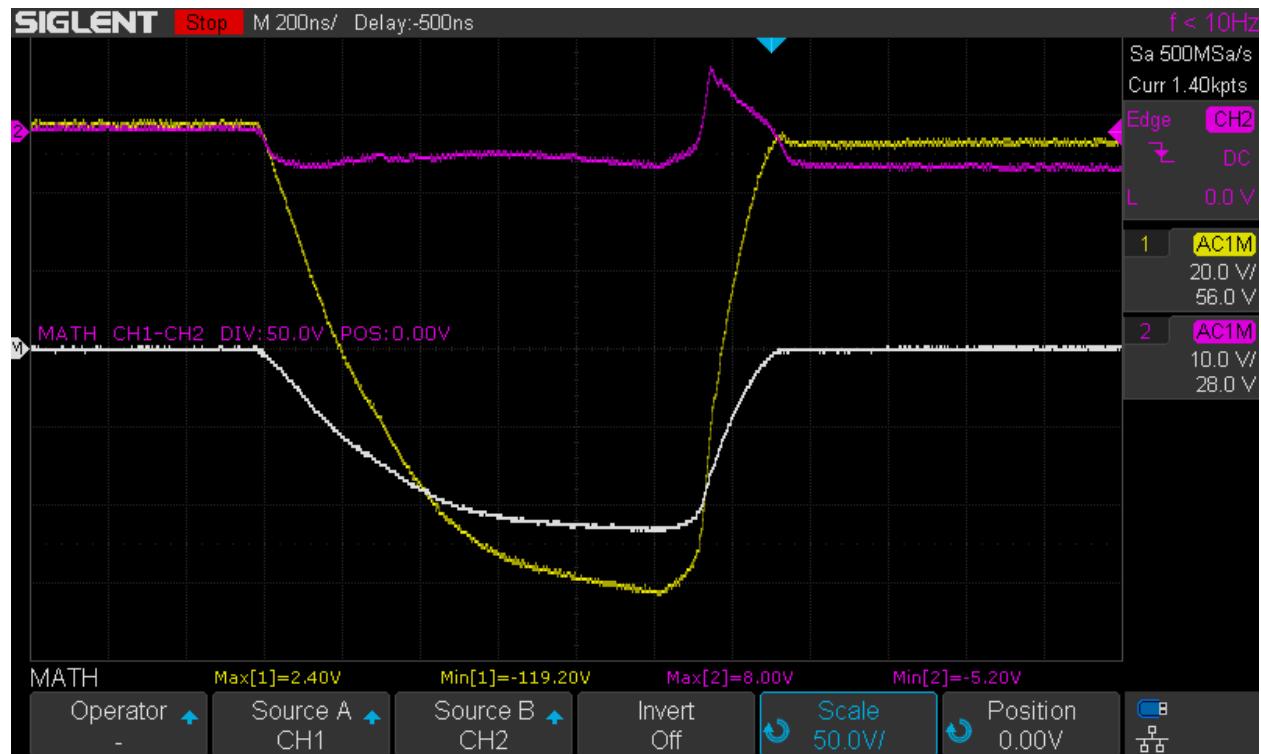
27

GATE: 9V

CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



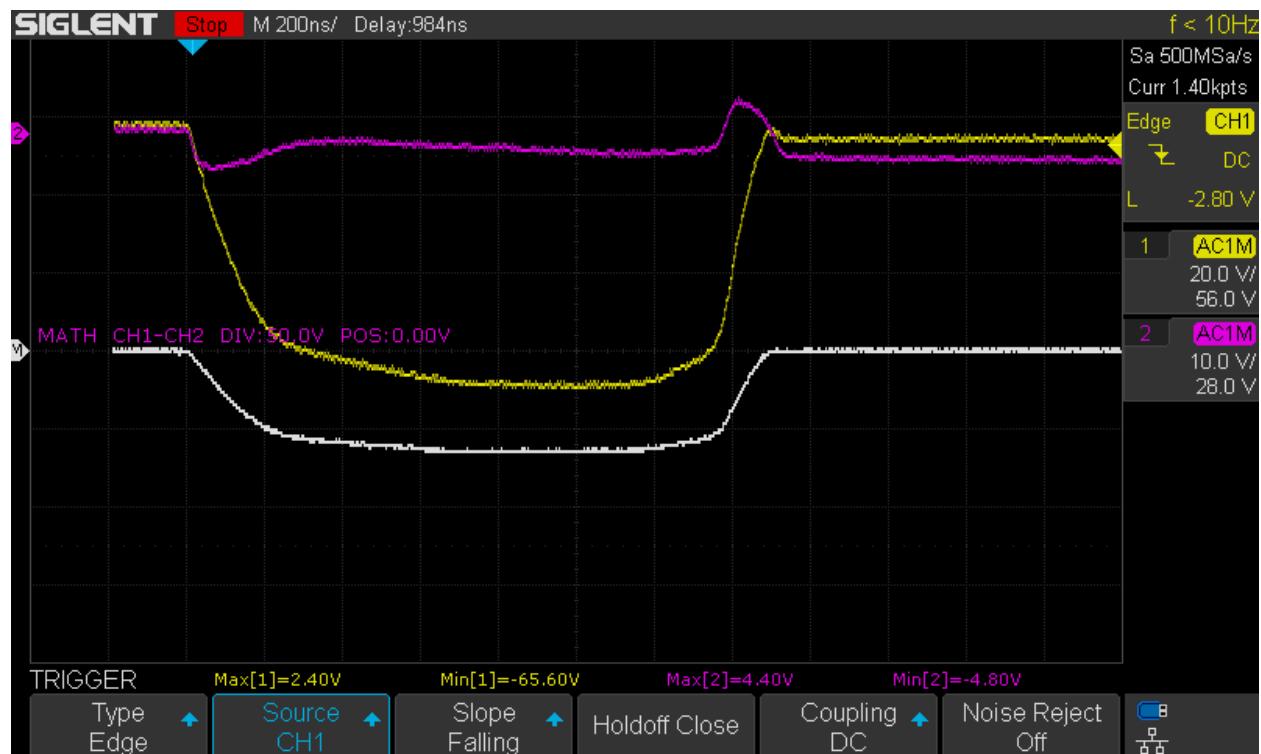
28

GATE: 10.5V

CAP ANODE: 60V

SERIES RESISTOR: 2R

DURATION: 1us



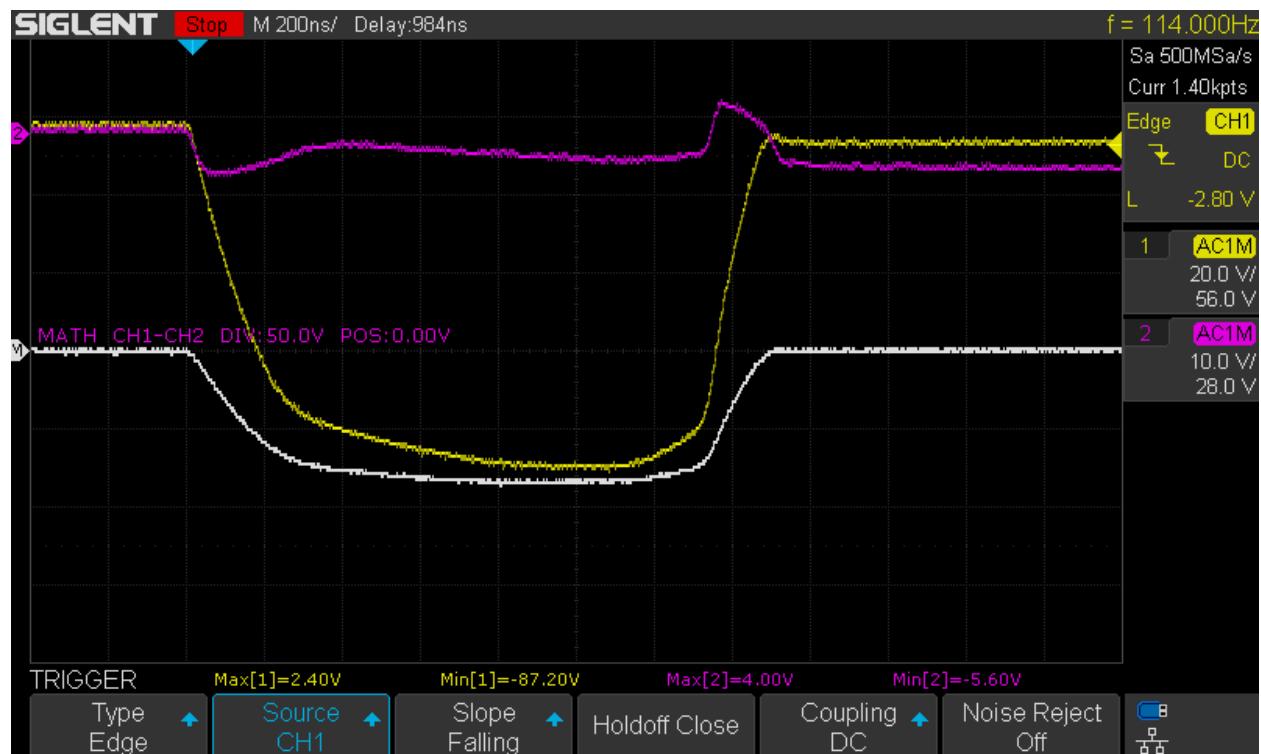
29

GATE: 10.5V

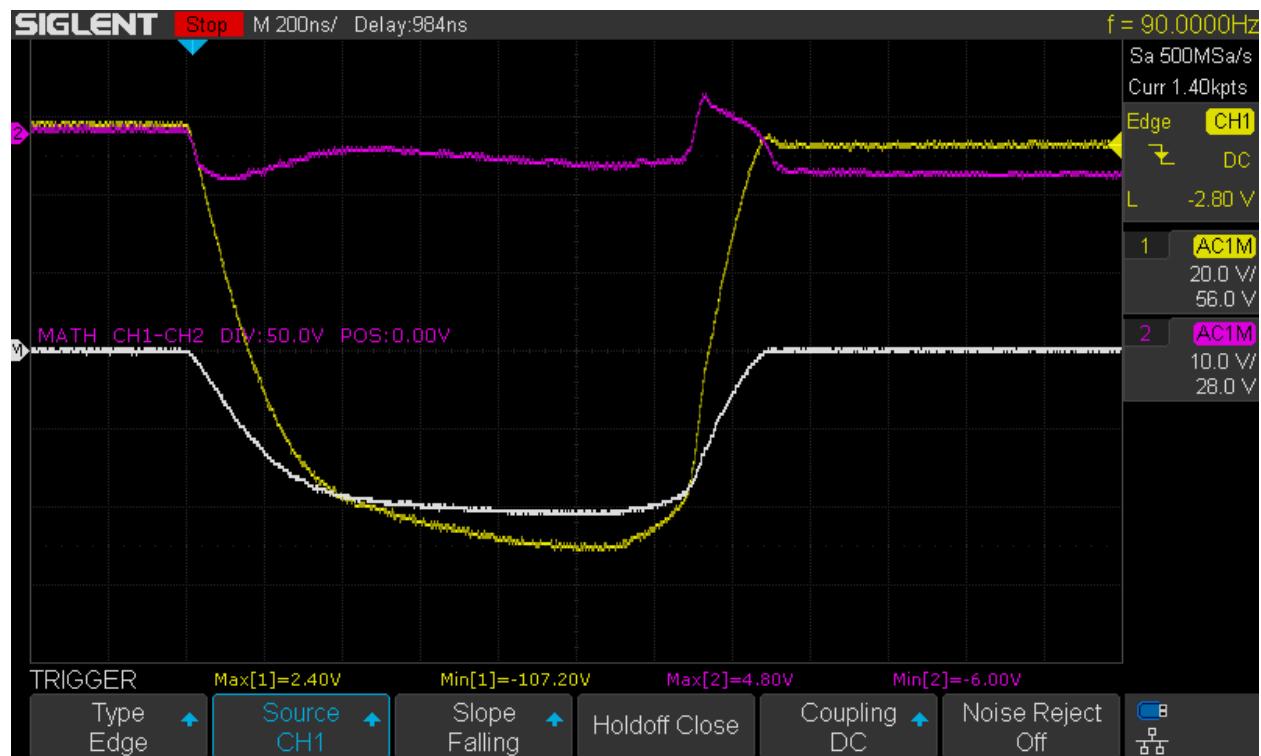
CAP ANODE: 80V

SERIES RESISTOR: 2R

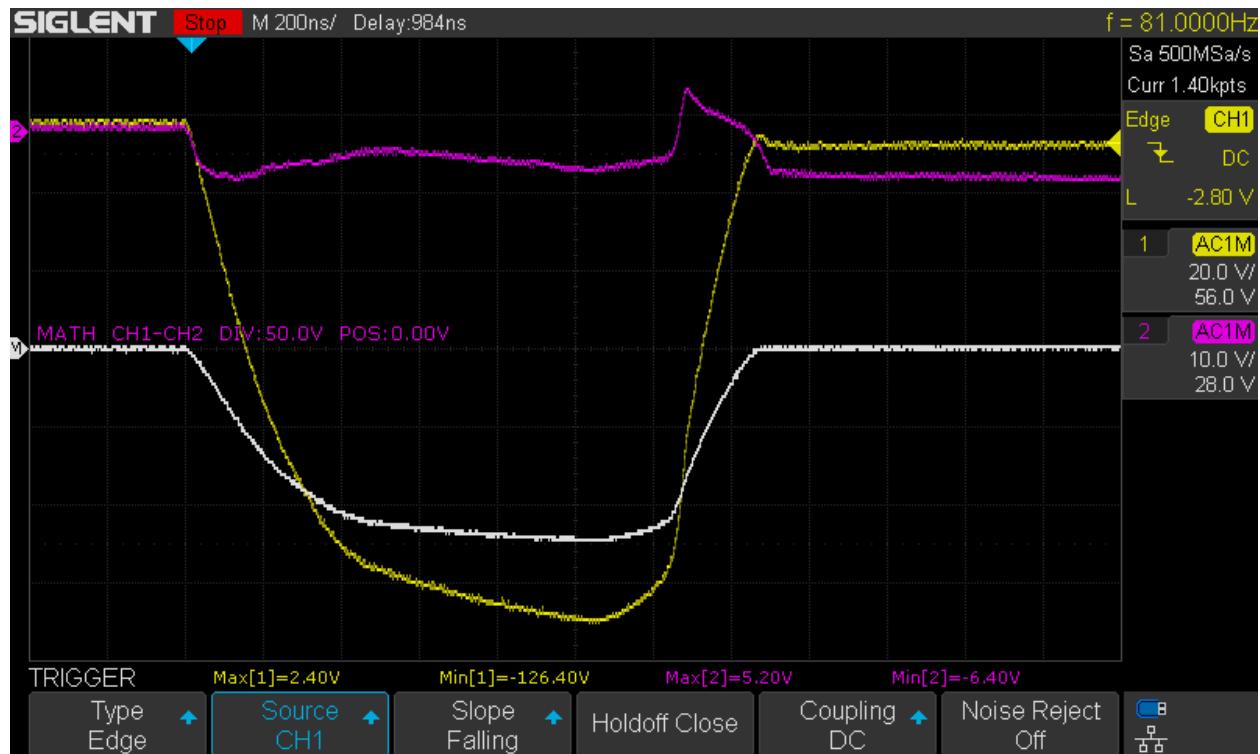
DURATION: 1us



30 GATE: 10.5V CAP ANODE: 100V SERIES RESISTOR: 2R DURATION: 1us



31, 32 (dup) GATE: 10.5V CAP ANODE: 120V SERIES RESISTOR: 2R DURATION: 1us



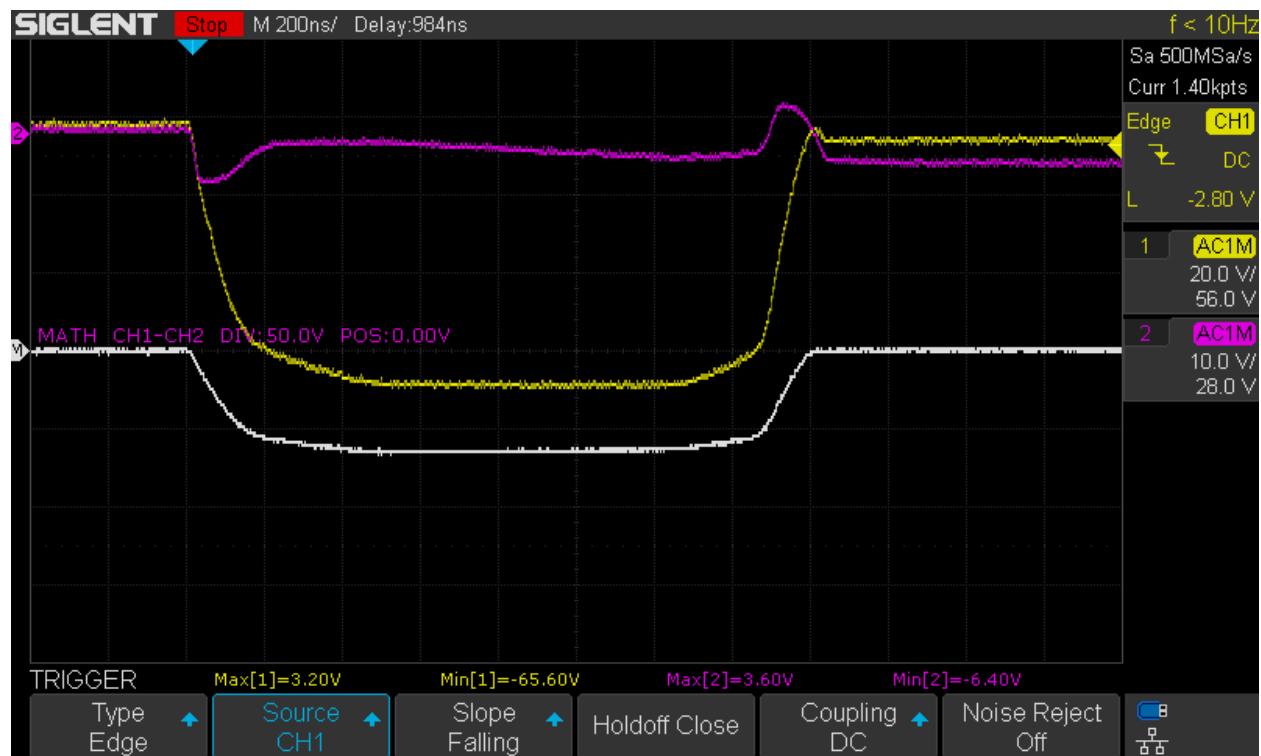
33

GATE: 12V

CAP ANODE: 60V

SERIES RESISTOR: 2R

DURATION: 1us



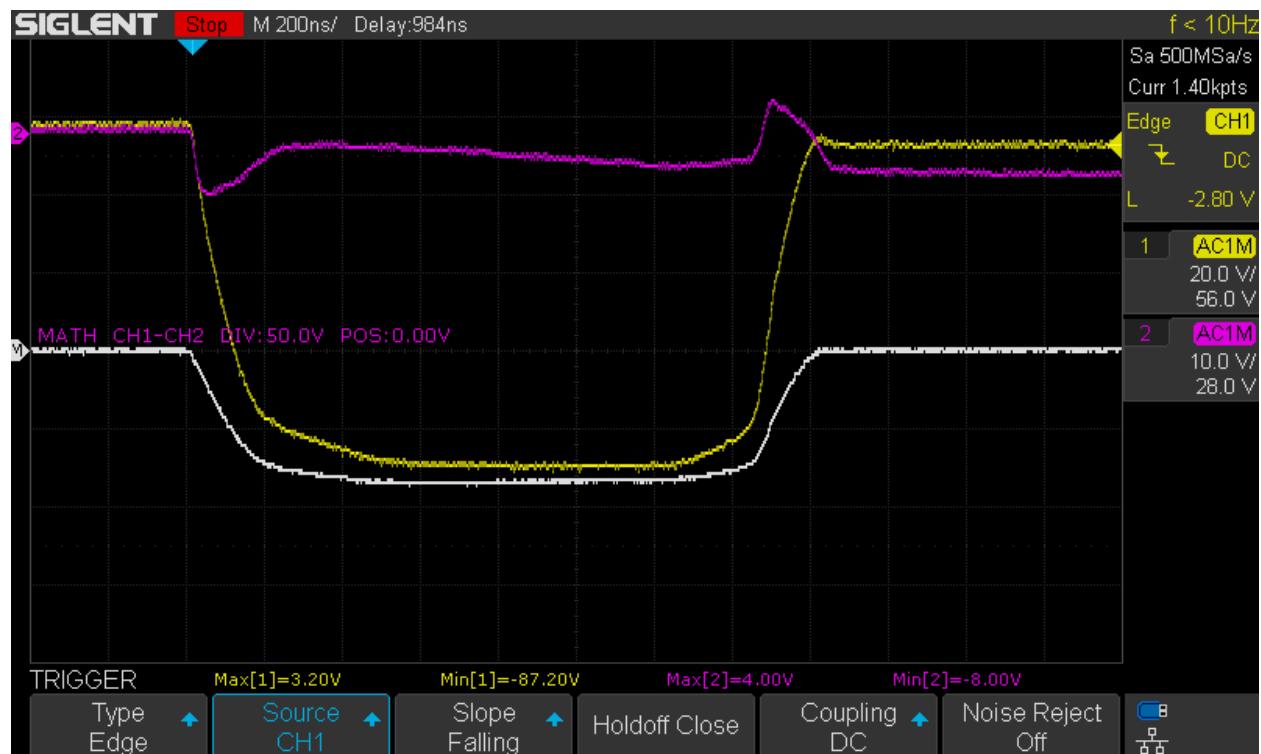
34

GATE: 12V

CAP ANODE: 80V

SERIES RESISTOR: 2R

DURATION: 1us



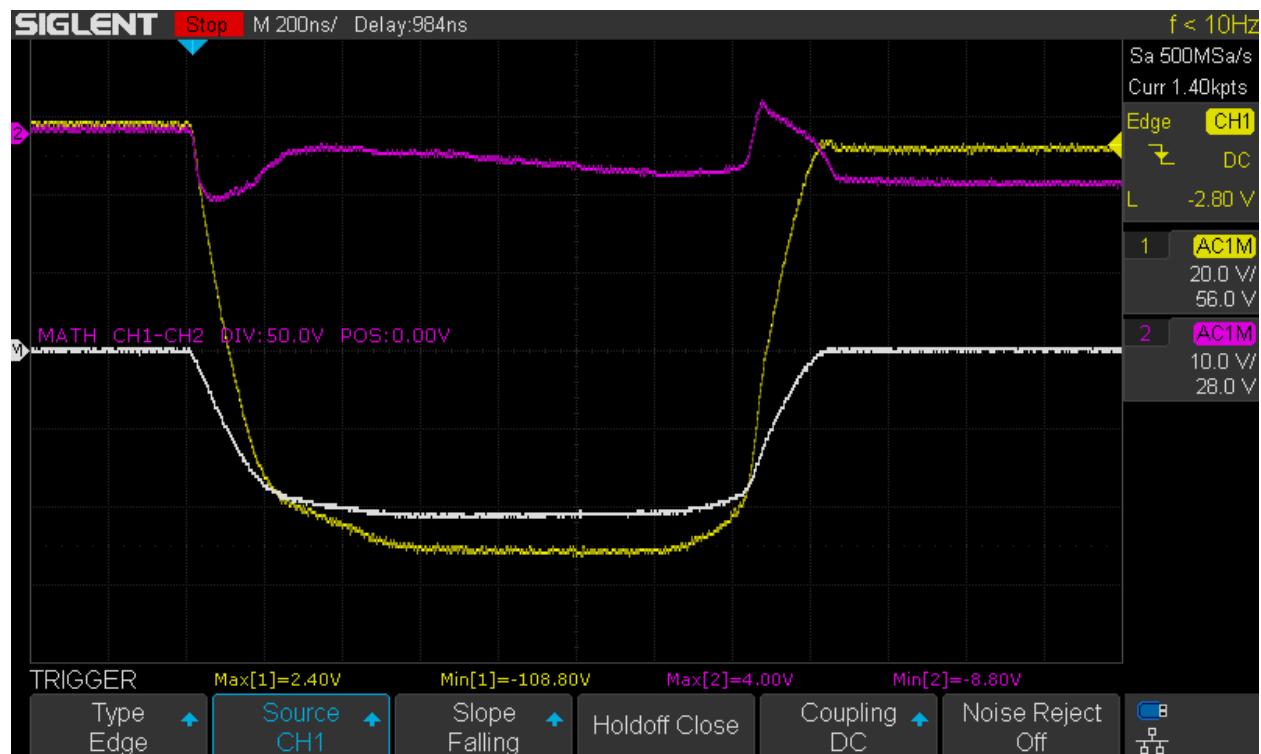
35

GATE: 12V

CAP ANODE: 100V

SERIES RESISTOR: 2R

DURATION: 1us



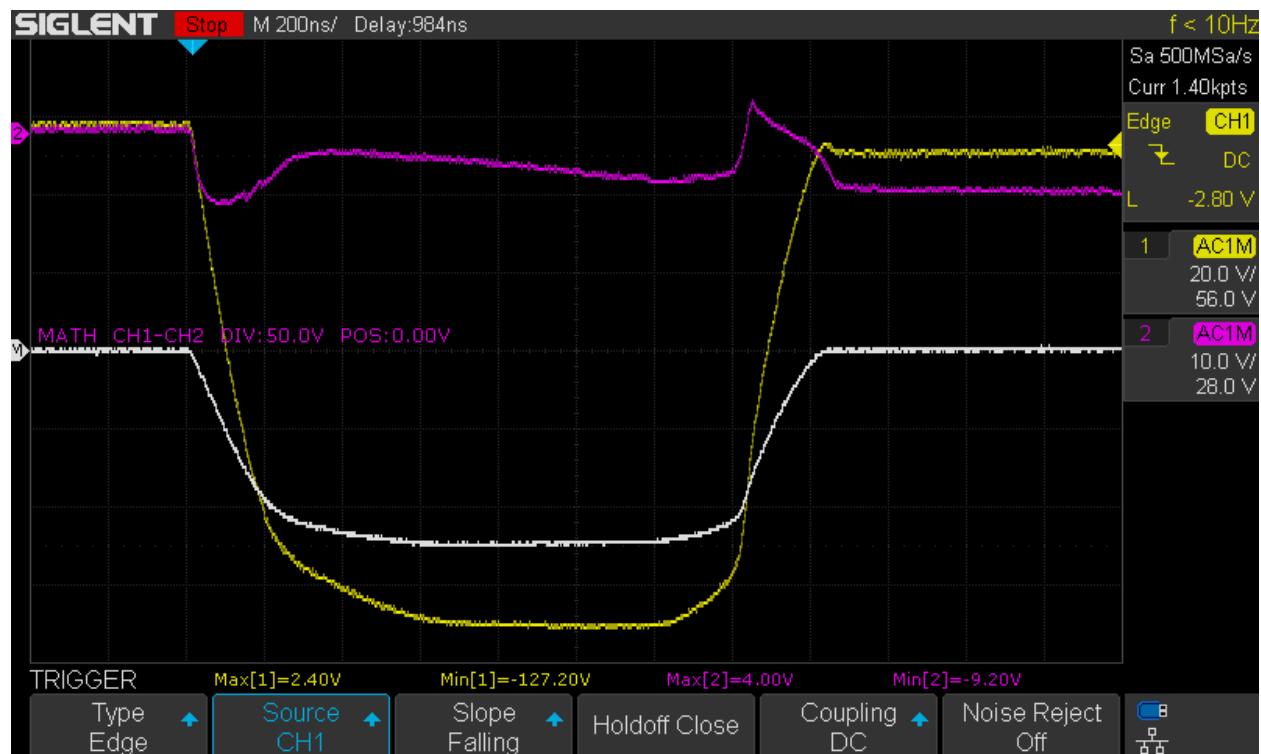
36

GATE: 12V

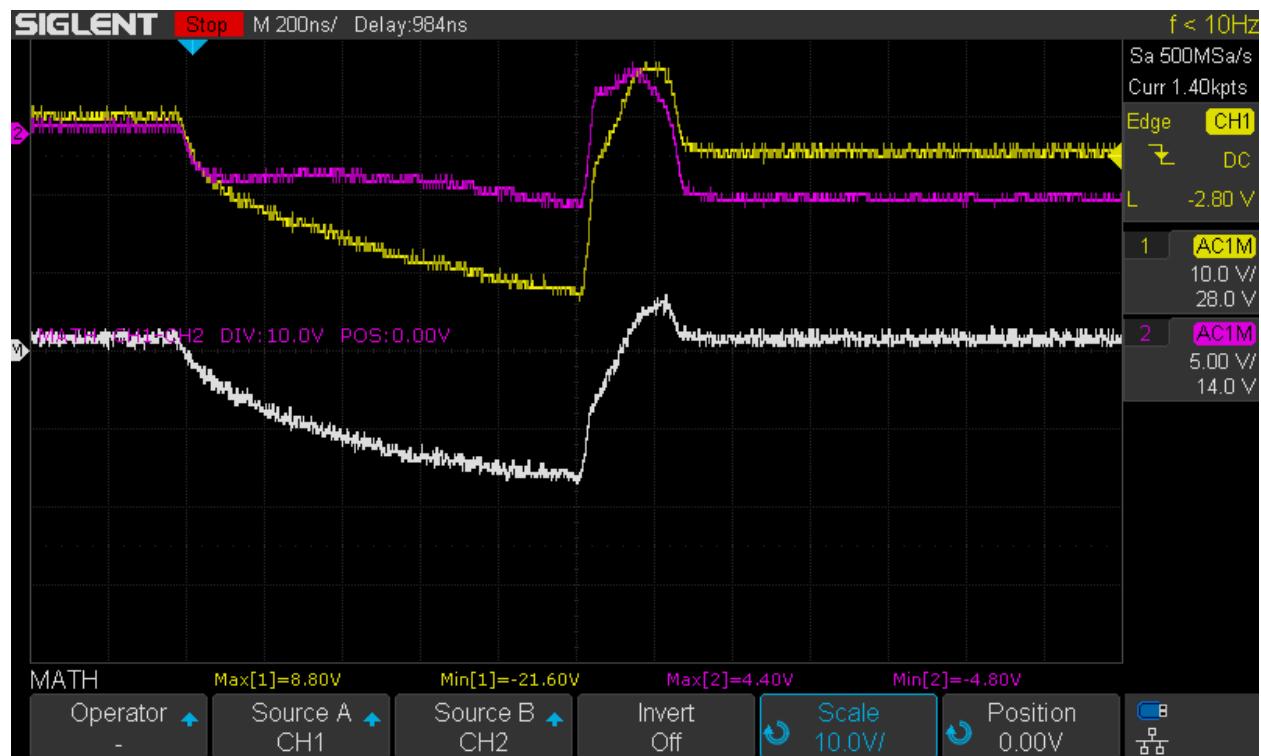
CAP ANODE: 120V

SERIES RESISTOR: 2R

DURATION: 1us



37 GATE: 9V CAP ANODE: 60V SERIES RESISTOR: R25 DURATION: 1us



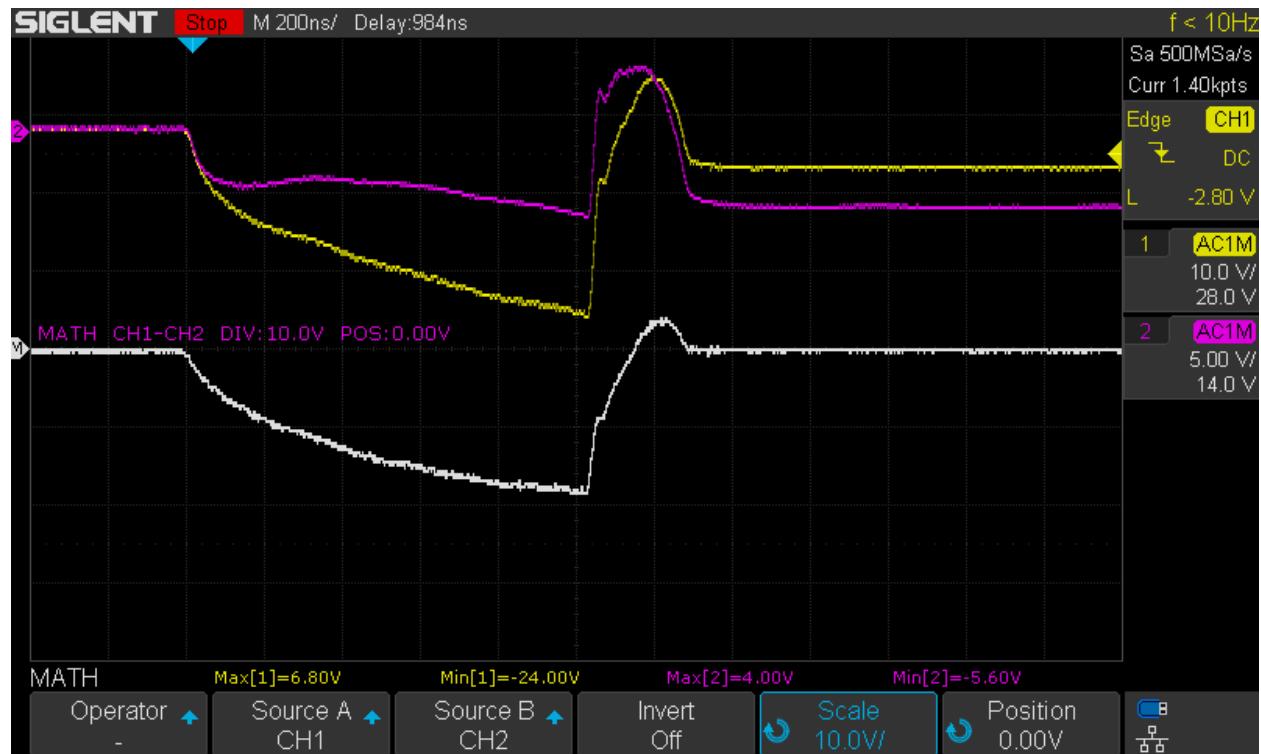
38

GATE: 9V

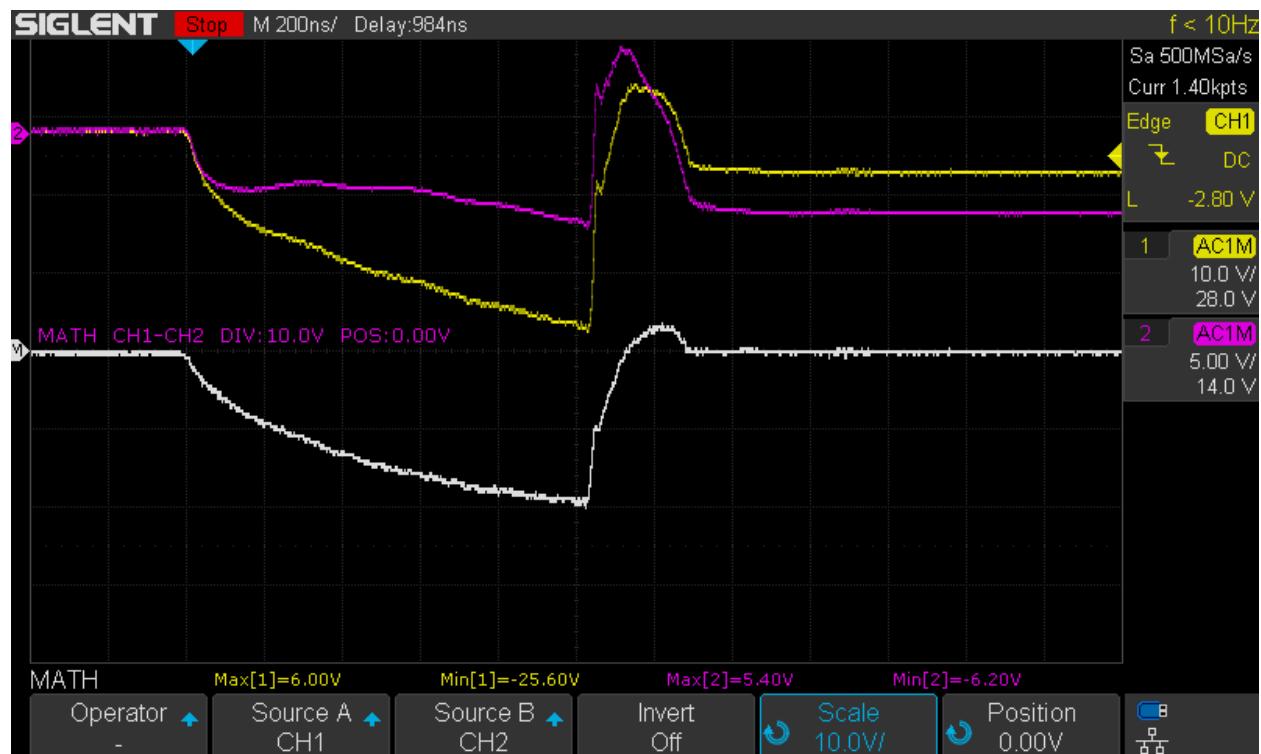
CAP ANODE: 80V

SERIES RESISTOR: R25

DURATION: 1us



39 GATE: 9V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



DRAFT 2020-08-23

E2 Flash Development Testing.odt

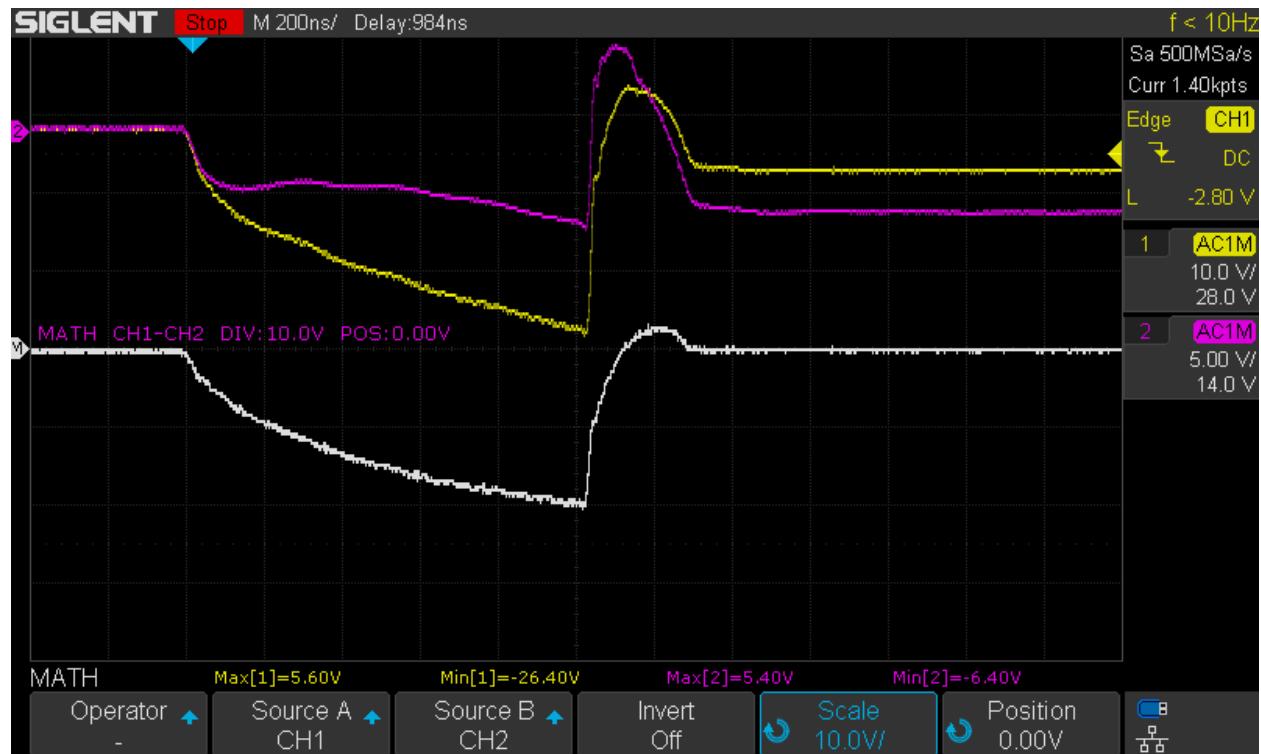
40

GATE: 9V

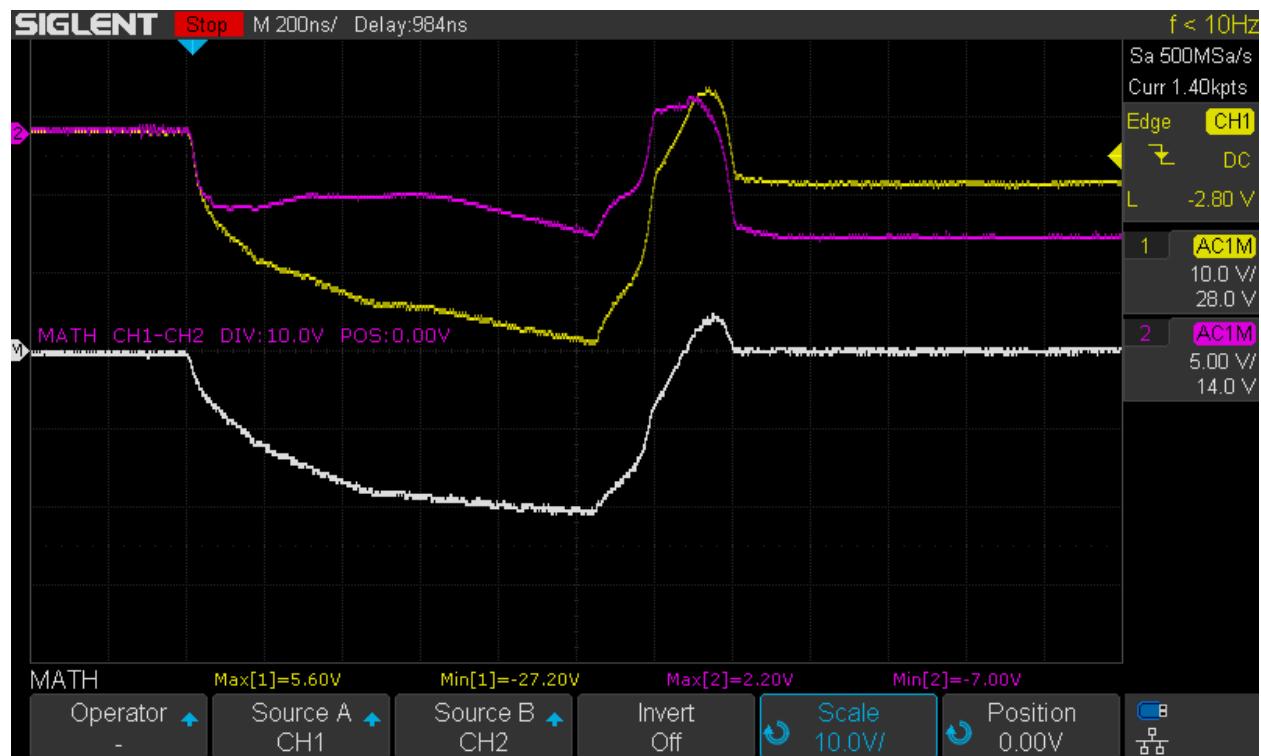
CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 1us

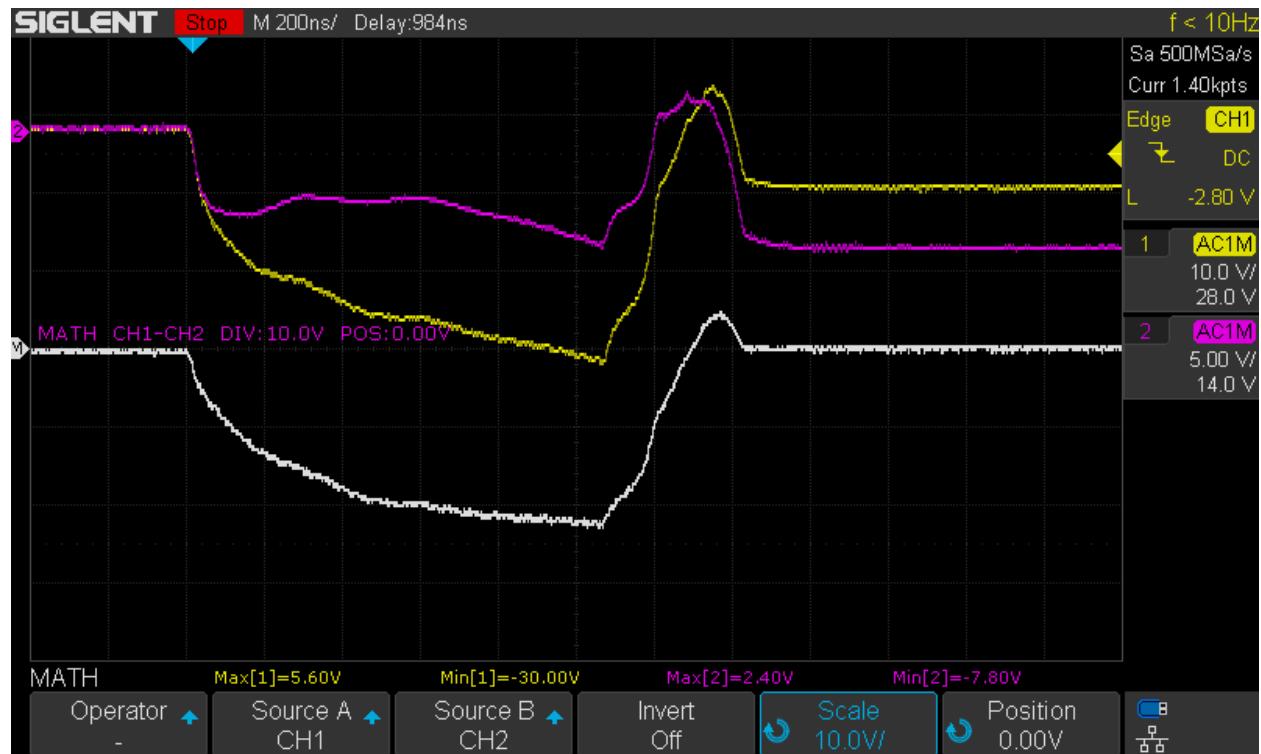


41 GATE: 10.5V CAP ANODE: 60V SERIES RESISTOR: R25 DURATION: 1us

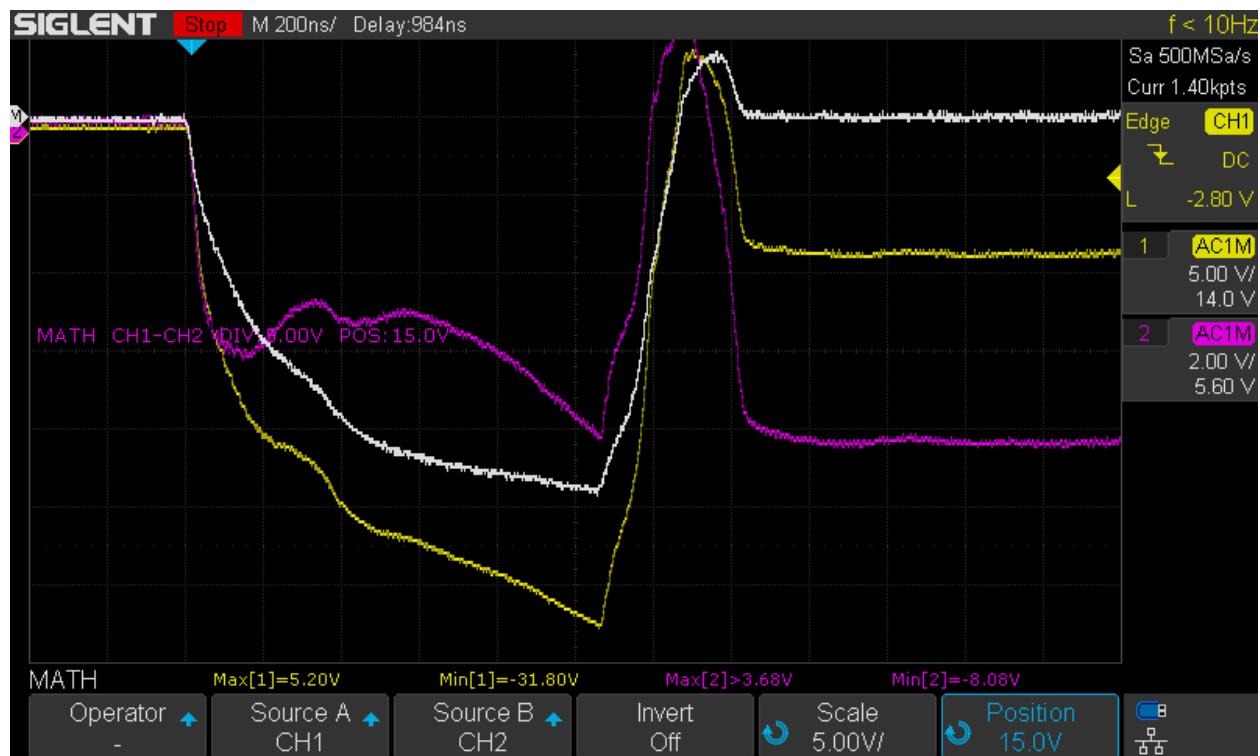


42

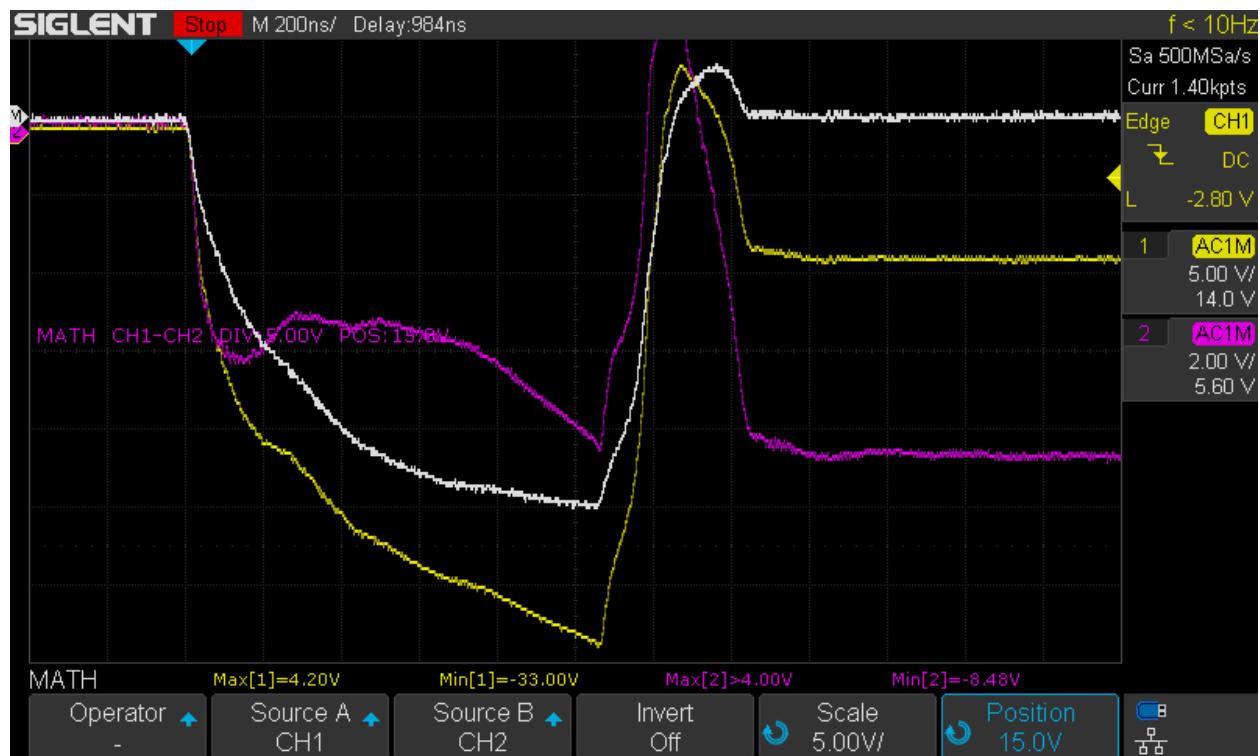
GATE: 10.5V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 1us



43 GATE: 10.5V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



44, 45 (dup) GATE: 10.5V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



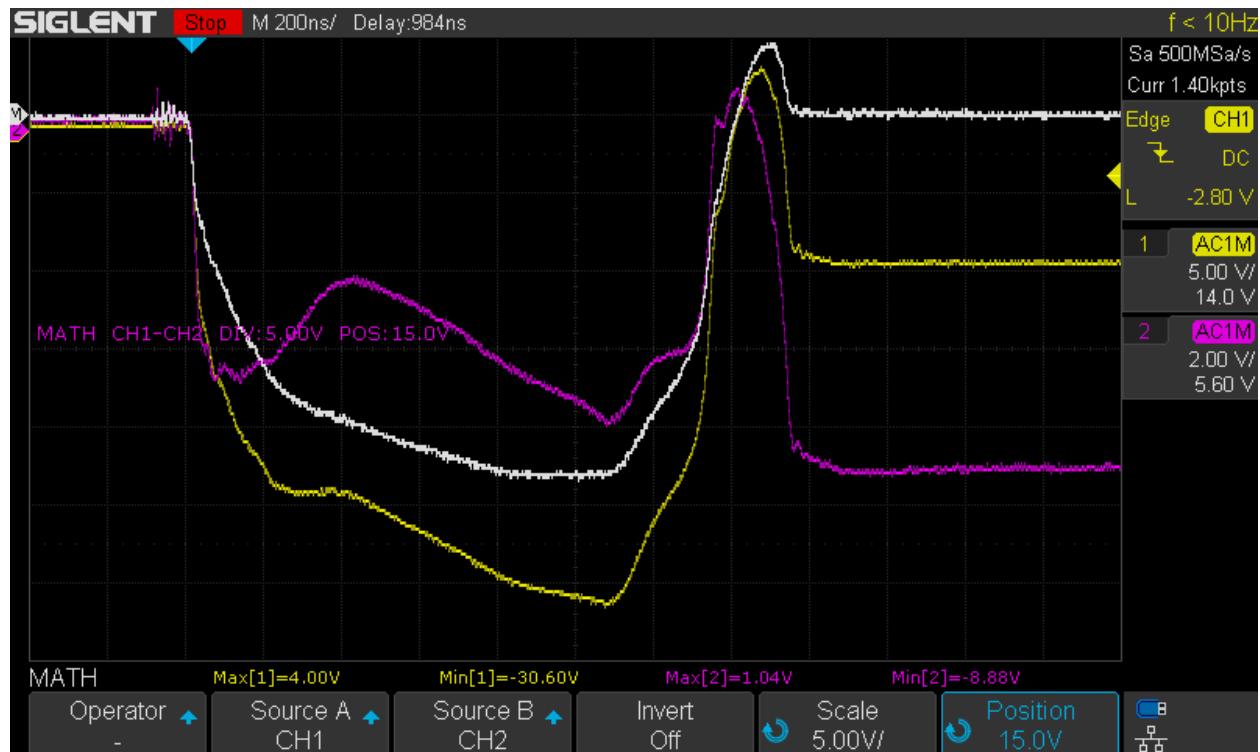
46

GATE: 12V

CAP ANODE: 60V

SERIES RESISTOR: R25

DURATION: 1us



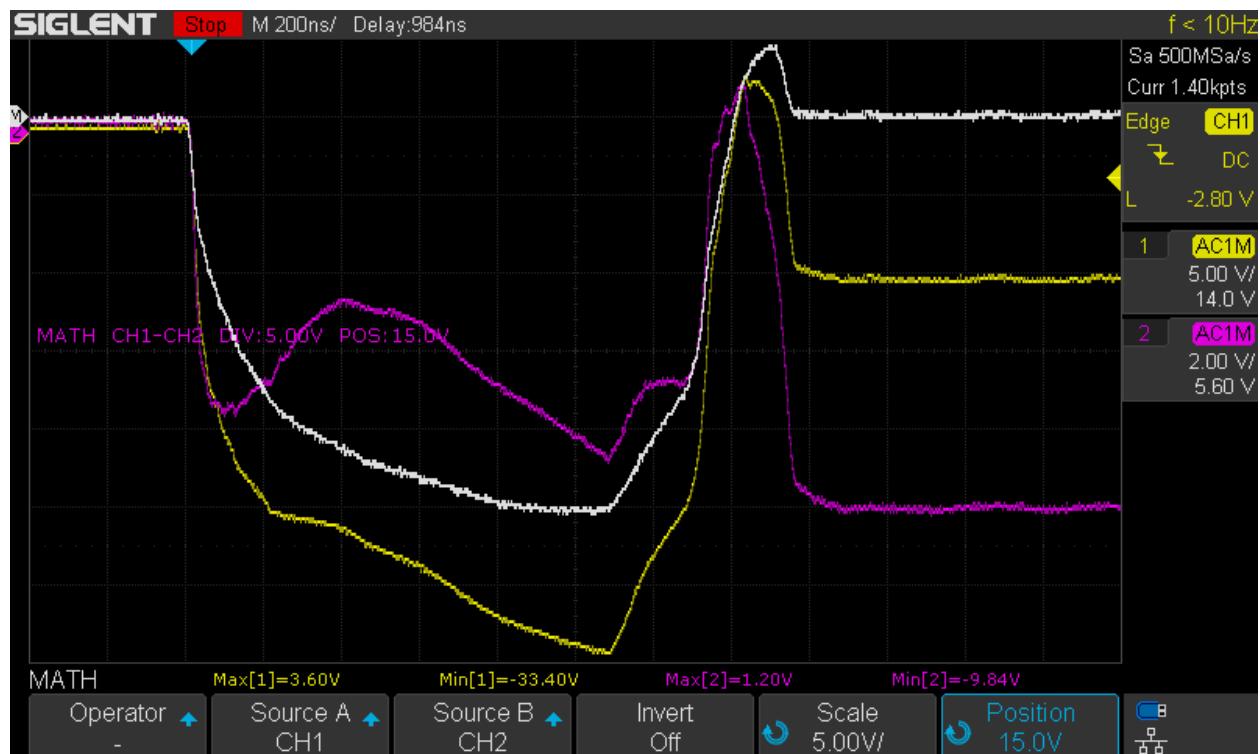
47

GATE: 12V

CAP ANODE: 80V

SERIES RESISTOR: R25

DURATION: 1us



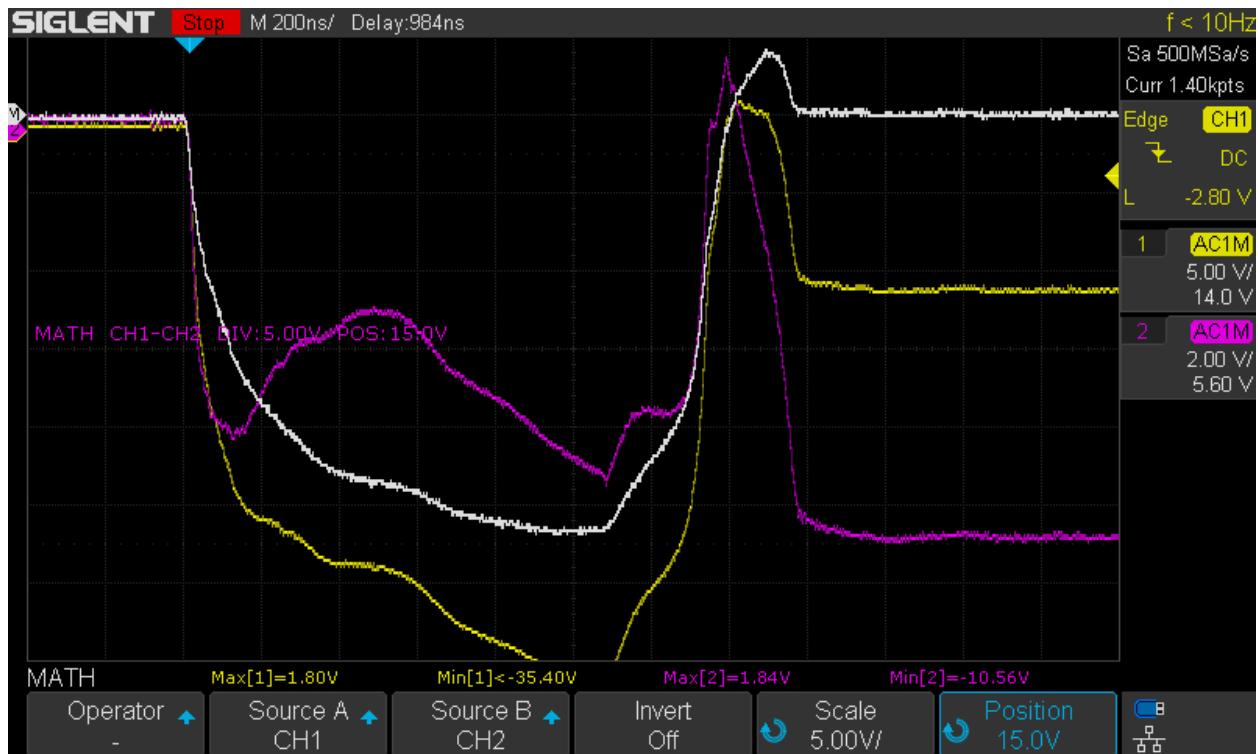
48

GATE: 12V

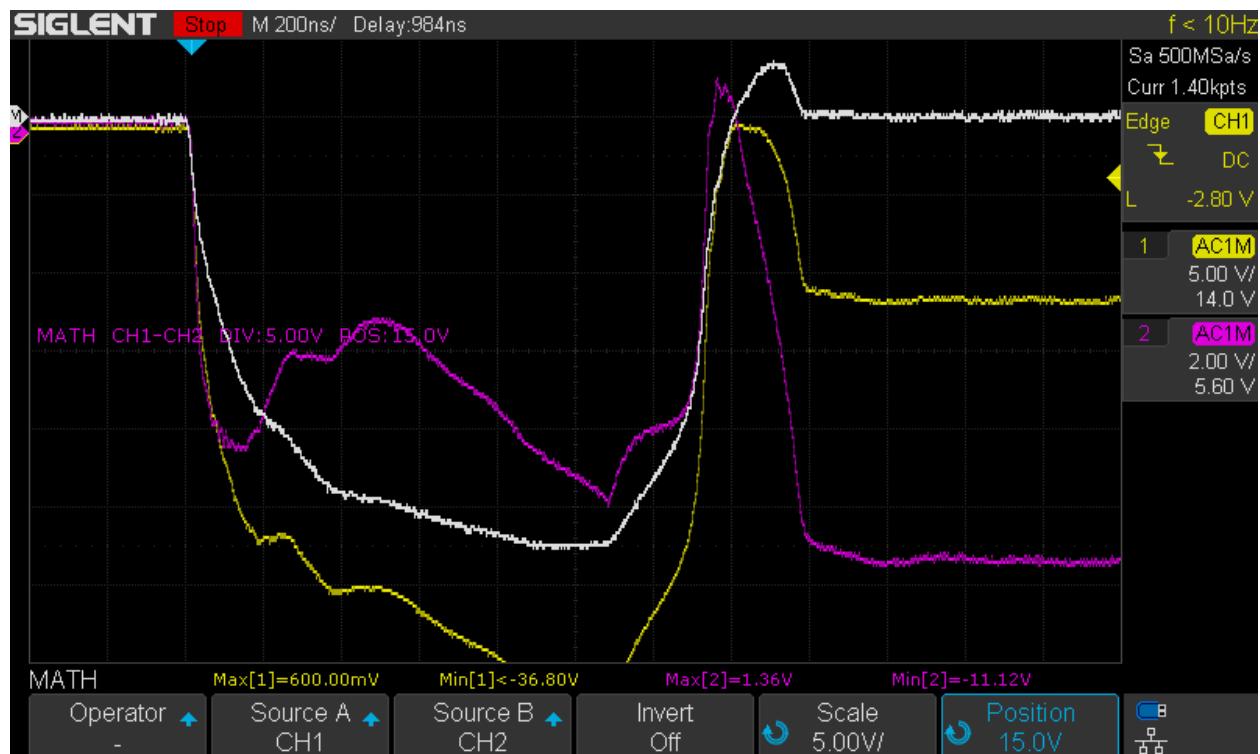
CAP ANODE: 100V

SERIES RESISTOR: R25

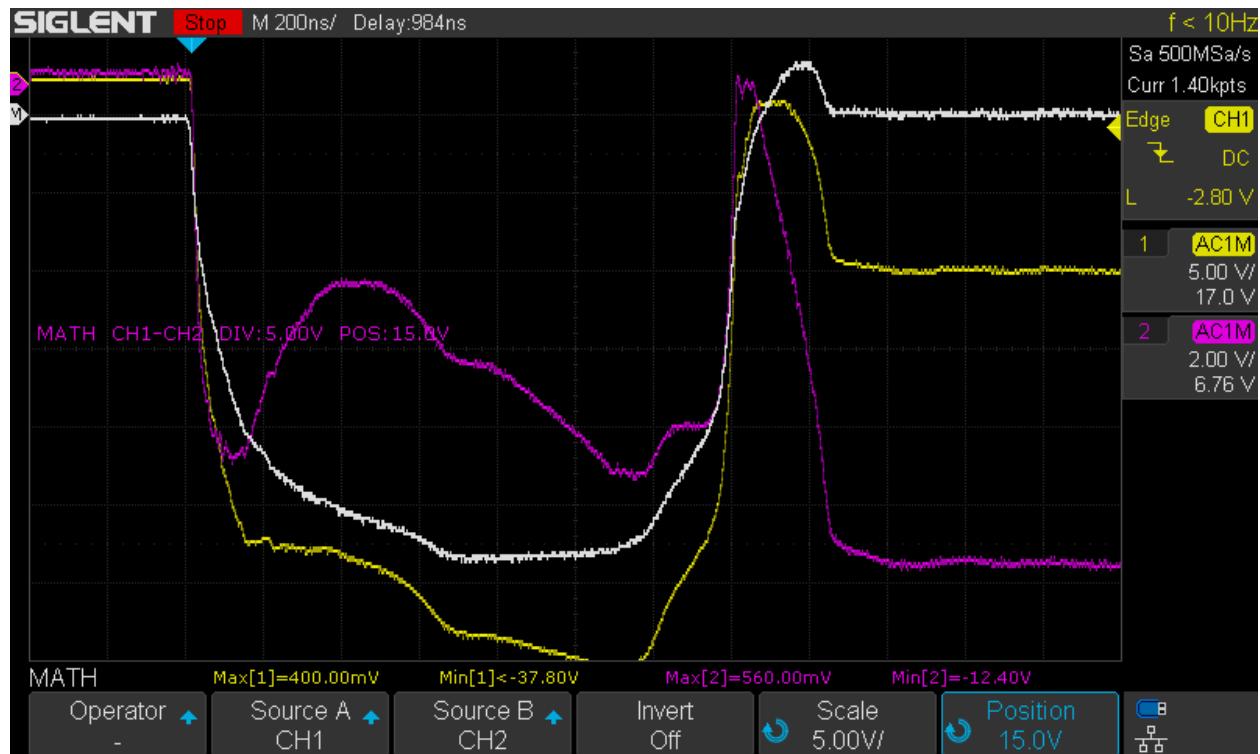
DURATION: 1us



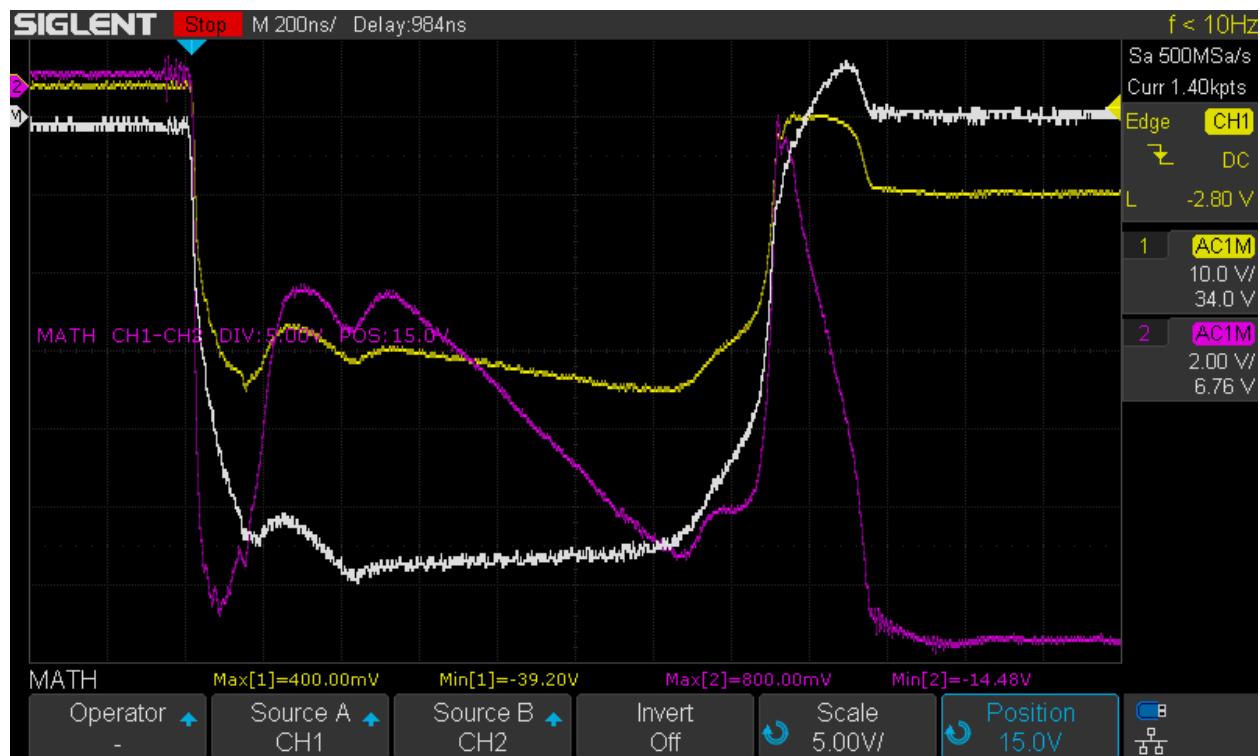
49 GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



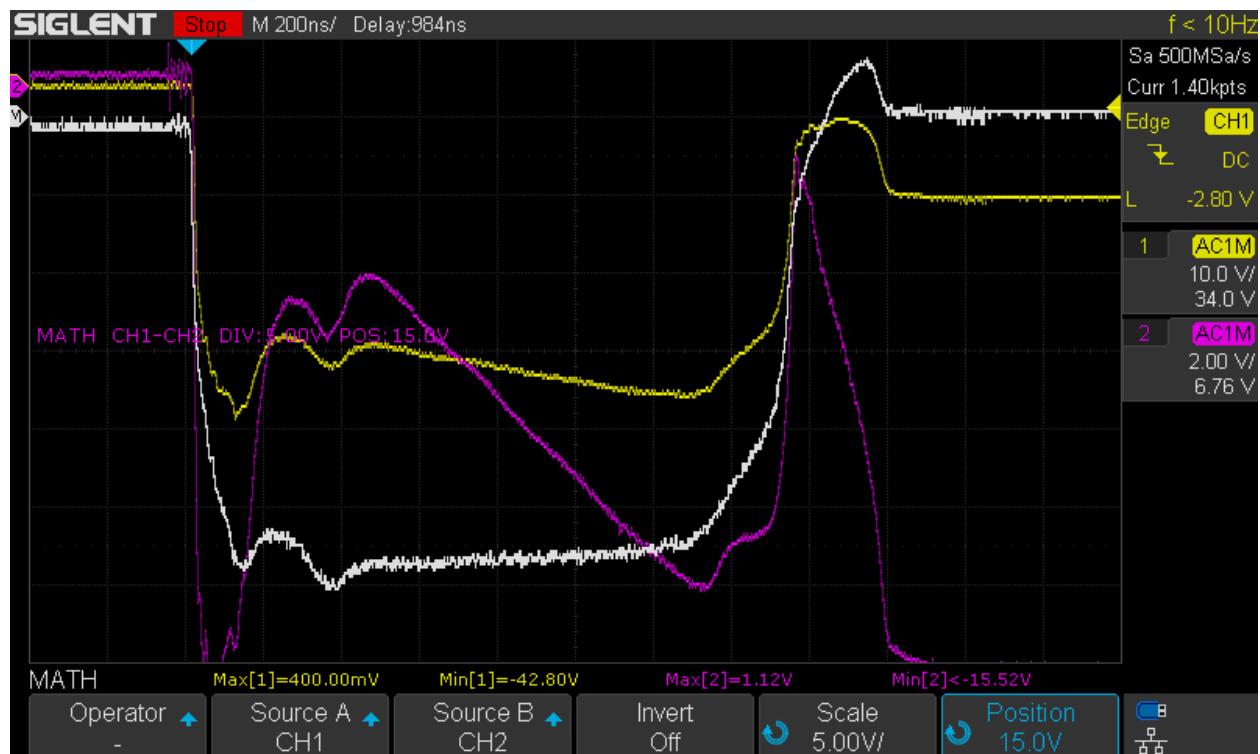
50, 51 (dup) GATE: 13.3V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



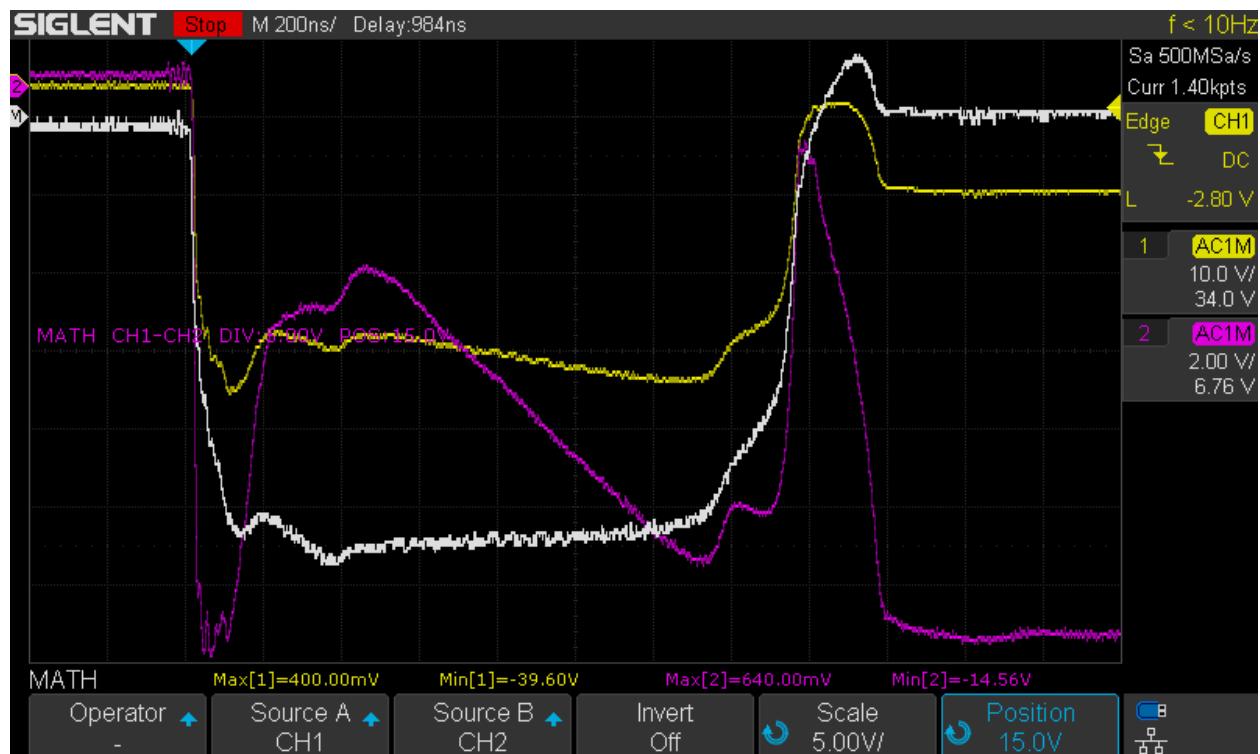
52, 53 (dup) GATE: 16.5V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



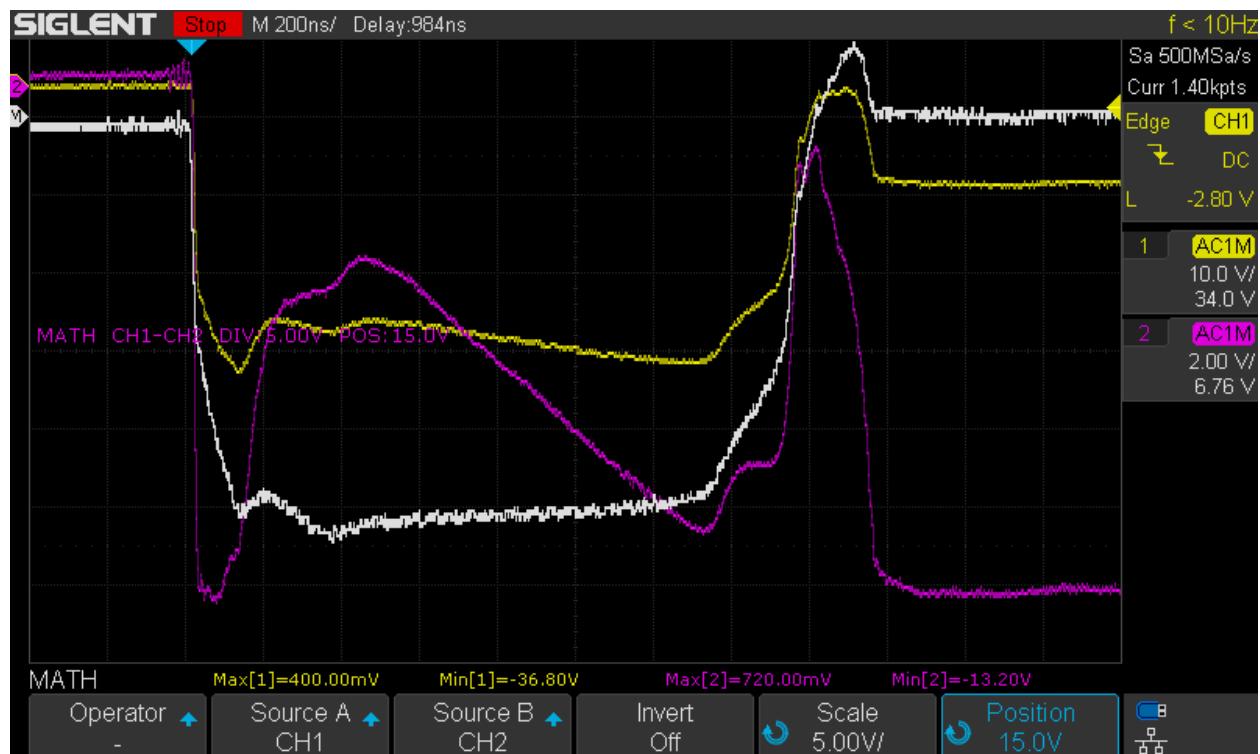
54, 55 (dup) GATE: 18.4V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



56 GATE: 18.4V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



57 GATE: 18.4V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 1us



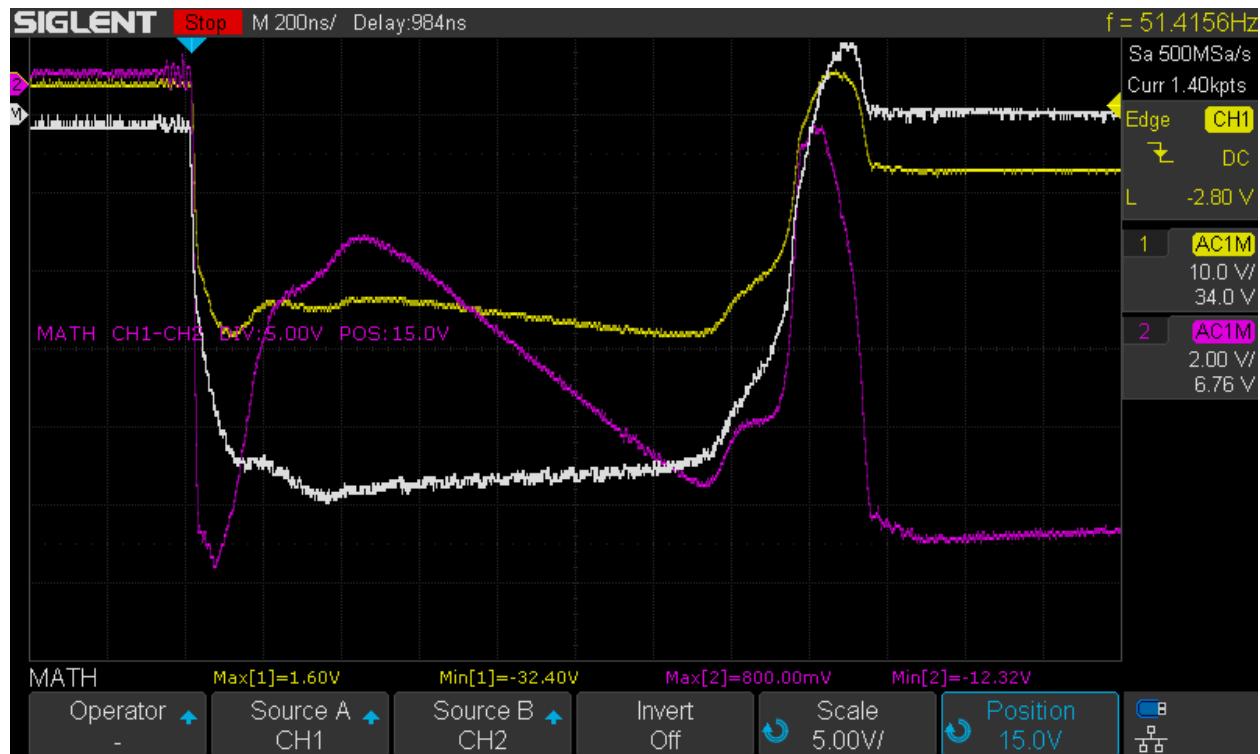
58

GATE: 18.4V

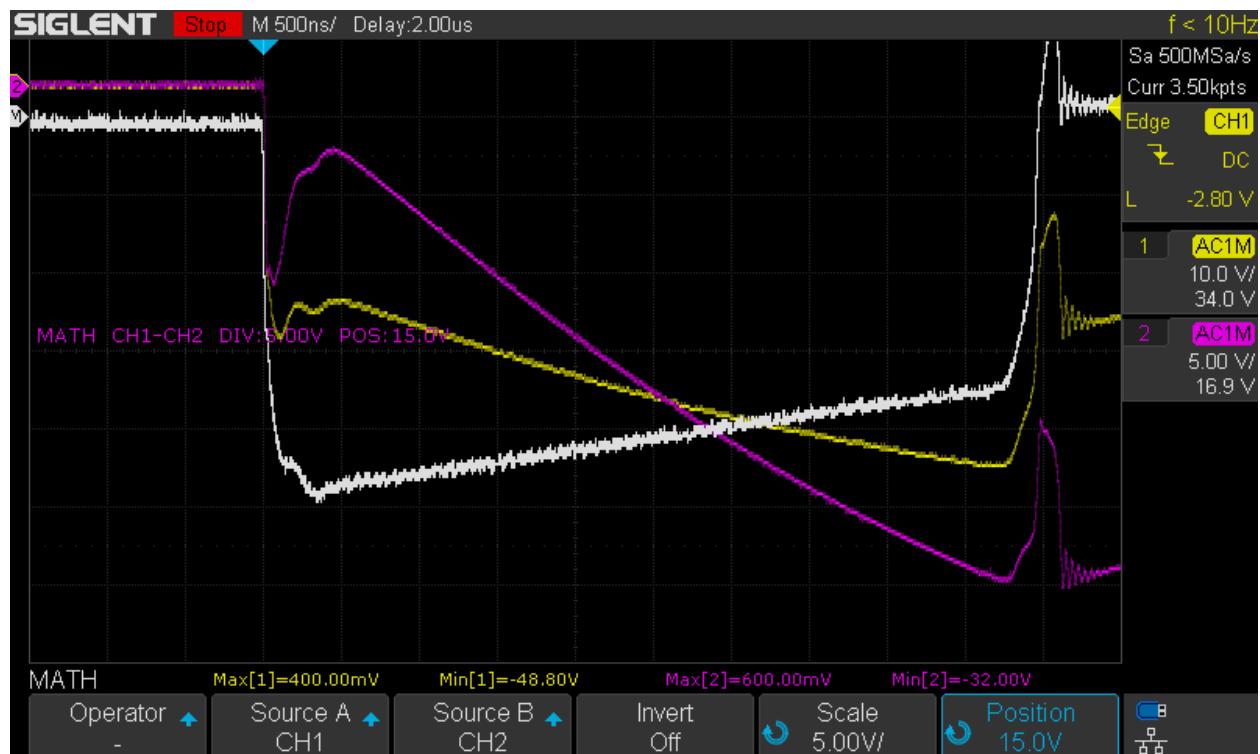
CAP ANODE: 60V

SERIES RESISTOR: R25

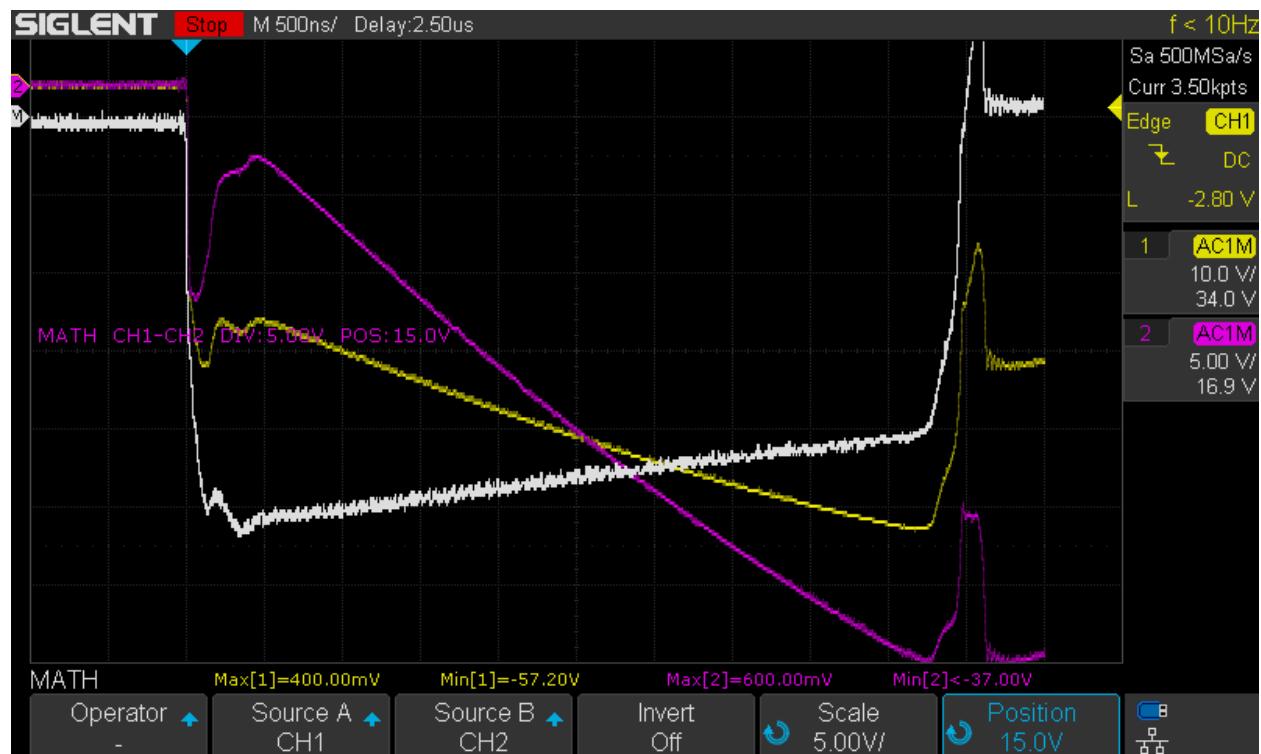
DURATION: 1us



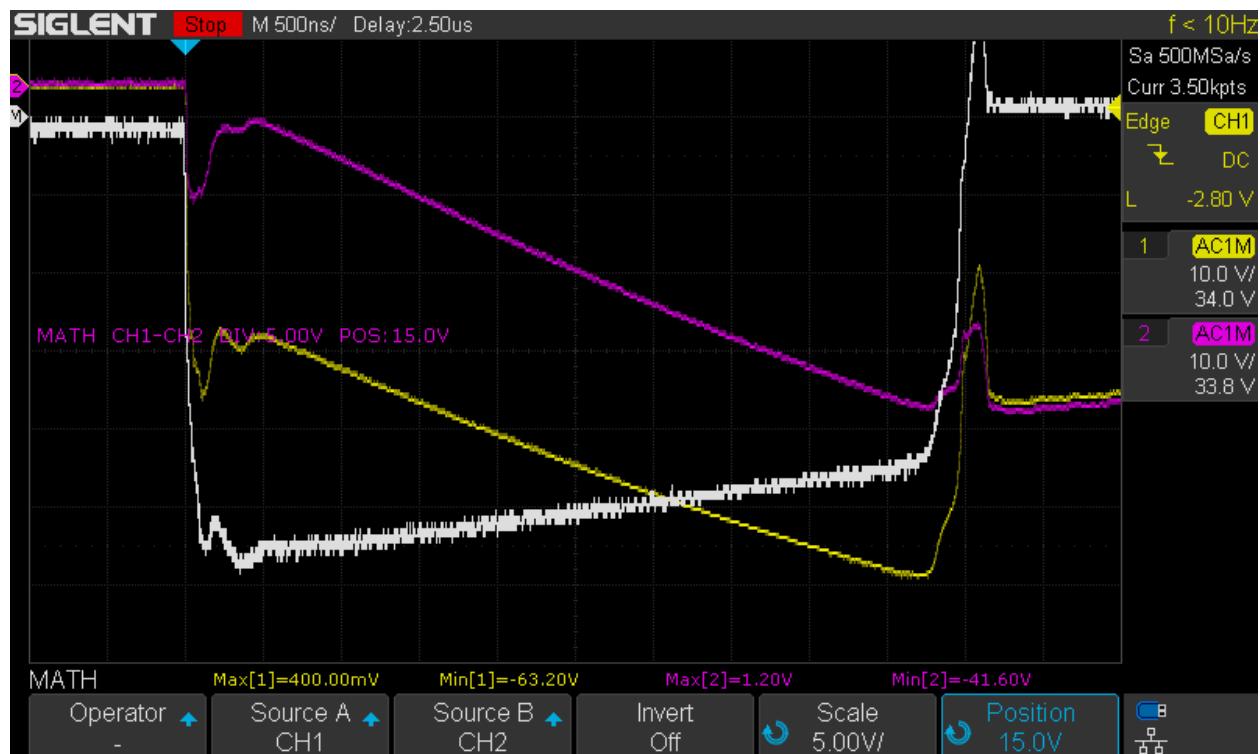
59 GATE: 18.4V CAP ANODE: 60V SERIES RESISTOR: R25 DURATION: 4us



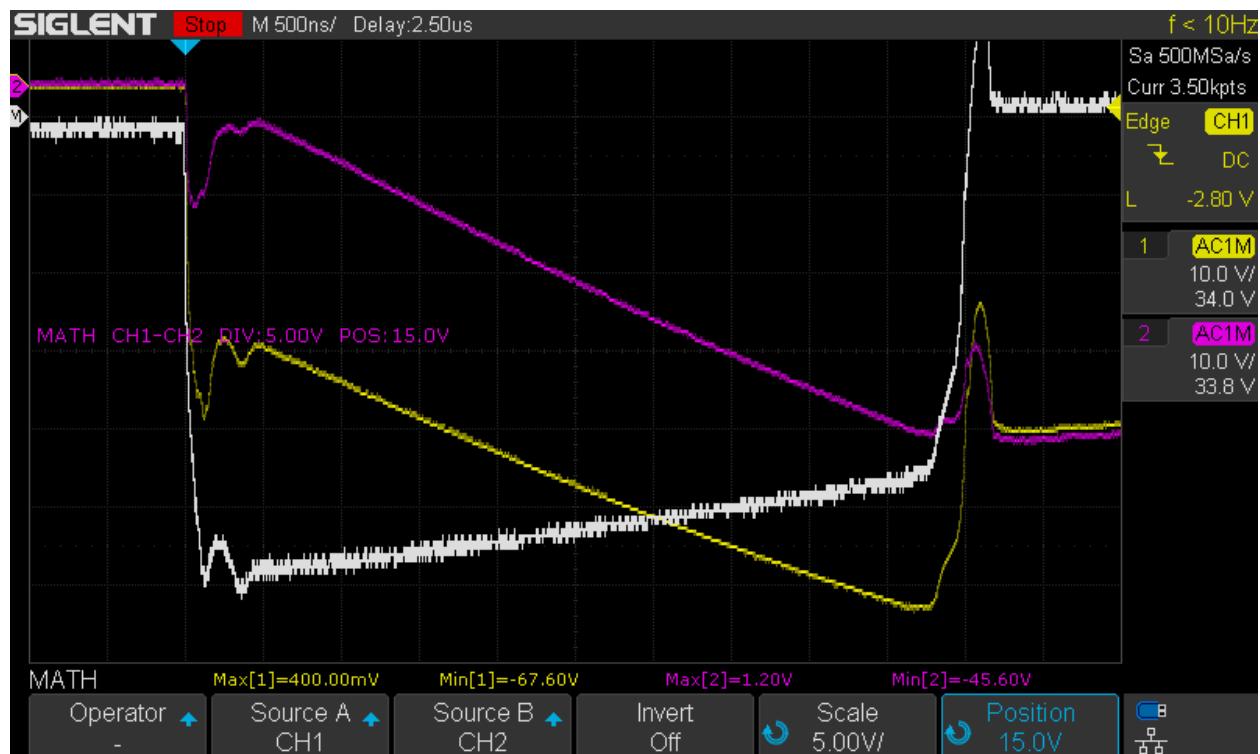
60 GATE: 18.4V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 4us



61 GATE: 18.4V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 4us



62, 63 (dup) GATE: 18.4V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us



Series 4 – IRFB4332 MOSFET Gate Circuit Development

2020-05-16

Overview:

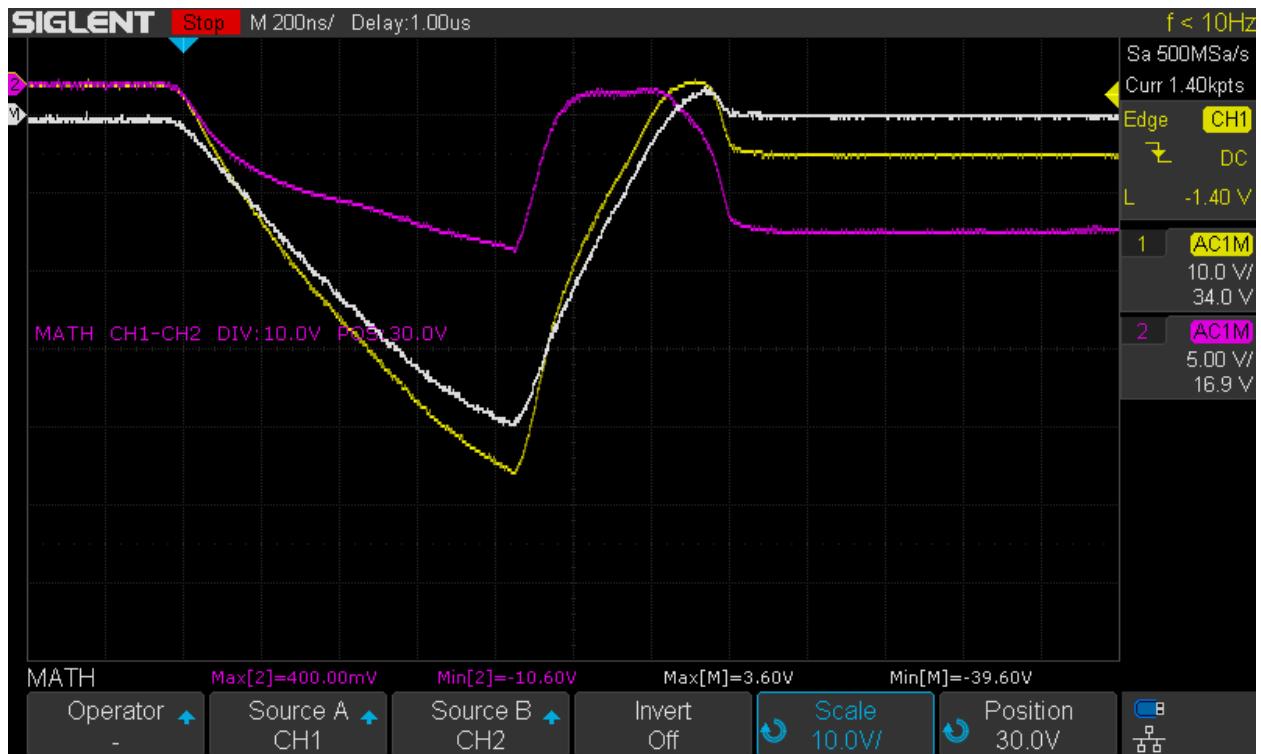
Purpose: To develop an effective gate driver circuit for the IRFB4332 MOSFET

Equipment:

- E2 Prototype with four banks of LED's in various states of damage
 - IPPR60 MOSFET's

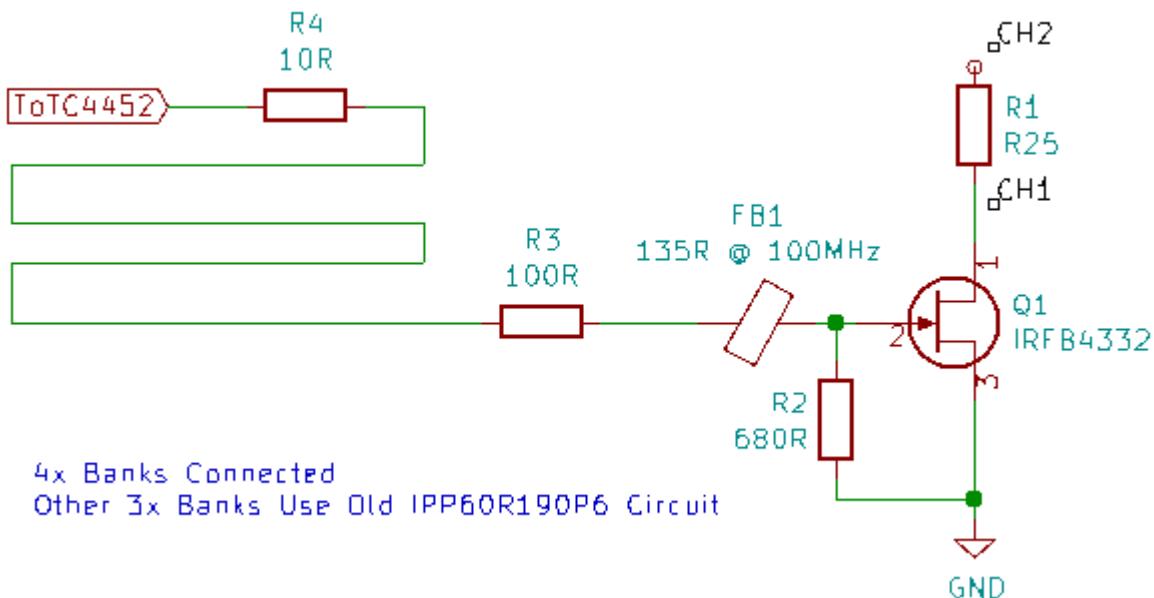
Test Data:

64 GATE: 12V CAP ANODE: 60V SERIES RESISTOR: R25 DURATION: 1us

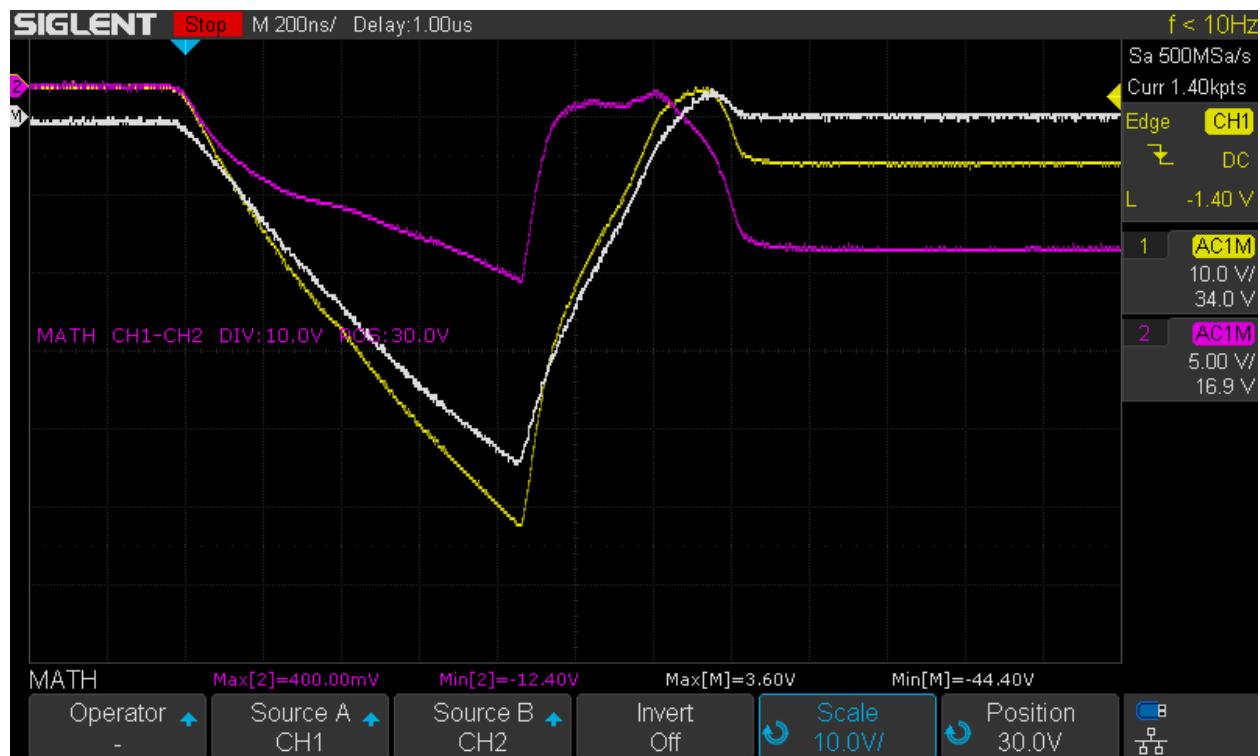


Measuring current through 0.25R resistor (R1)

No changes to gate circuit from IPP60R190P6 circuit

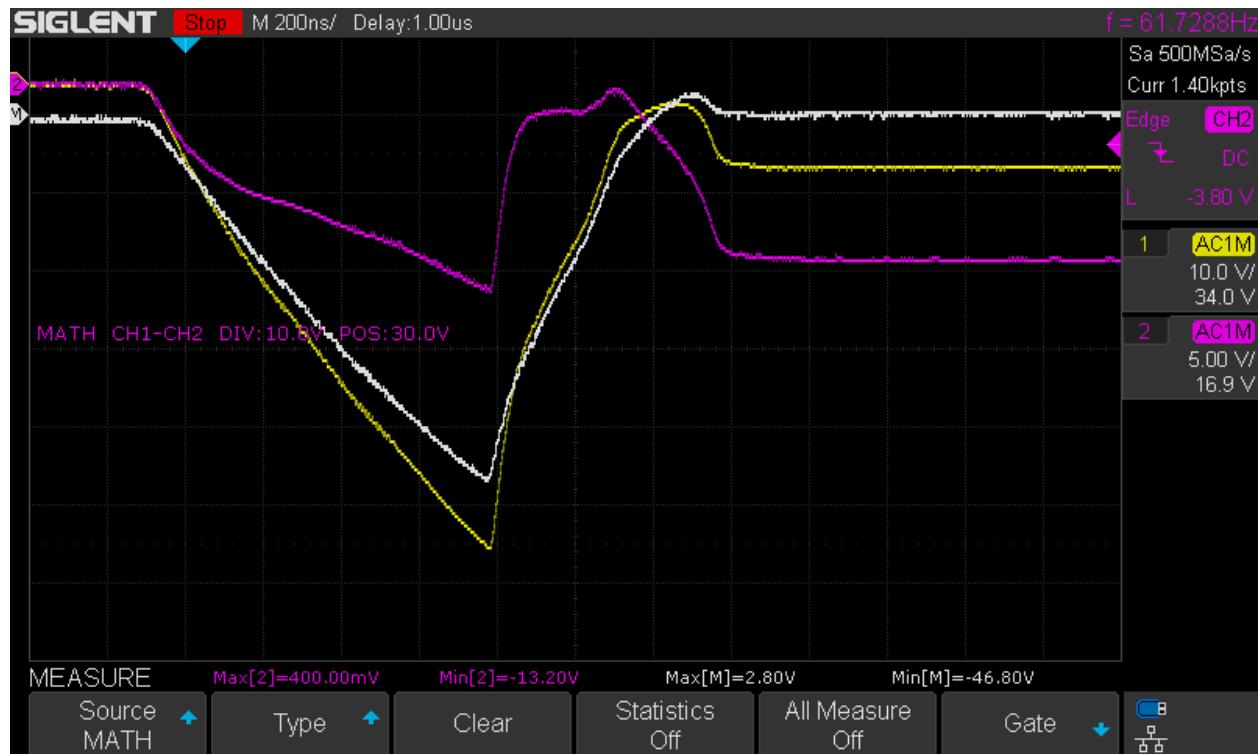


65 GATE: 12V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 1us



No Change

66, 67 (dup) GATE: 12V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



No Change

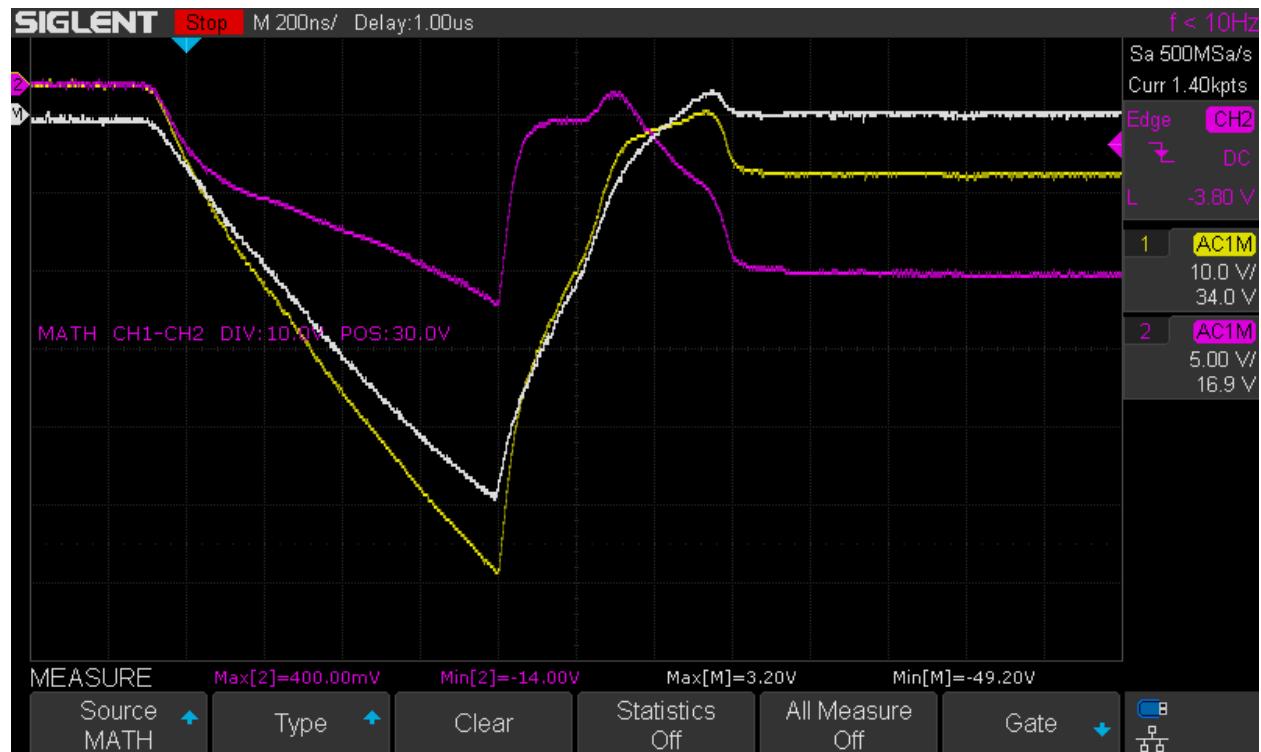
68

GATE: 12V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 1us



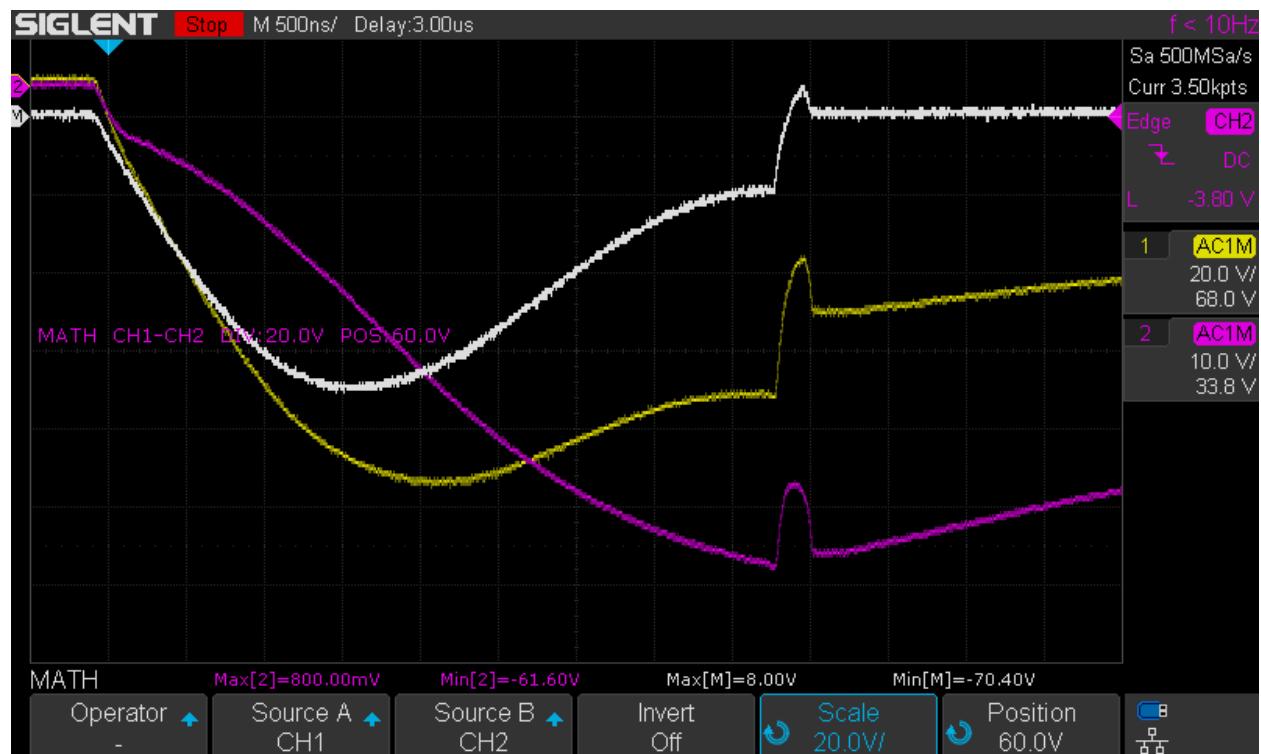
69

GATE: 12V

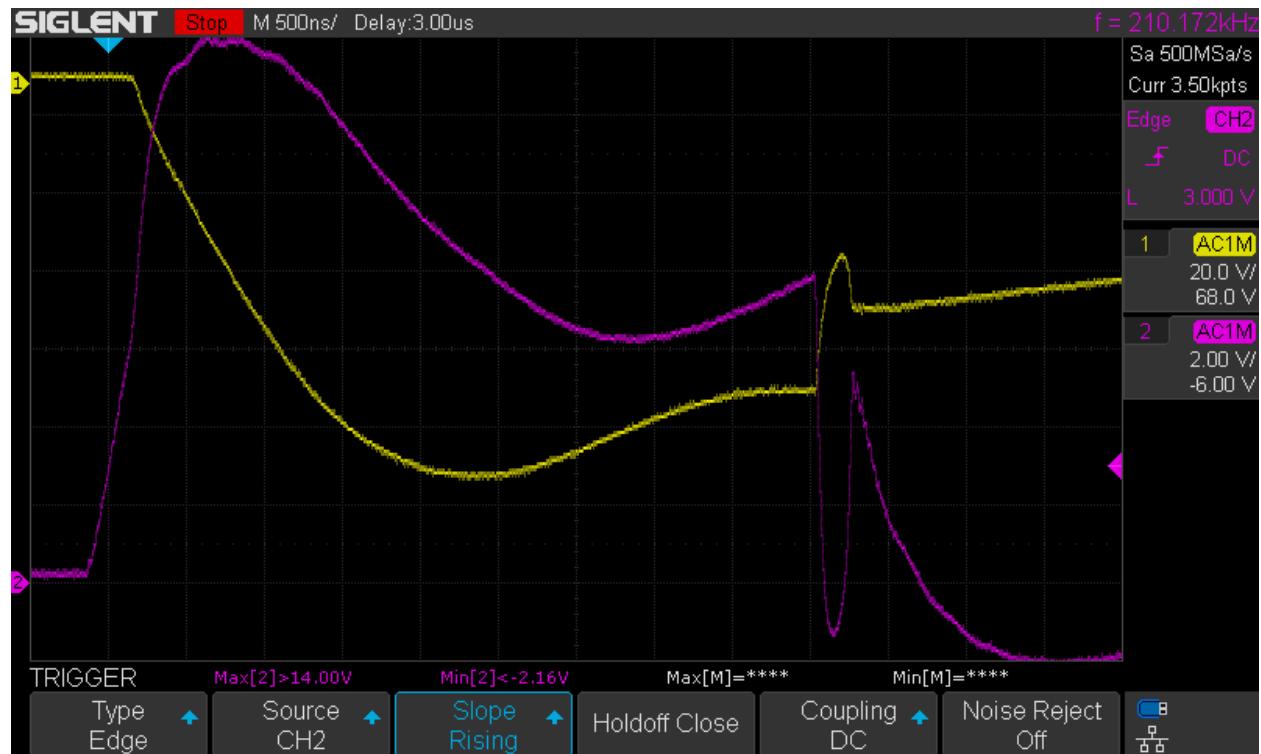
CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 4us



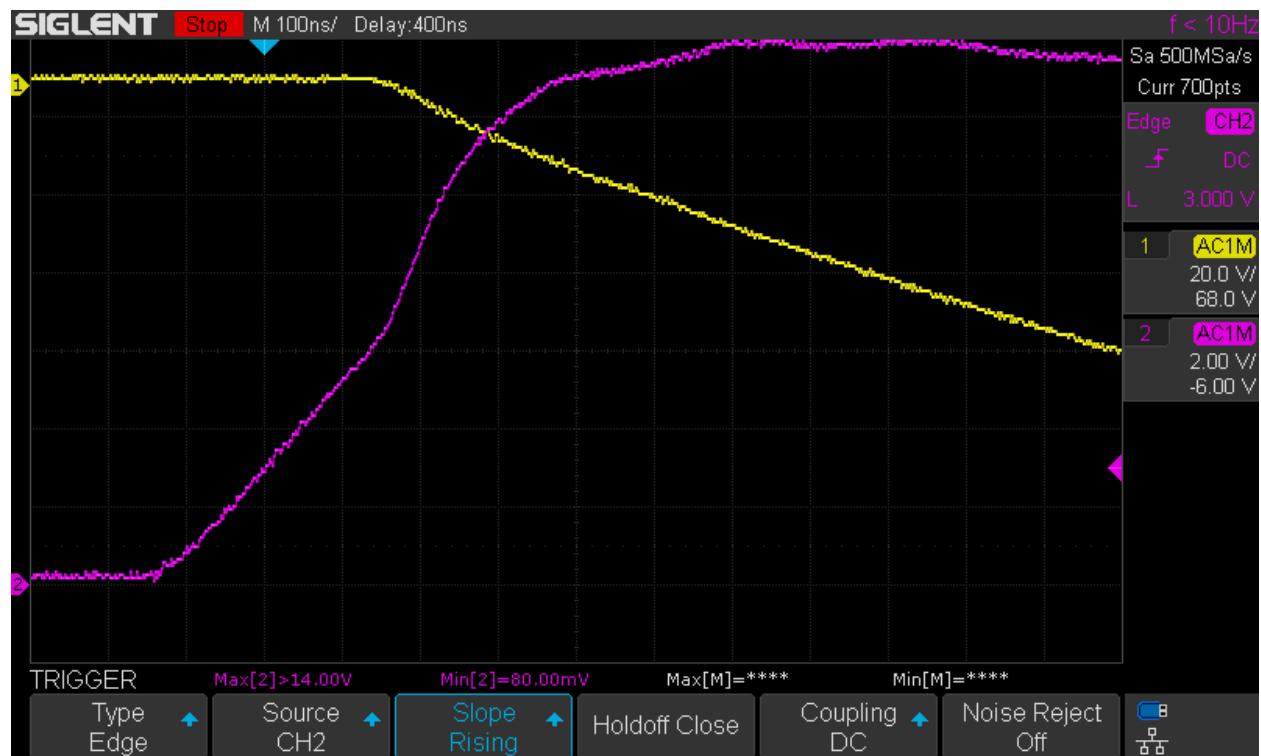
70 GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us



No change to circuit

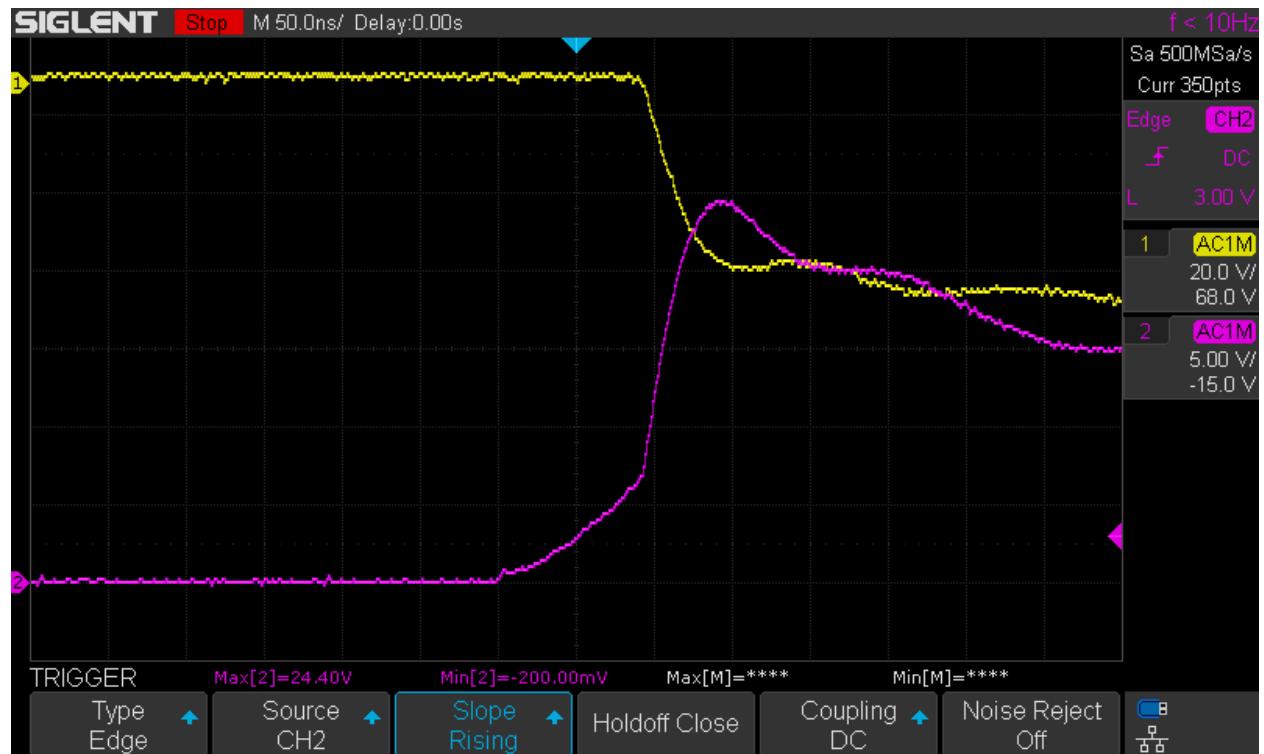
CH2 – MOSFET Gate

71 GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us

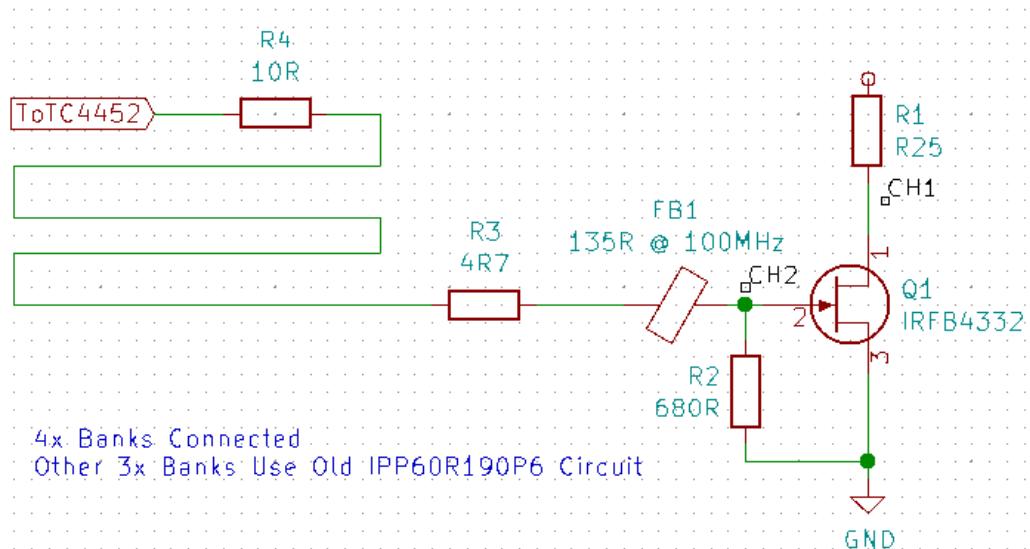


No Change

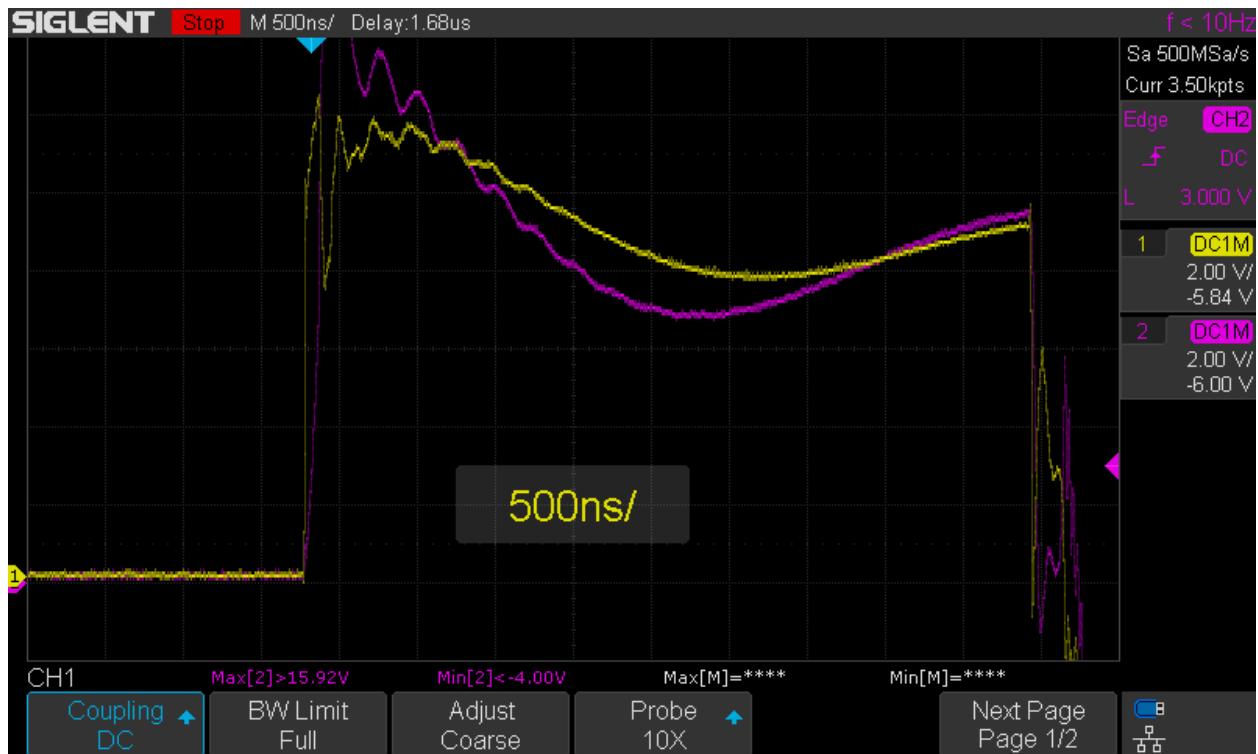
72 GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us



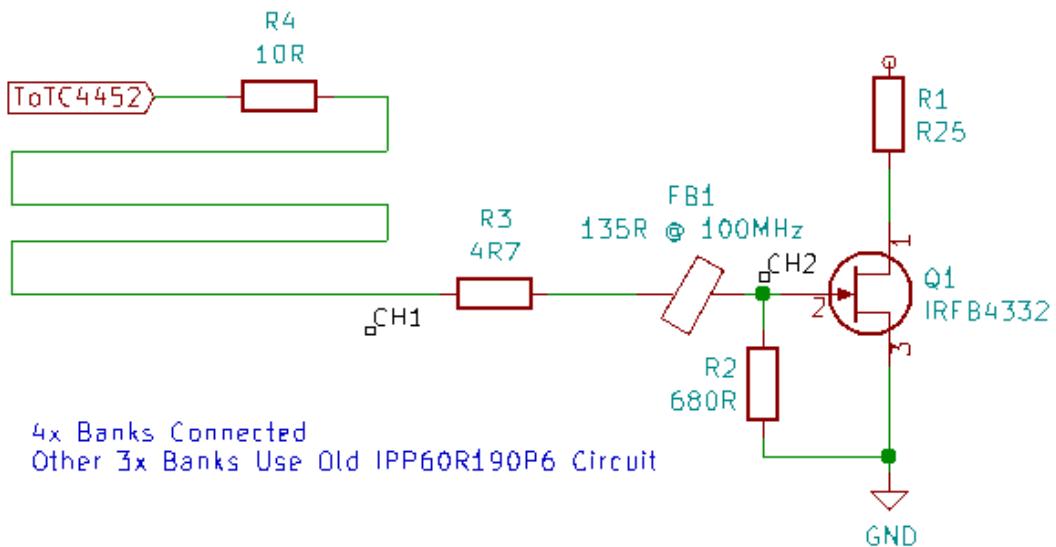
Changed 100R gate resistor to 4R7



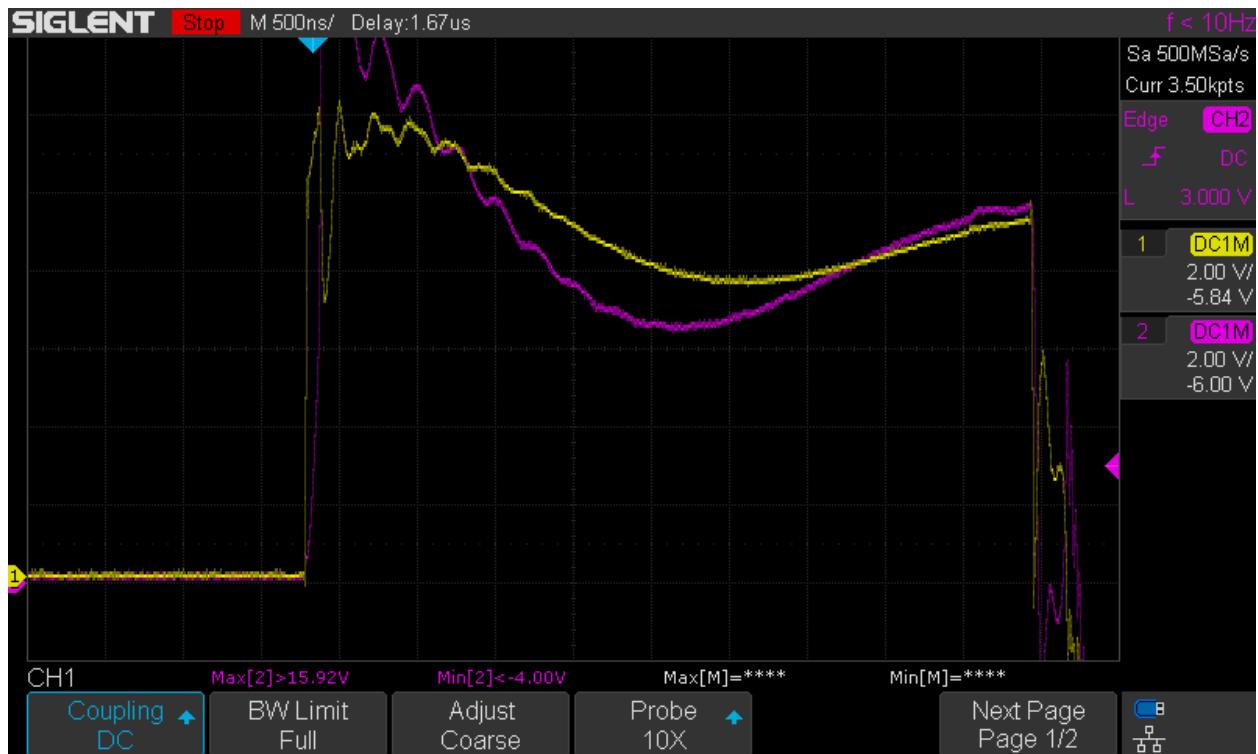
73 GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us



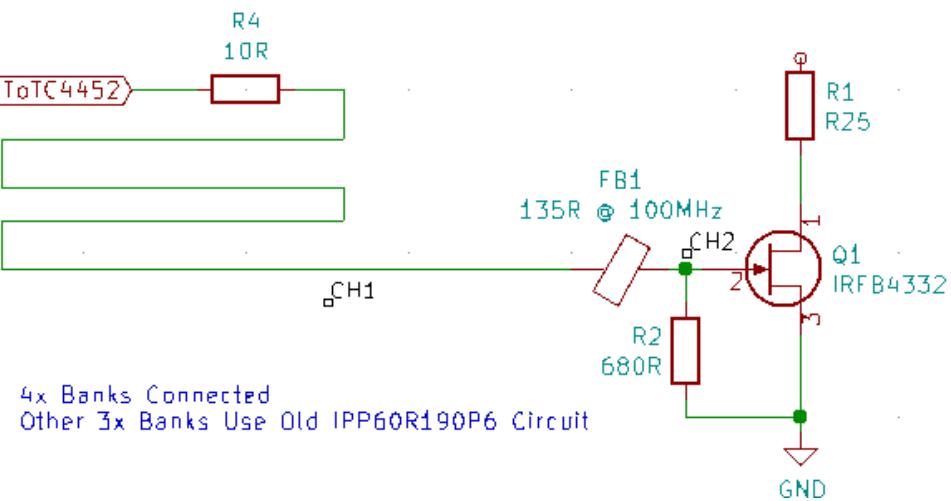
CH1 – R3



74, 75 (dup) GATE: 12V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 4us



Removed Gate resistor



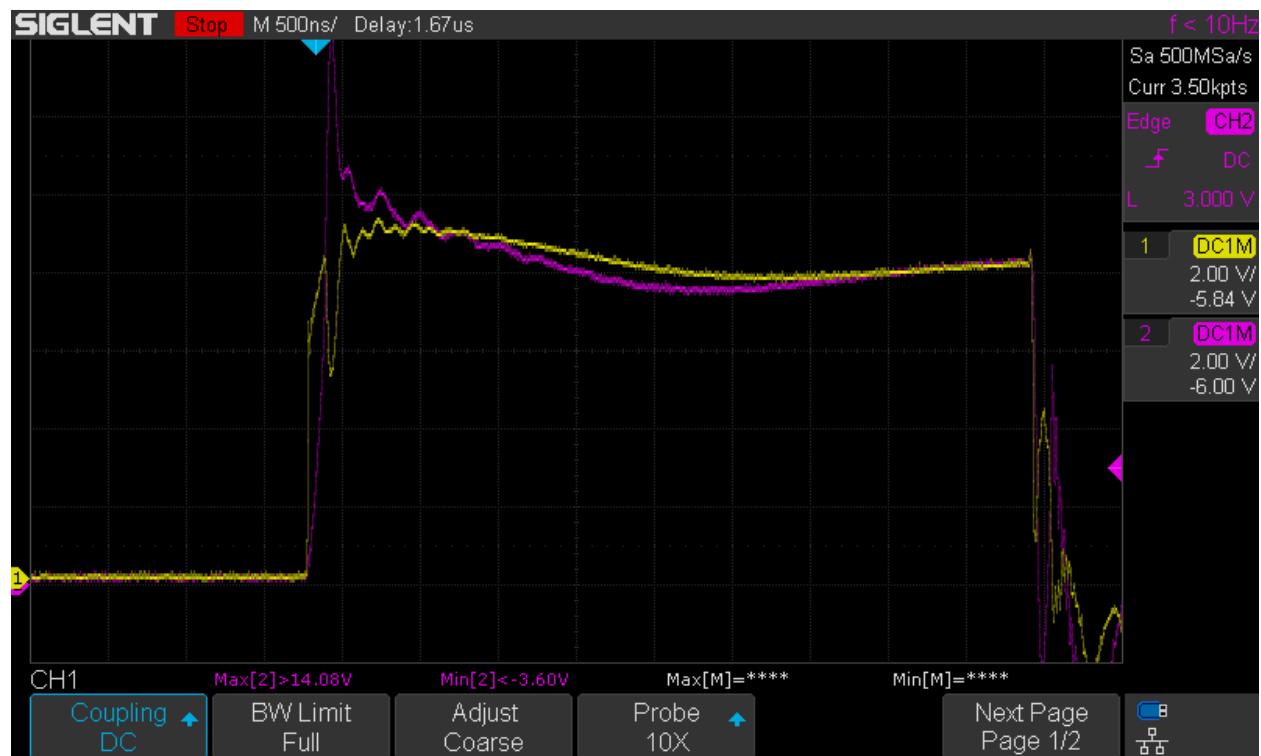
76

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 4us



Lowered TC4452 voltage

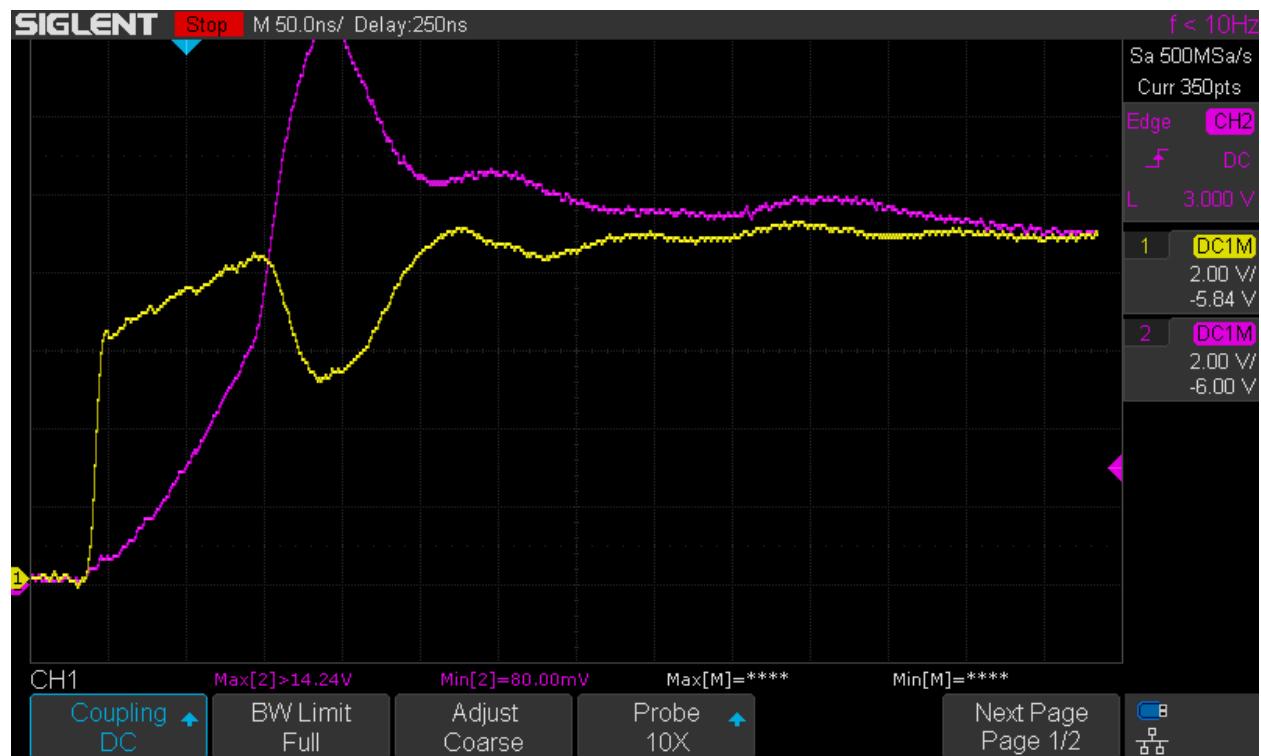
77

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 4us



No change

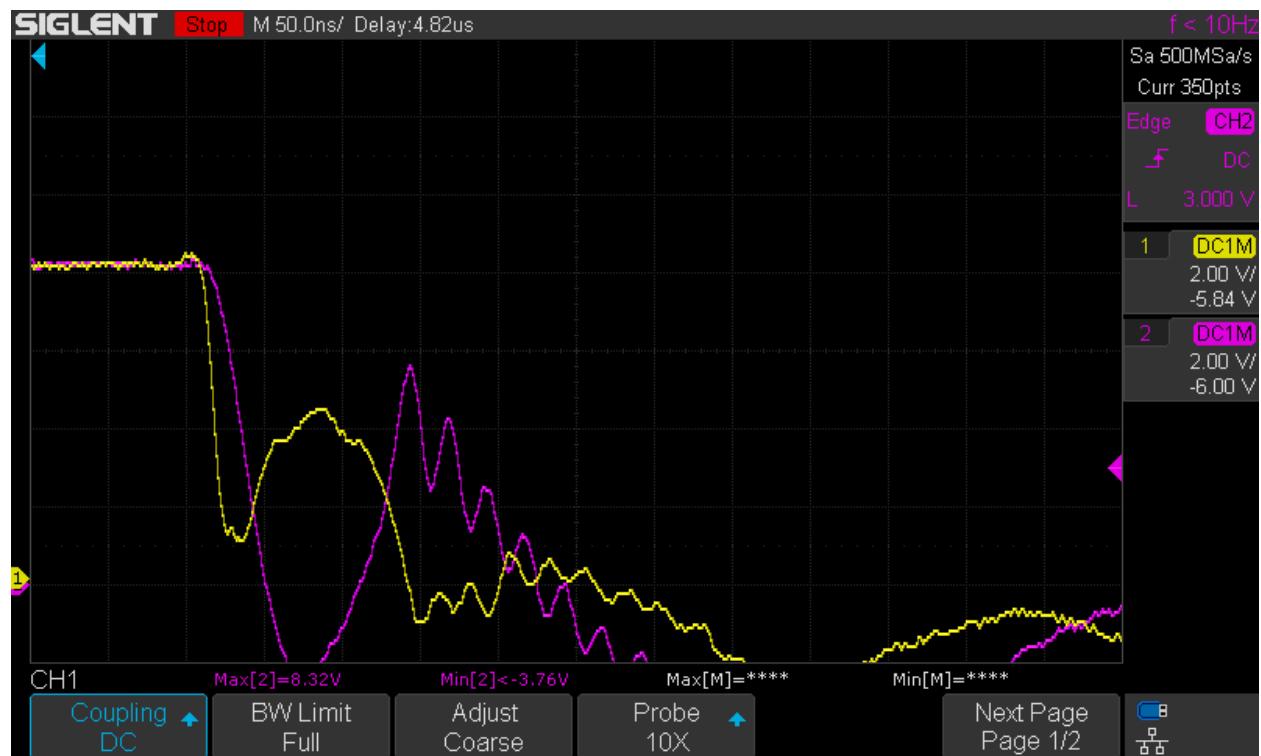
78

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 4us



No Change

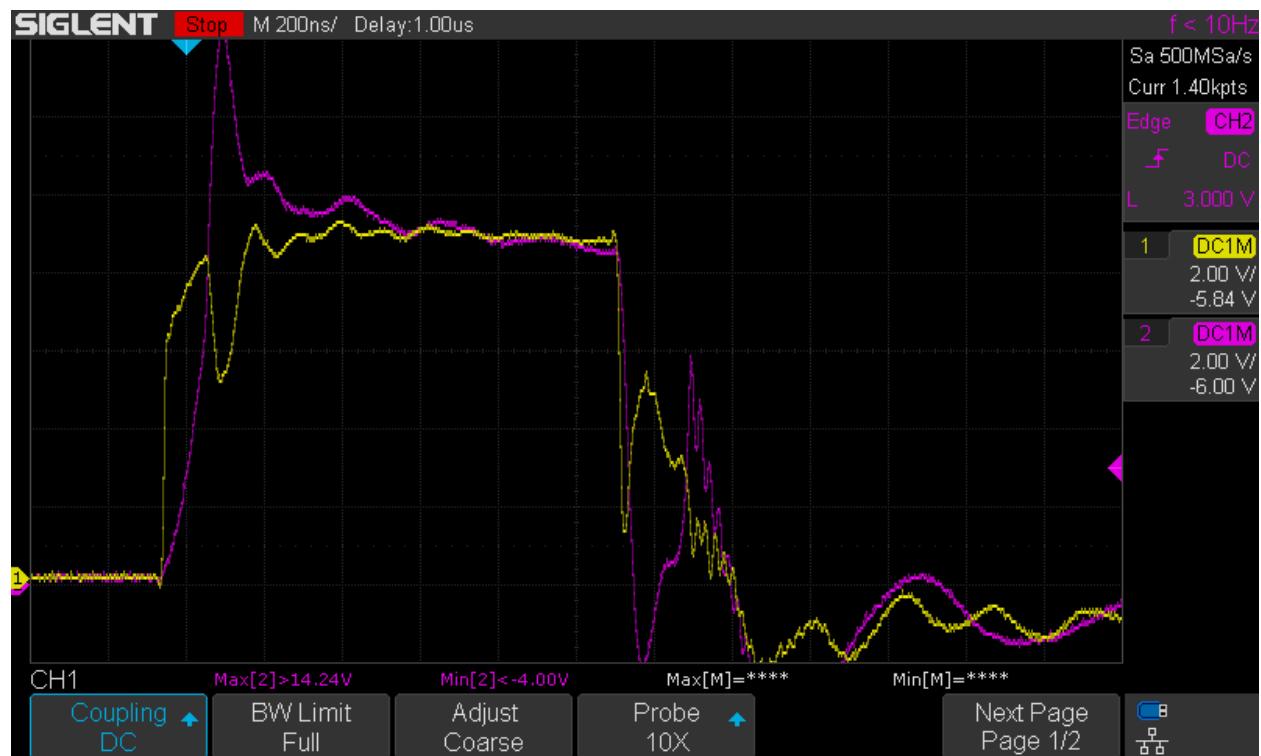
79

GATE: 8V

CAP ANODE: 120V

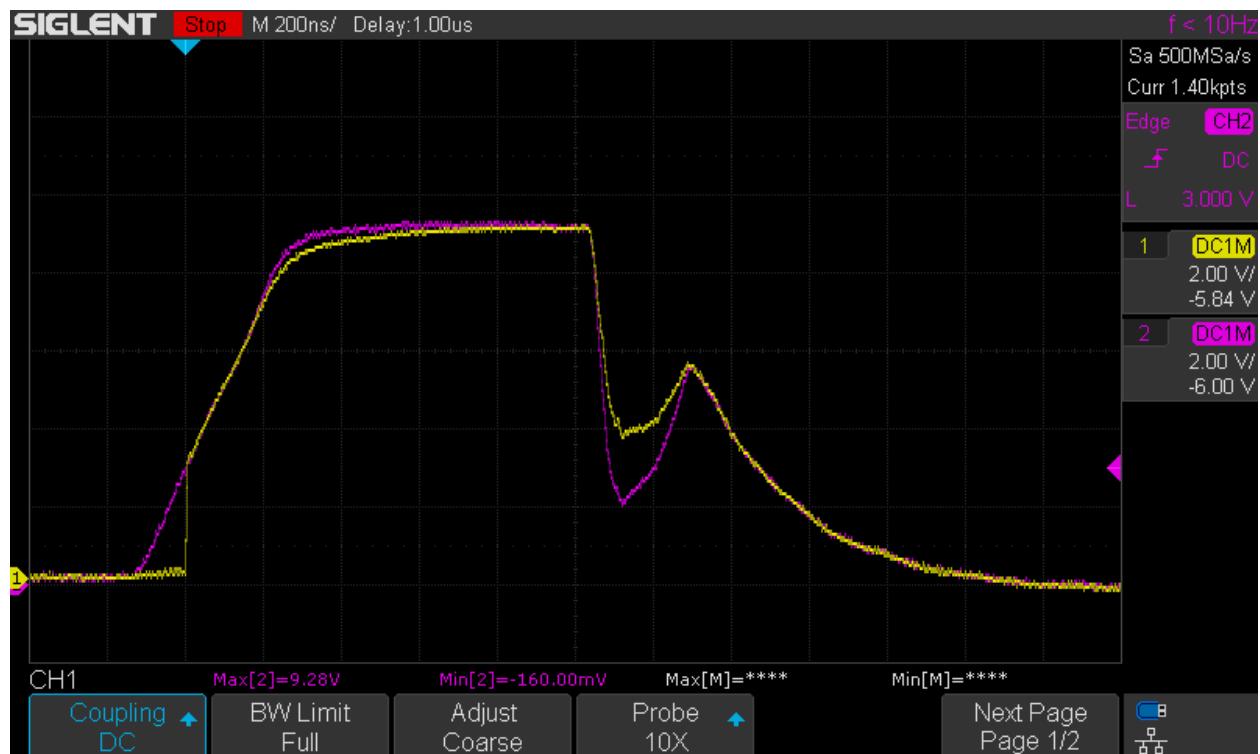
SERIES RESISTOR: R25

DURATION: 1us



1us strobe

80 GARBAGE



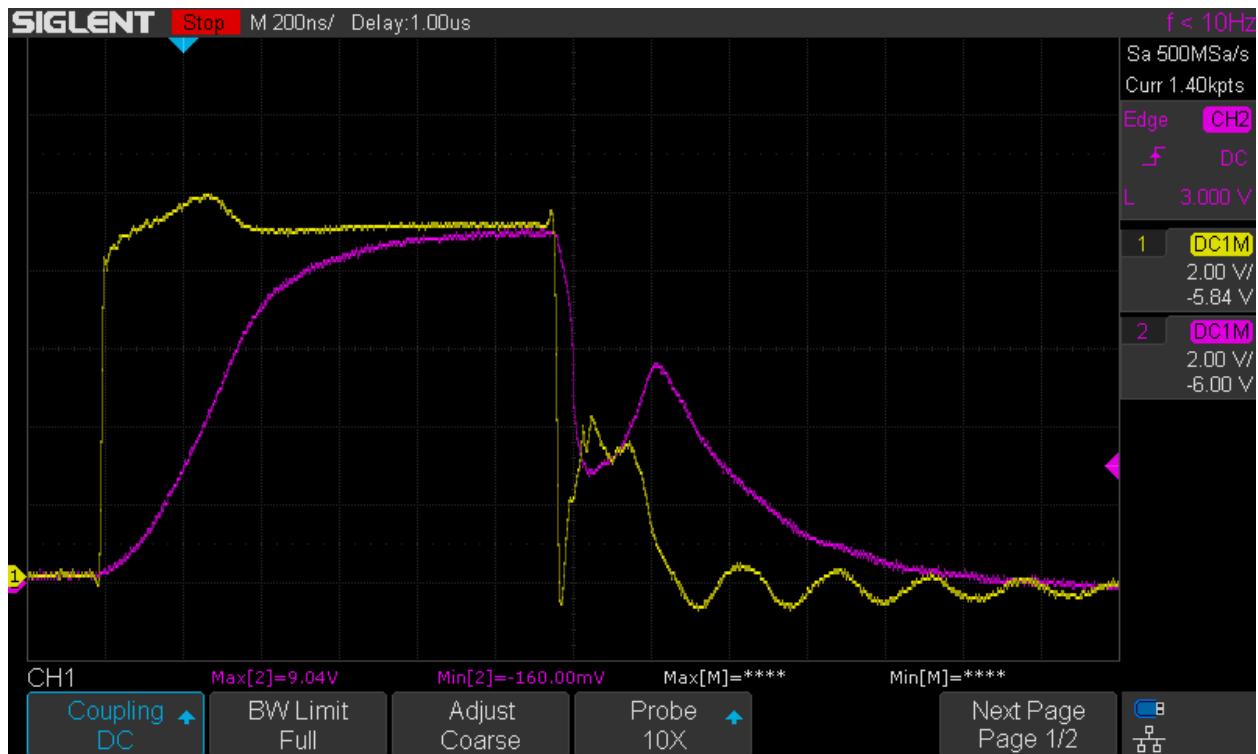
81

GATE: 8V

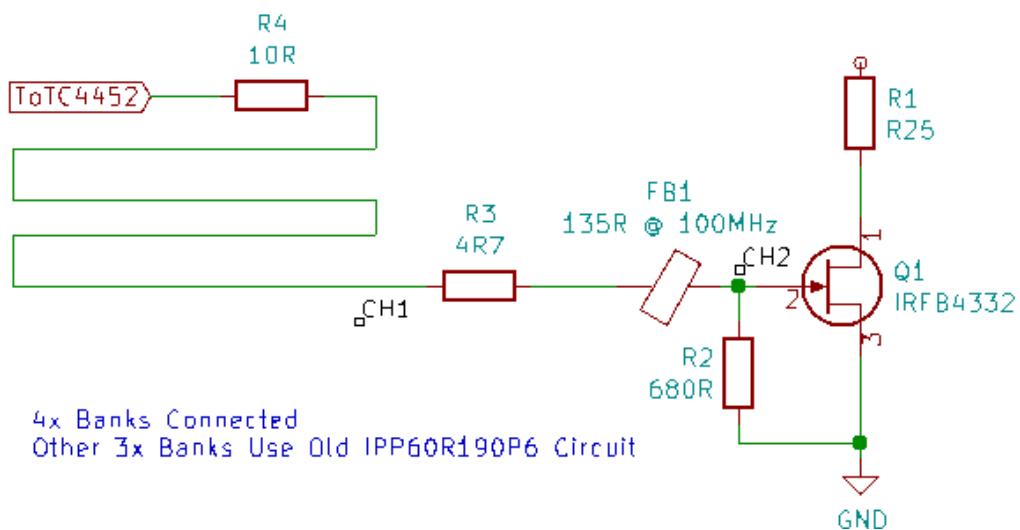
CAP ANODE: 120V

SERIES RESISTOR: R25

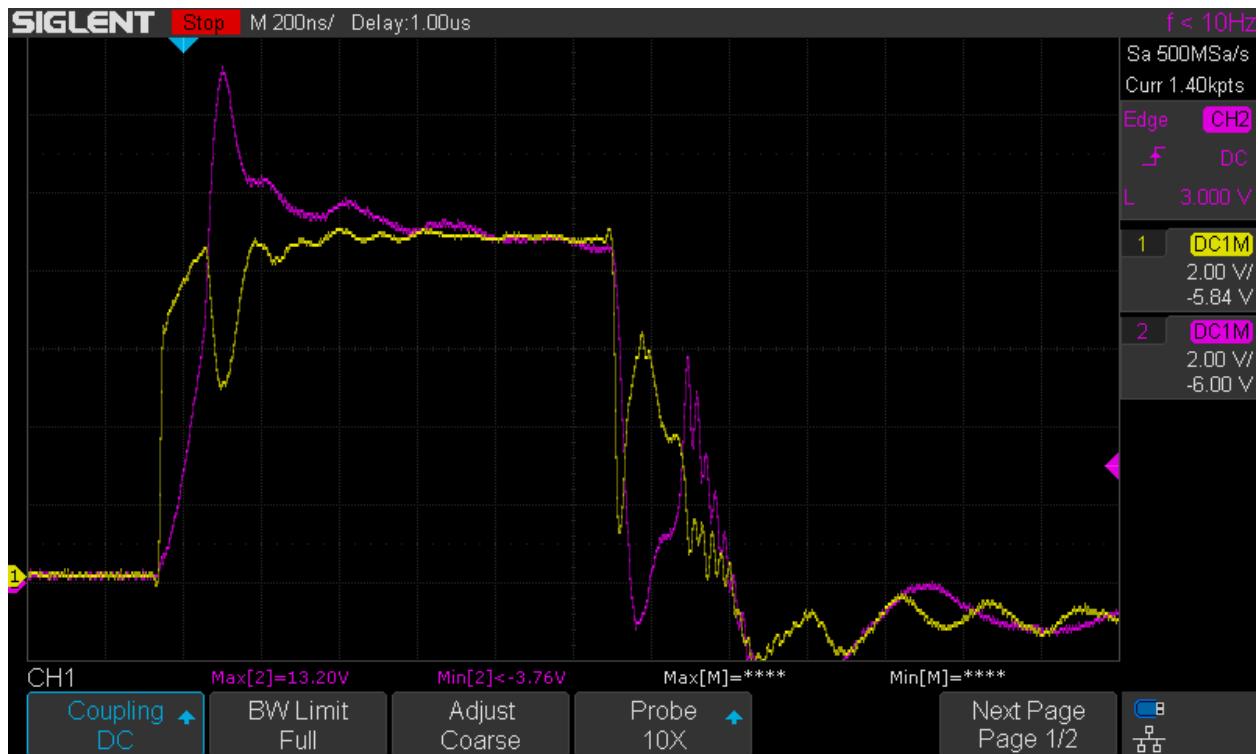
DURATION: 1us



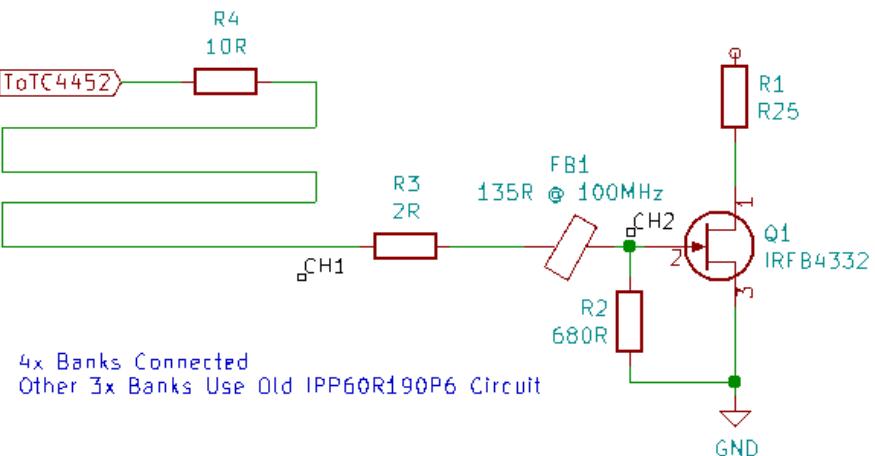
Re-installed 4R7 resistor to gate circuit



82, 83 (dup) GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



Replaced 4R7 gate resistor with 2R resistor



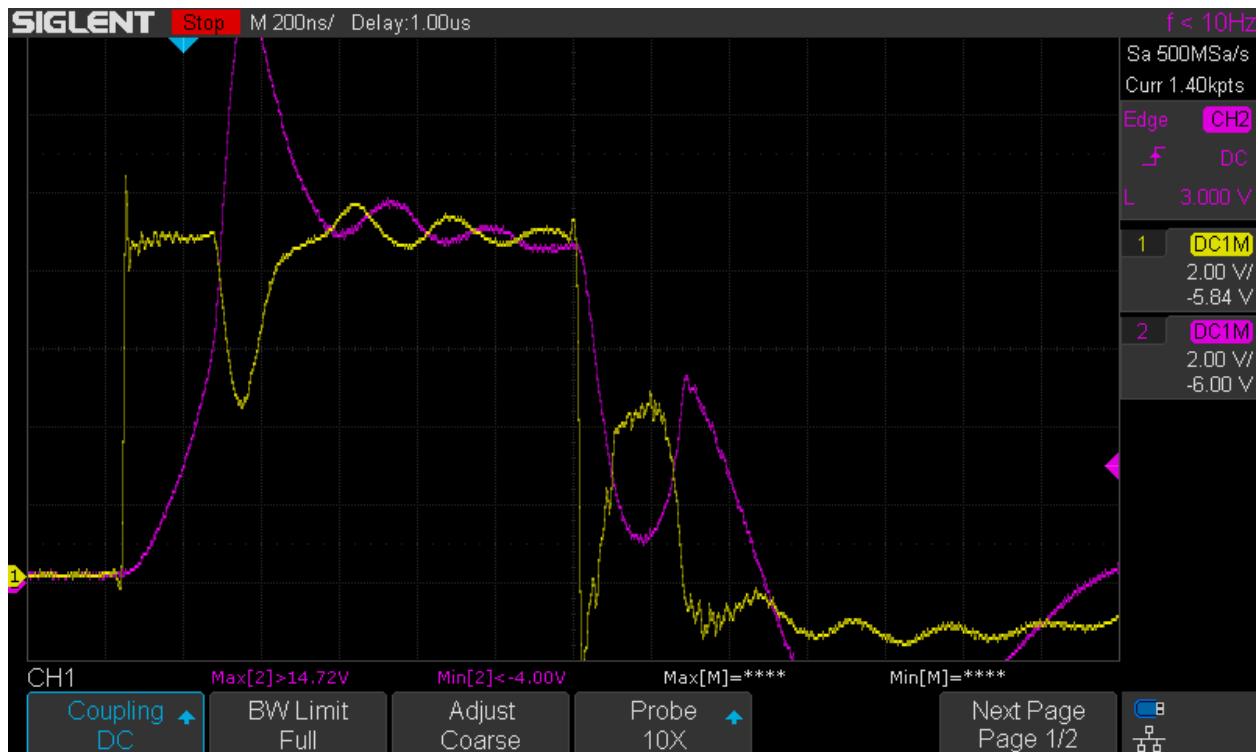
84

GATE: 8V

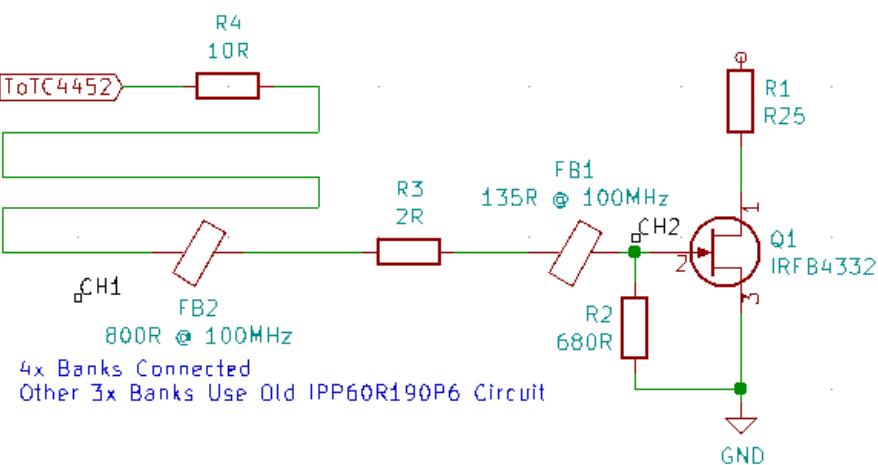
CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 1us



Added 800R @ 100MHz Ferrite Bead to gate circuit



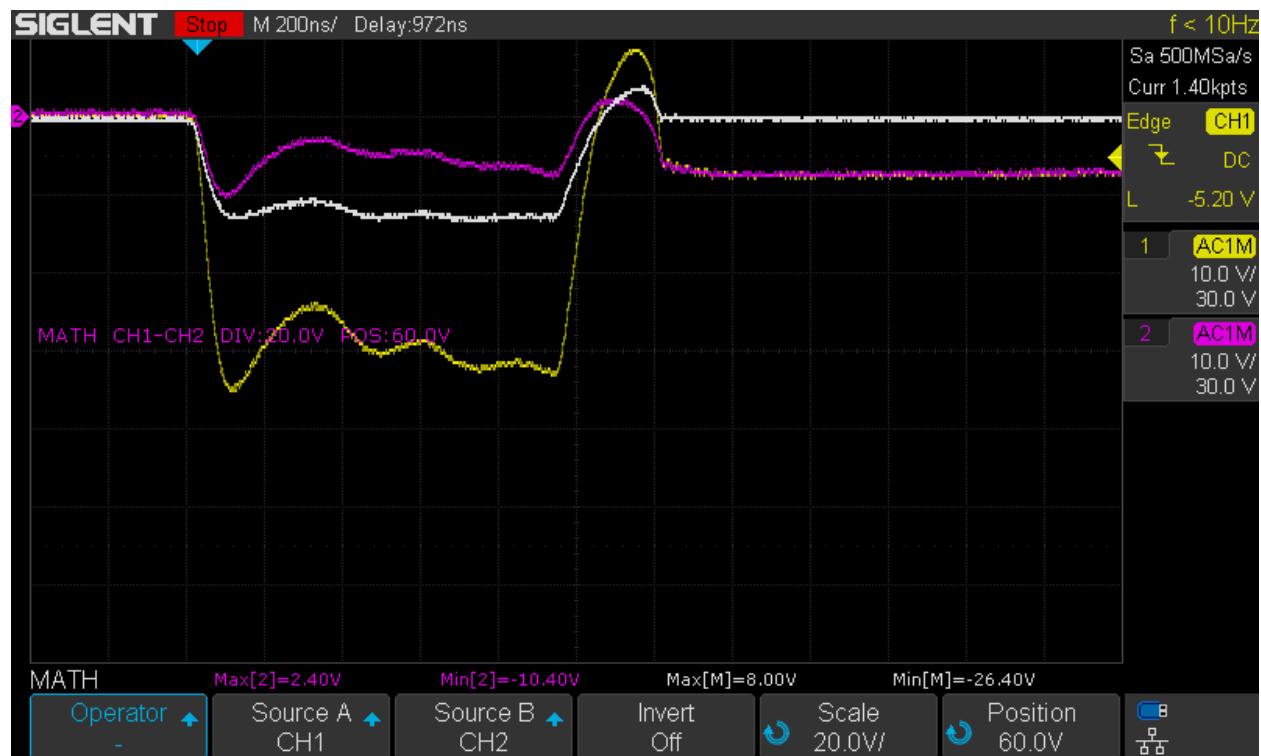
85

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 1us



Current Test

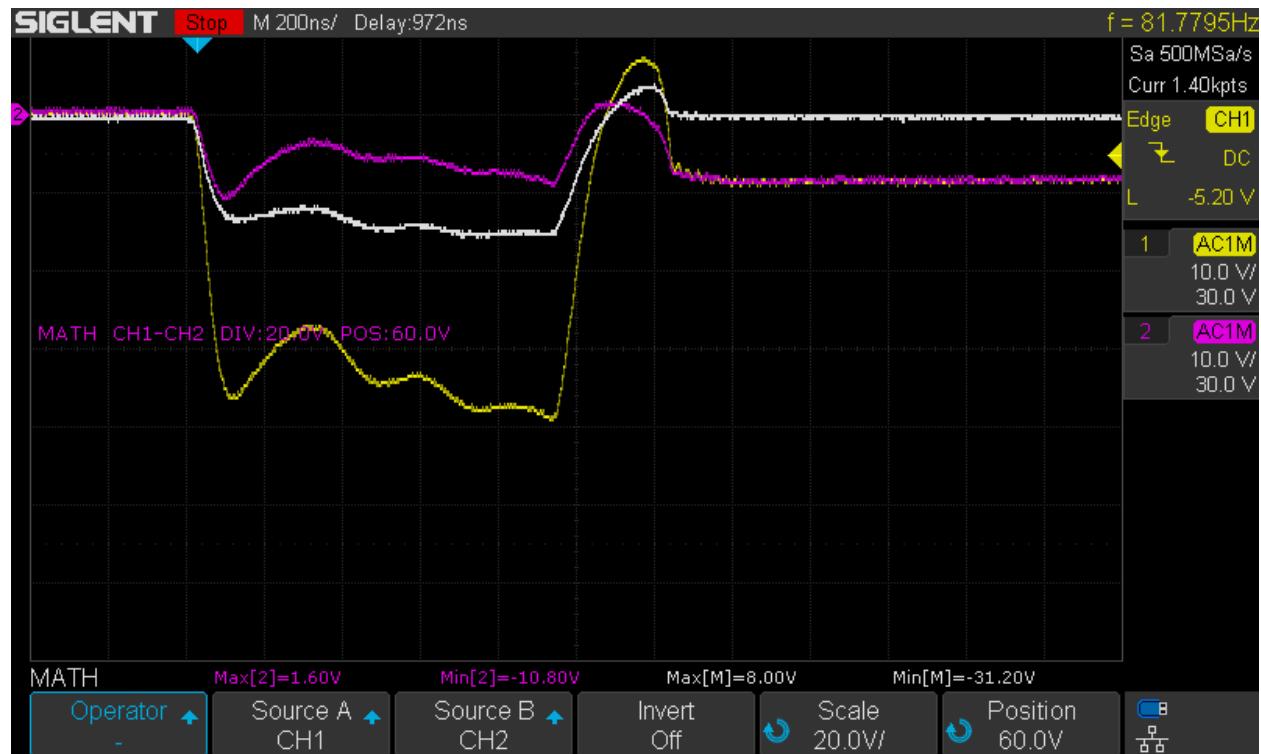
86

GATE: 8.5V

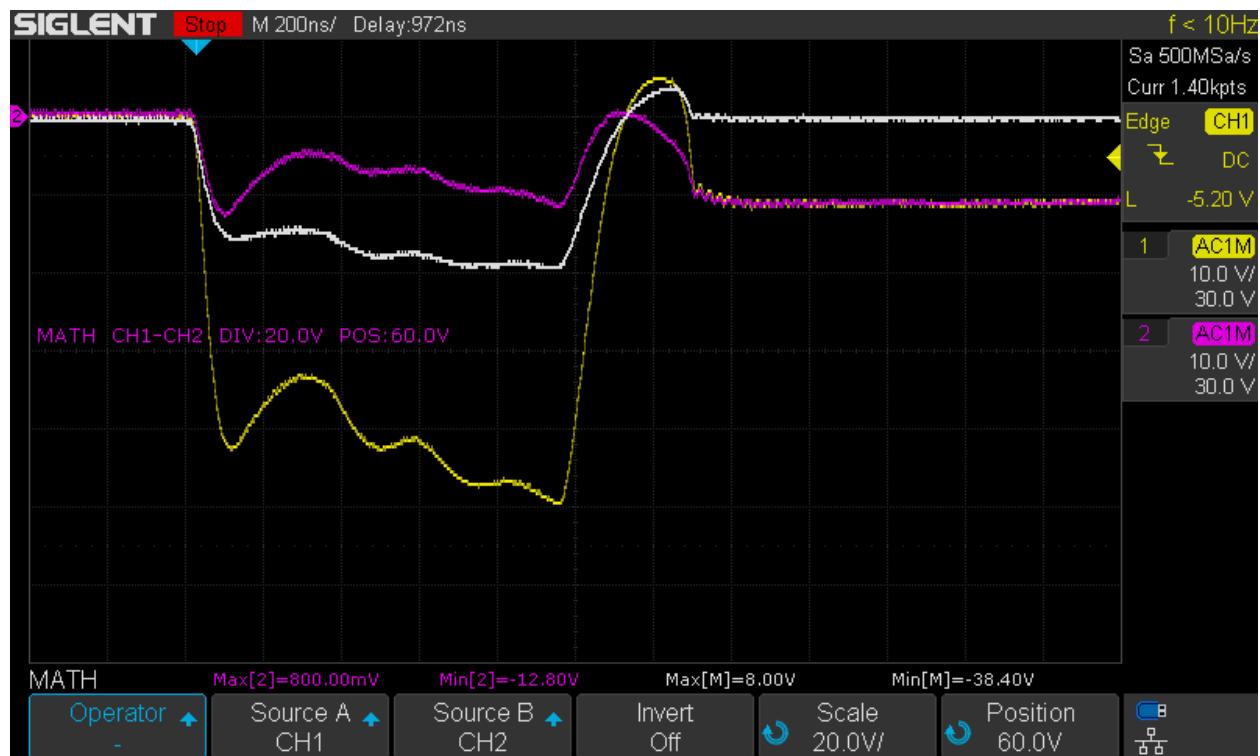
CAP ANODE: 120V

SERIES RESISTOR: R25

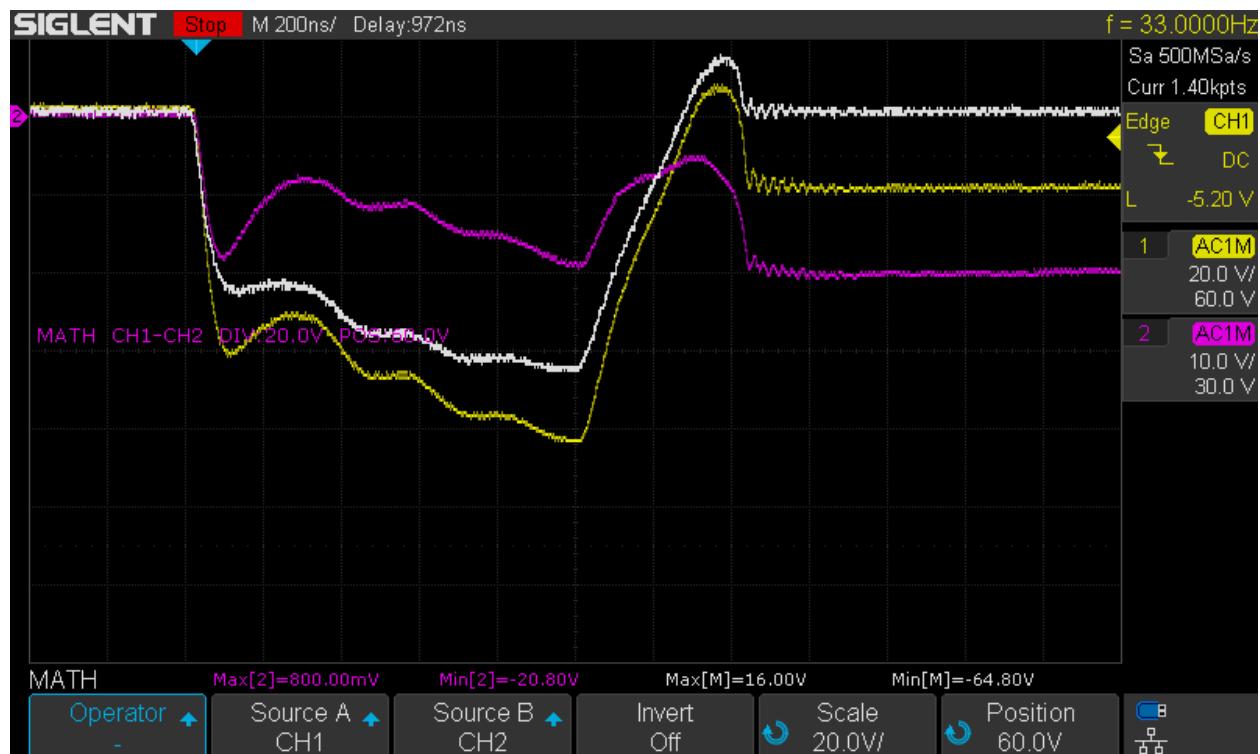
DURATION: 1us



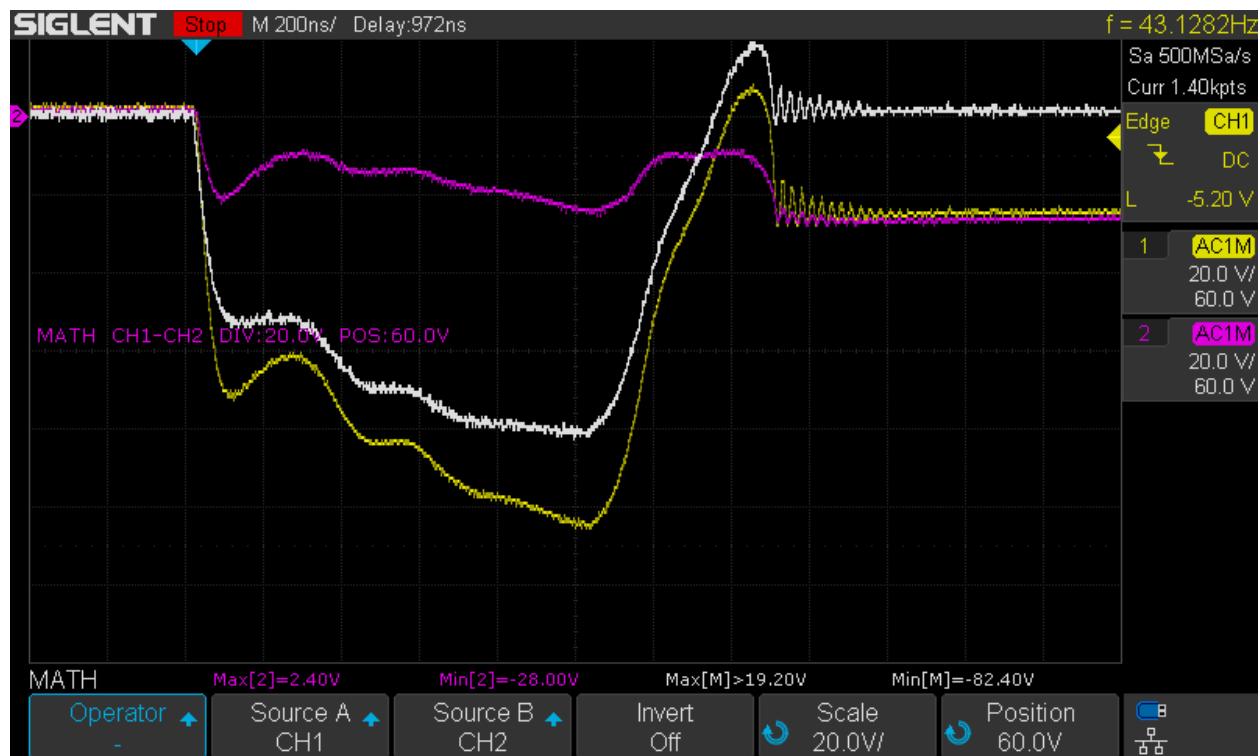
87 GATE: 9.1V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



88, 89 (dup) GATE: 11V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



90, 91 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



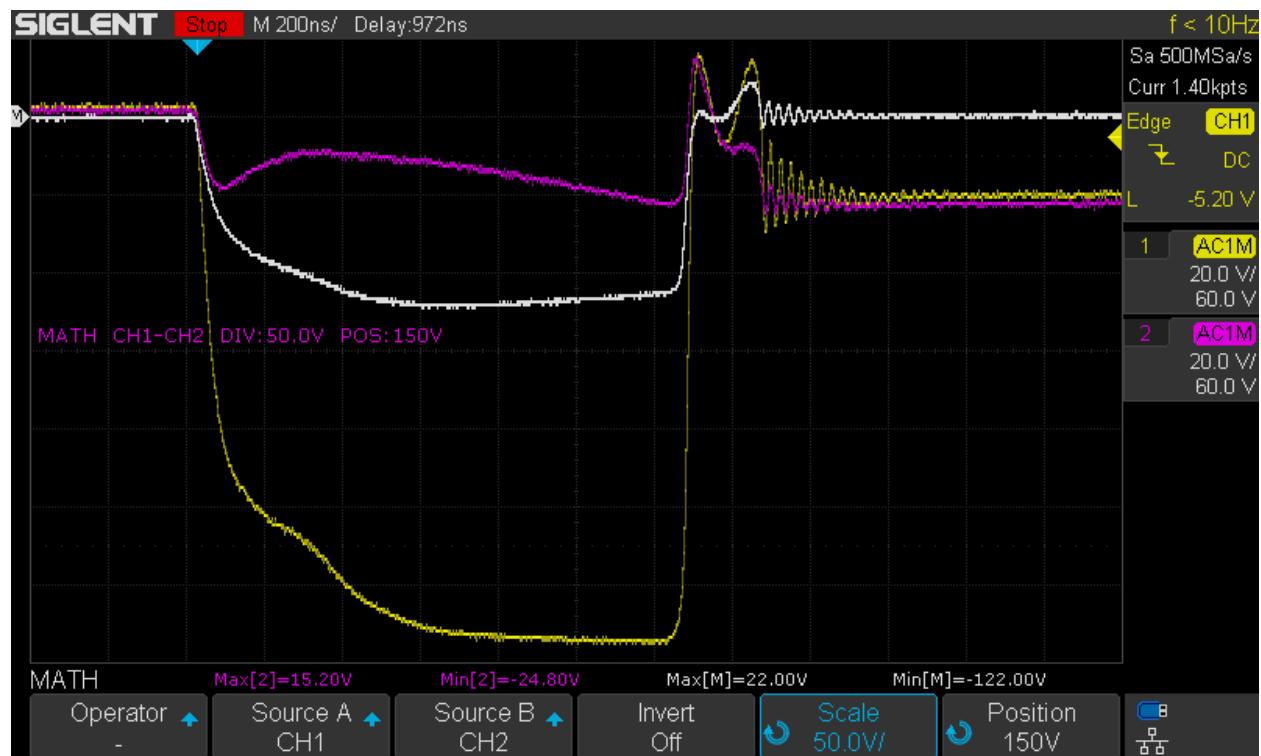
92

GATE: 12.8V

CAP ANODE: 120V

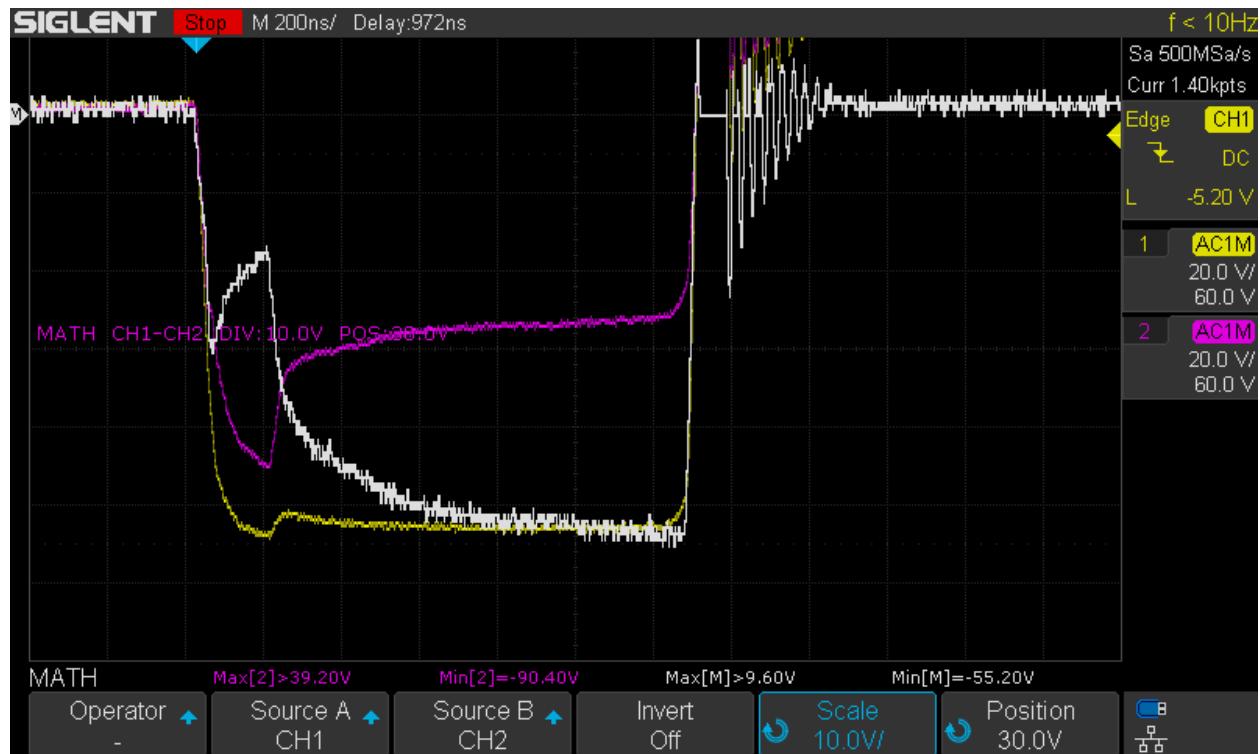
SERIES RESISTOR: R5

DURATION: 1us



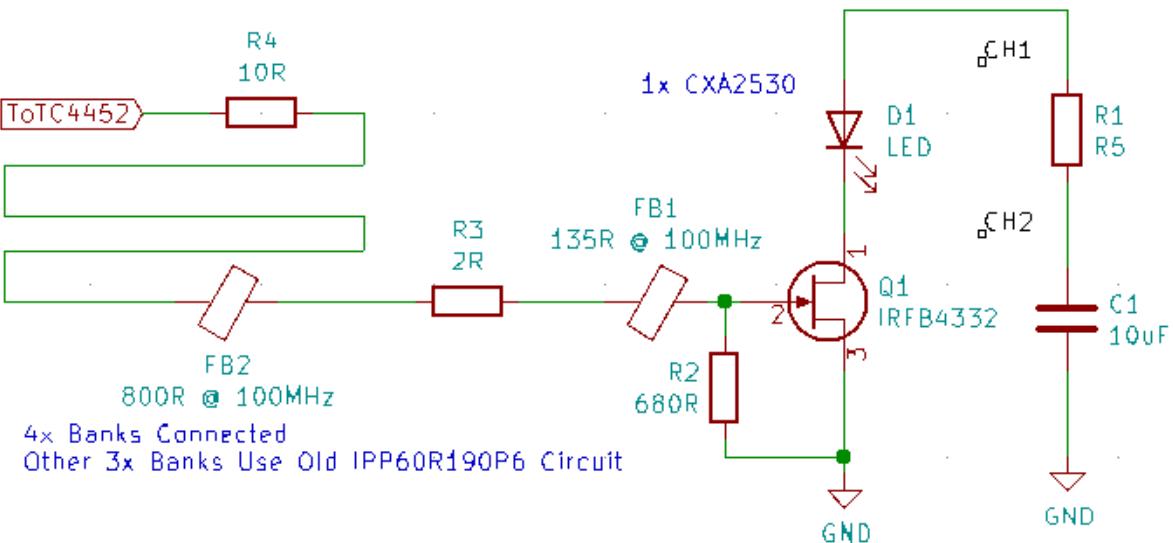
0R5 Current sense resistor

93, 94 (dup) GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

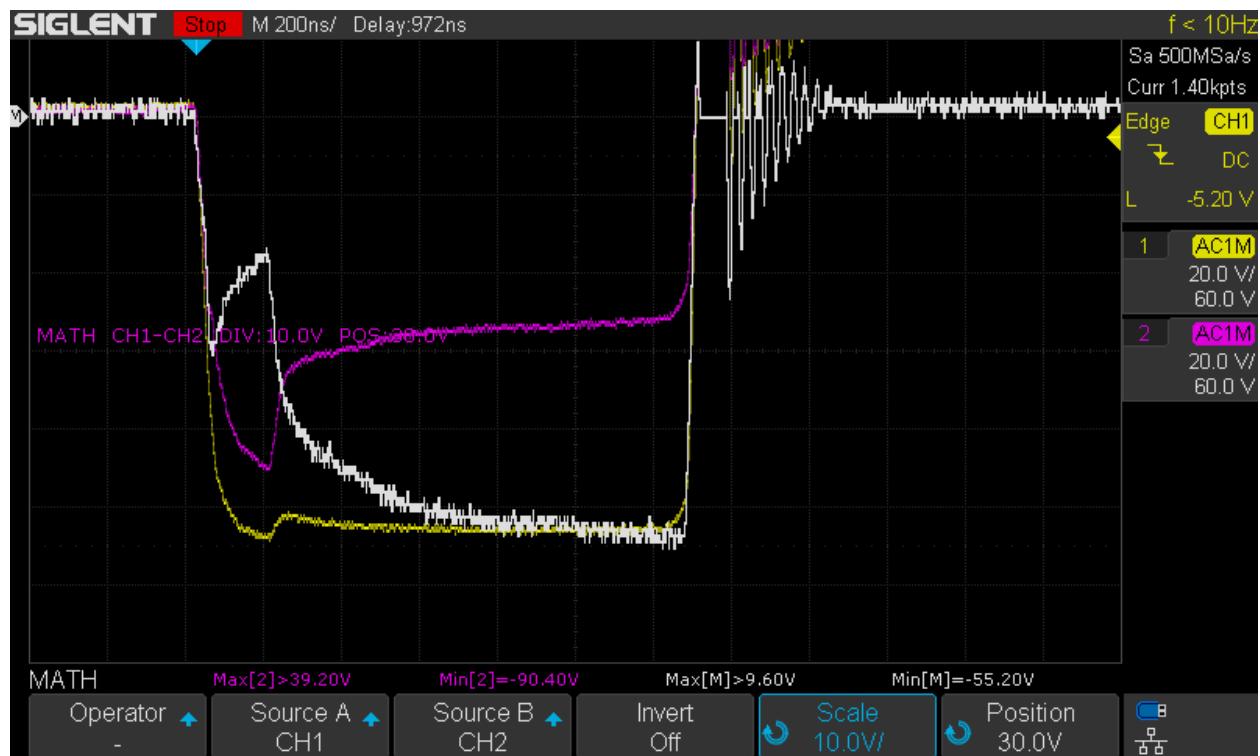


With single CXA2530 LED (T0) in series

Measuring current across R1



95 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



No Change

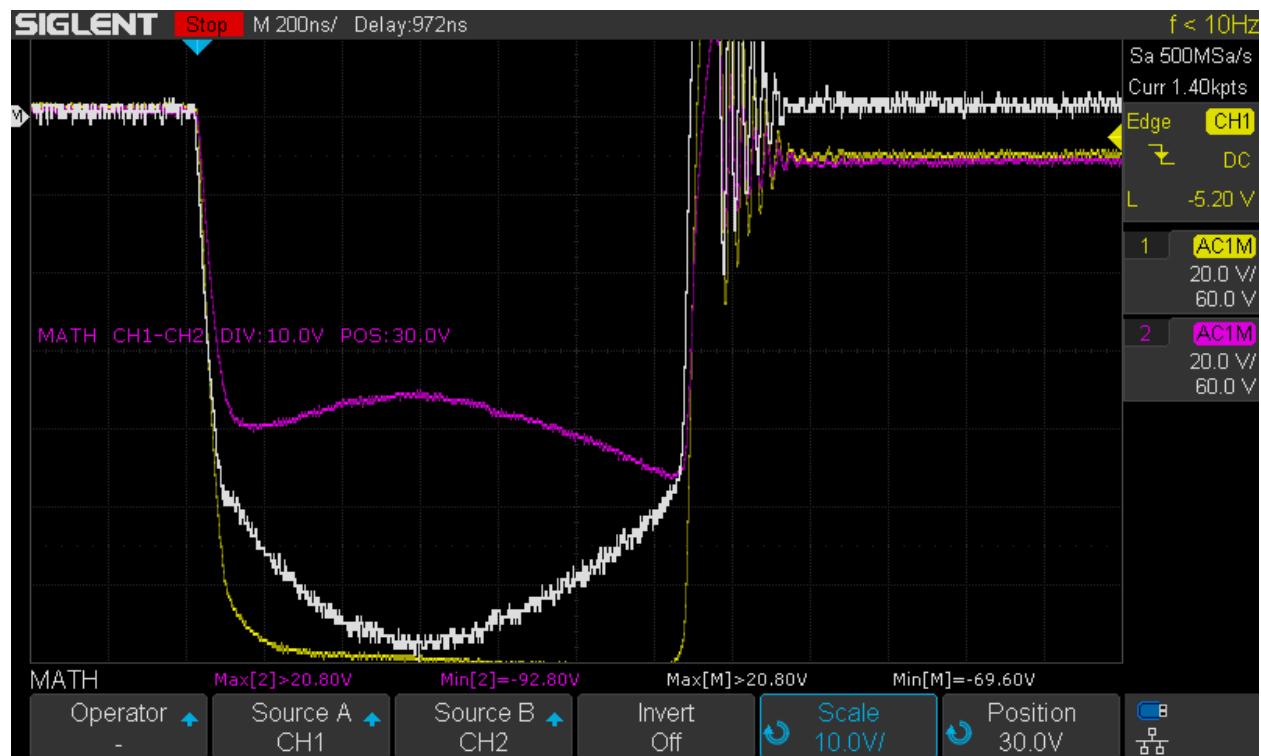
96

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R5

DURATION: 1us



No Change

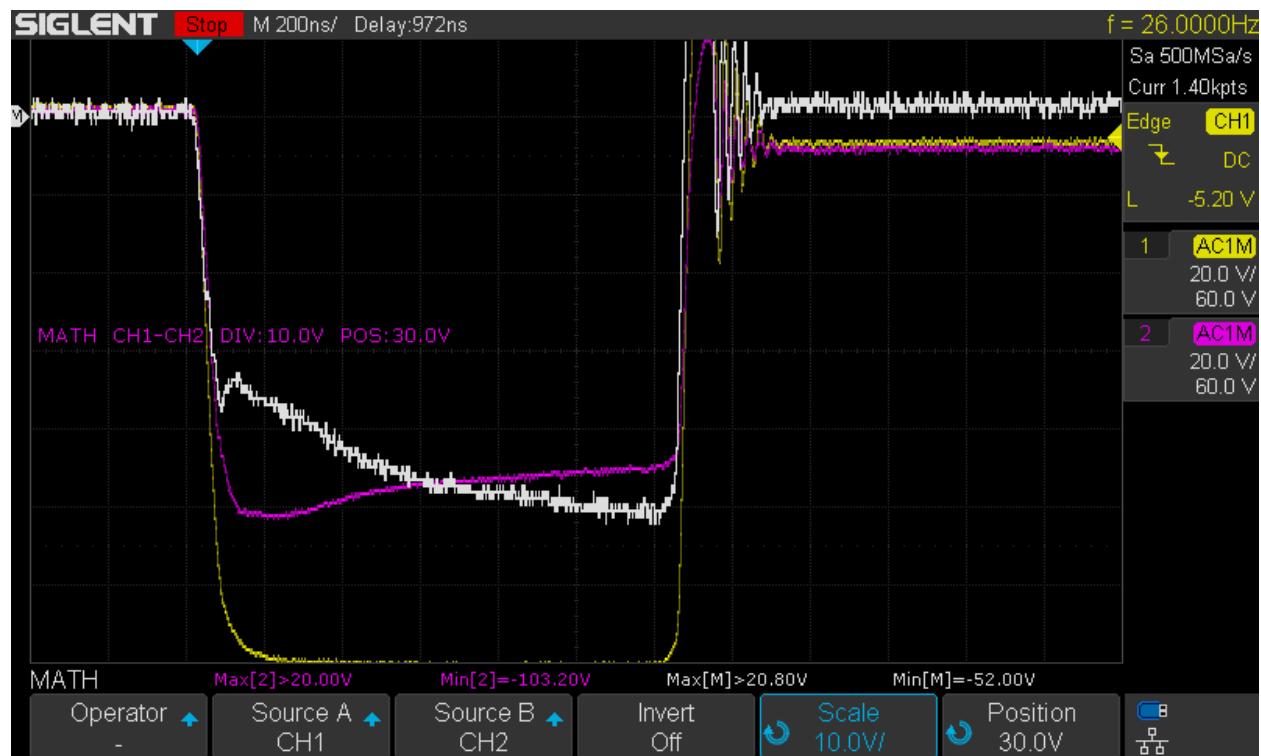
97

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R5

DURATION: 1us



No Change

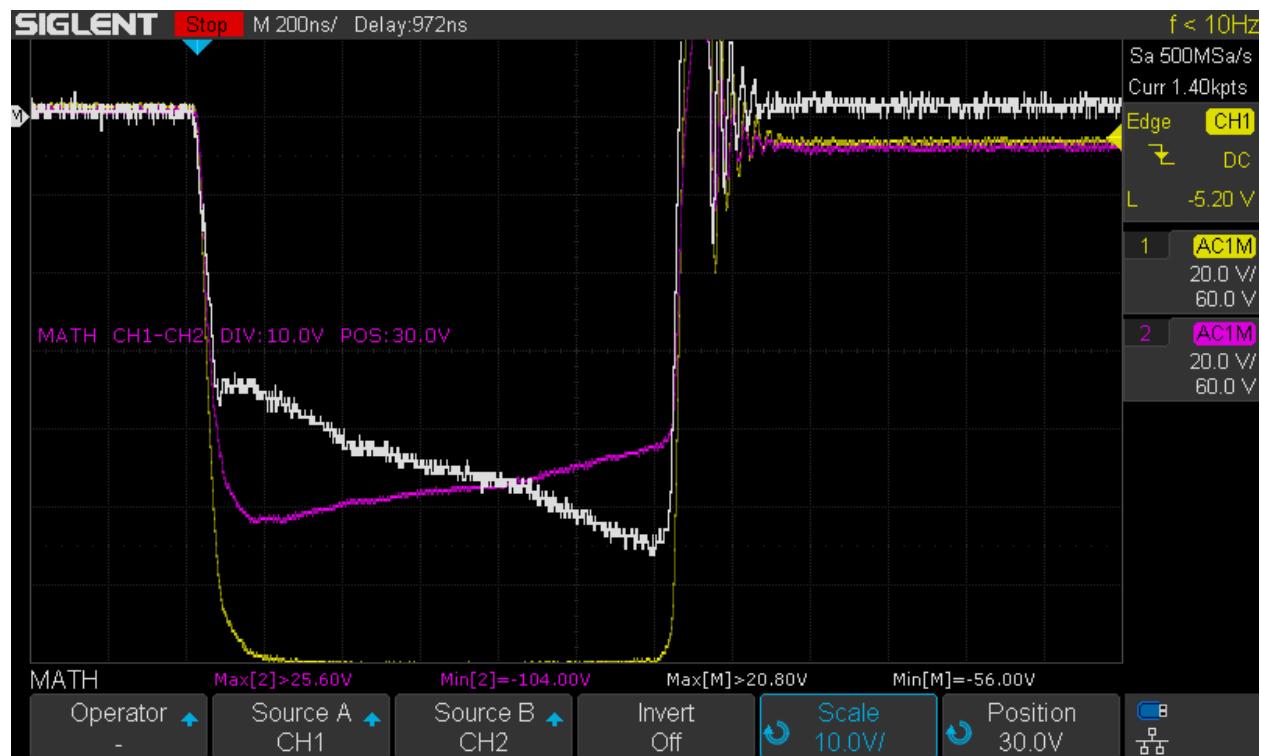
98

GATE: 8V

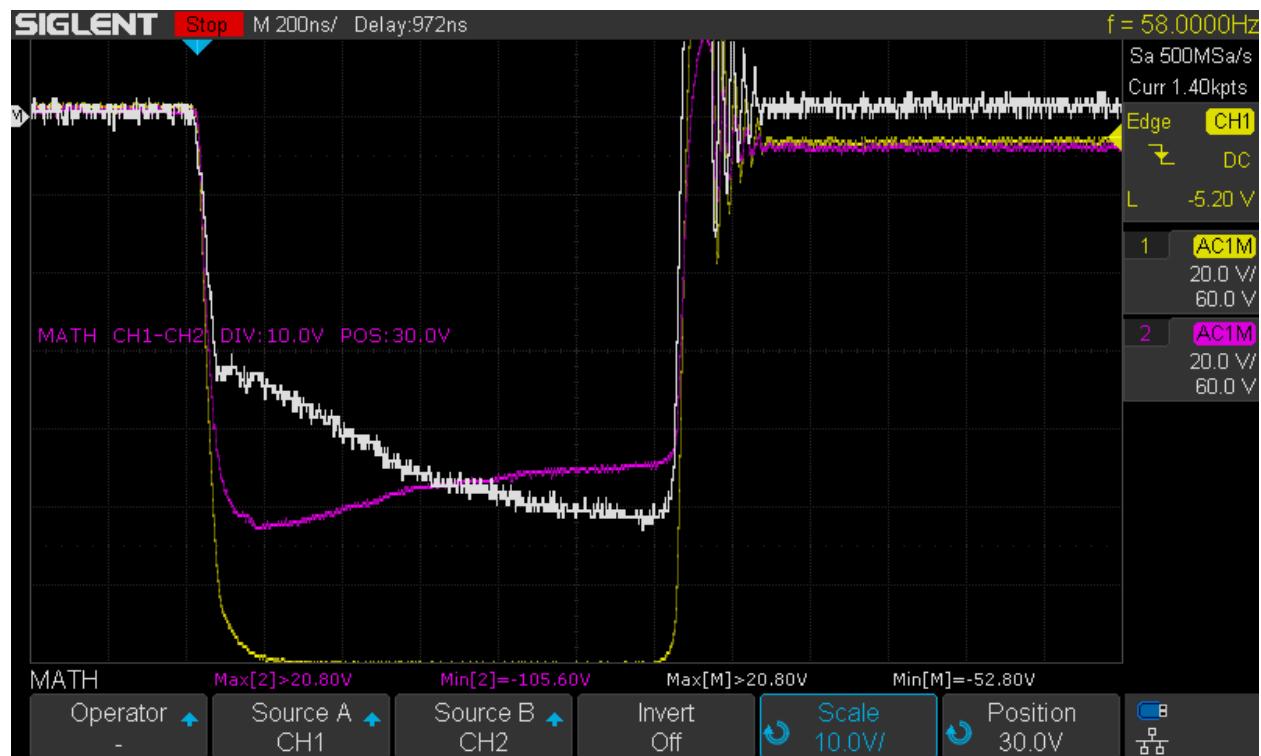
CAP ANODE: 120V

SERIES RESISTOR: R5

DURATION: 1us

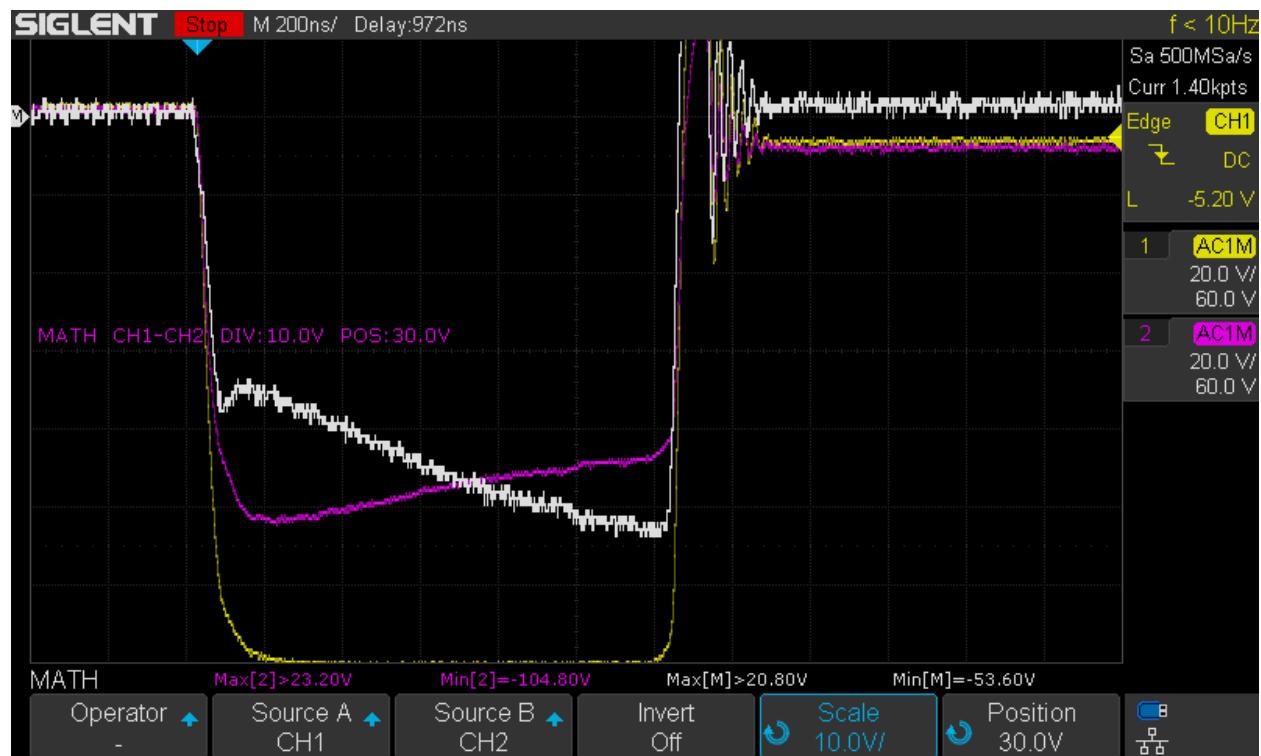


99 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



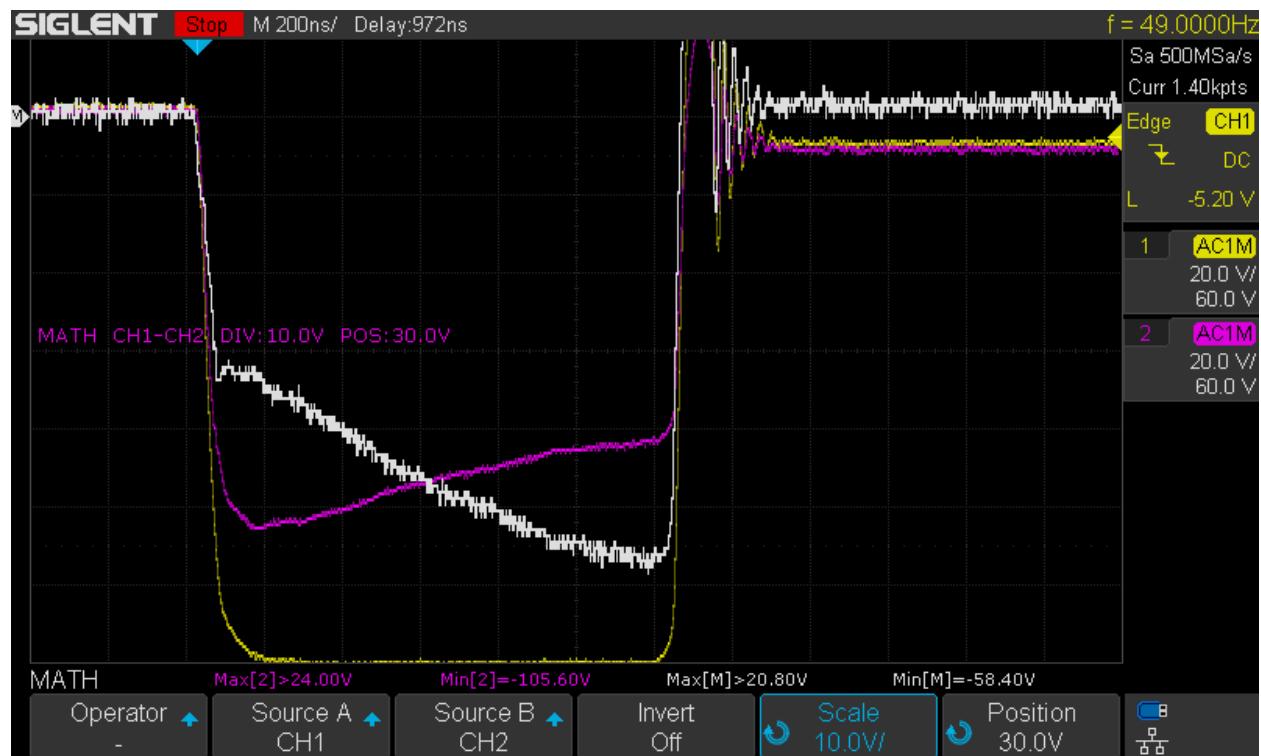
No Change

100 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

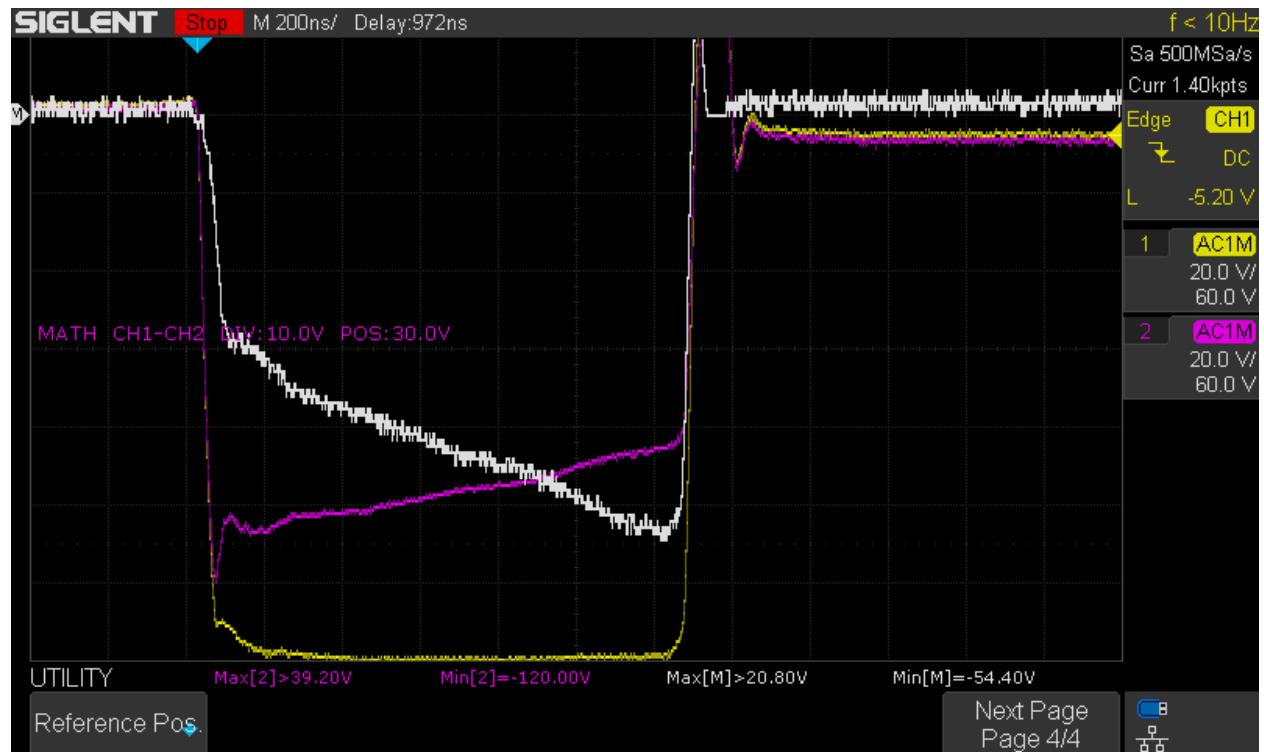


No Change

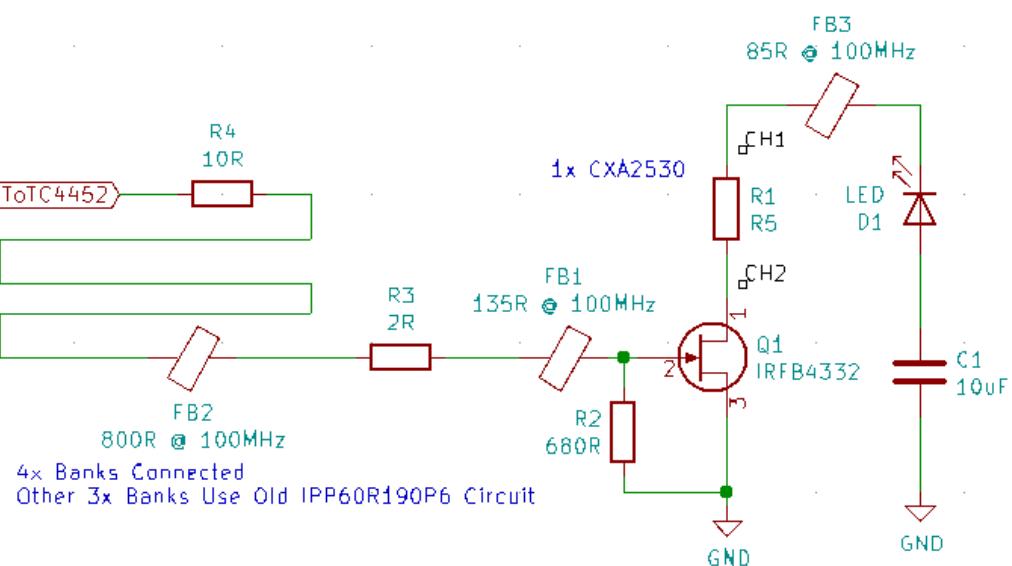
10? GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



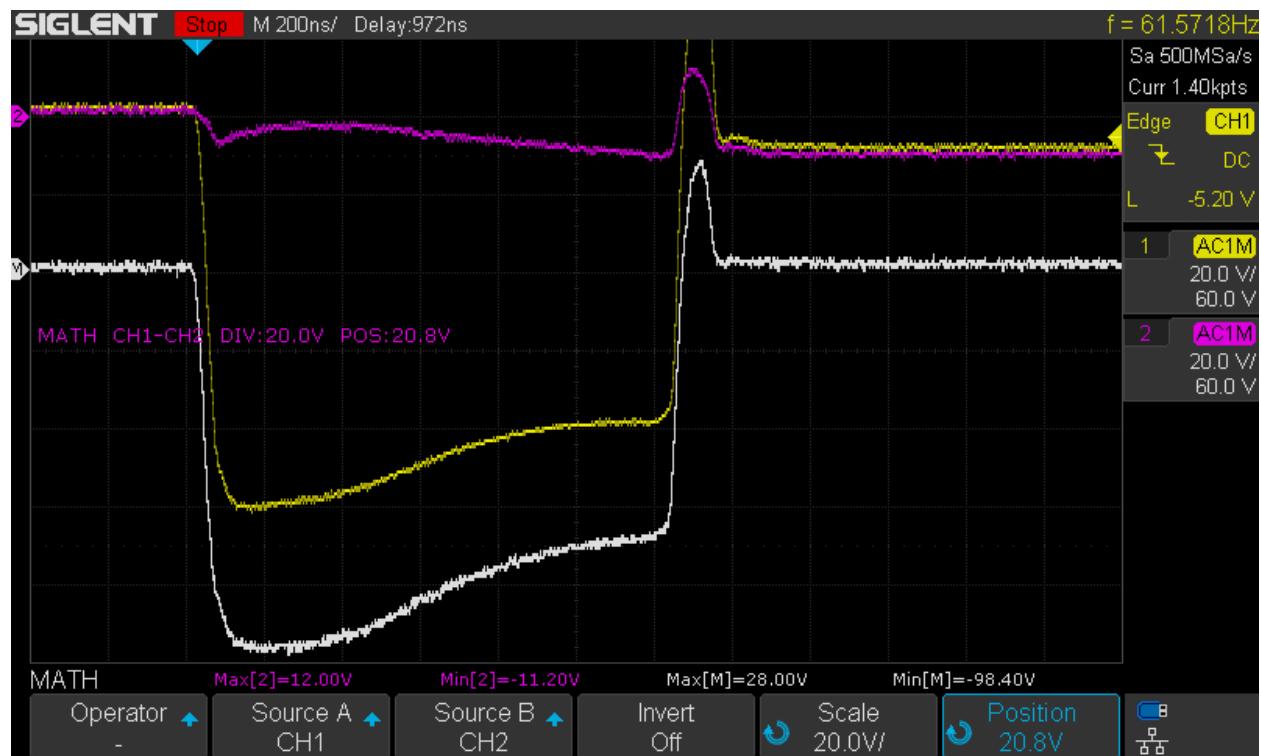
101 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Added 85R @ 100MHz Ferrite Bead in series with LED

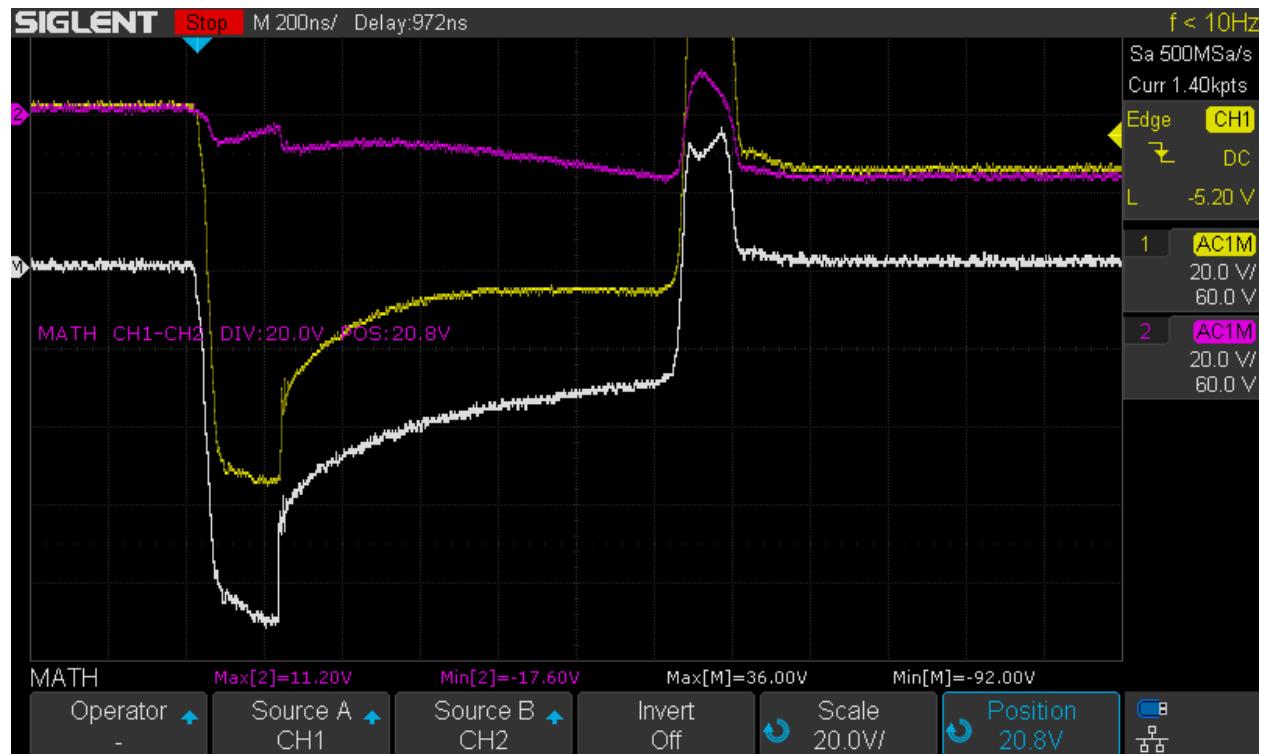


102 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

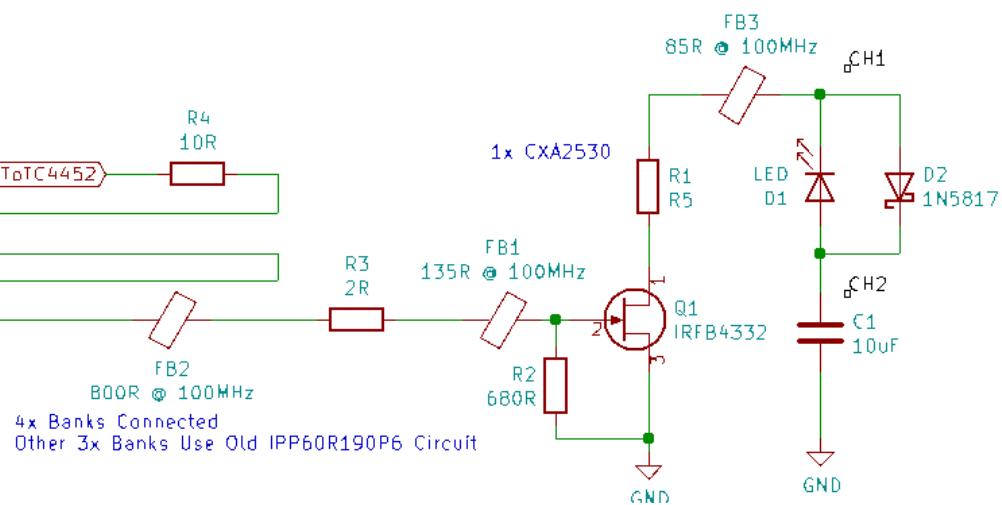


Measuring voltage drop across LED

103 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Added flyback diode across LED



DRAFT 2020-08-23

E2 Flash Development Testing.odt

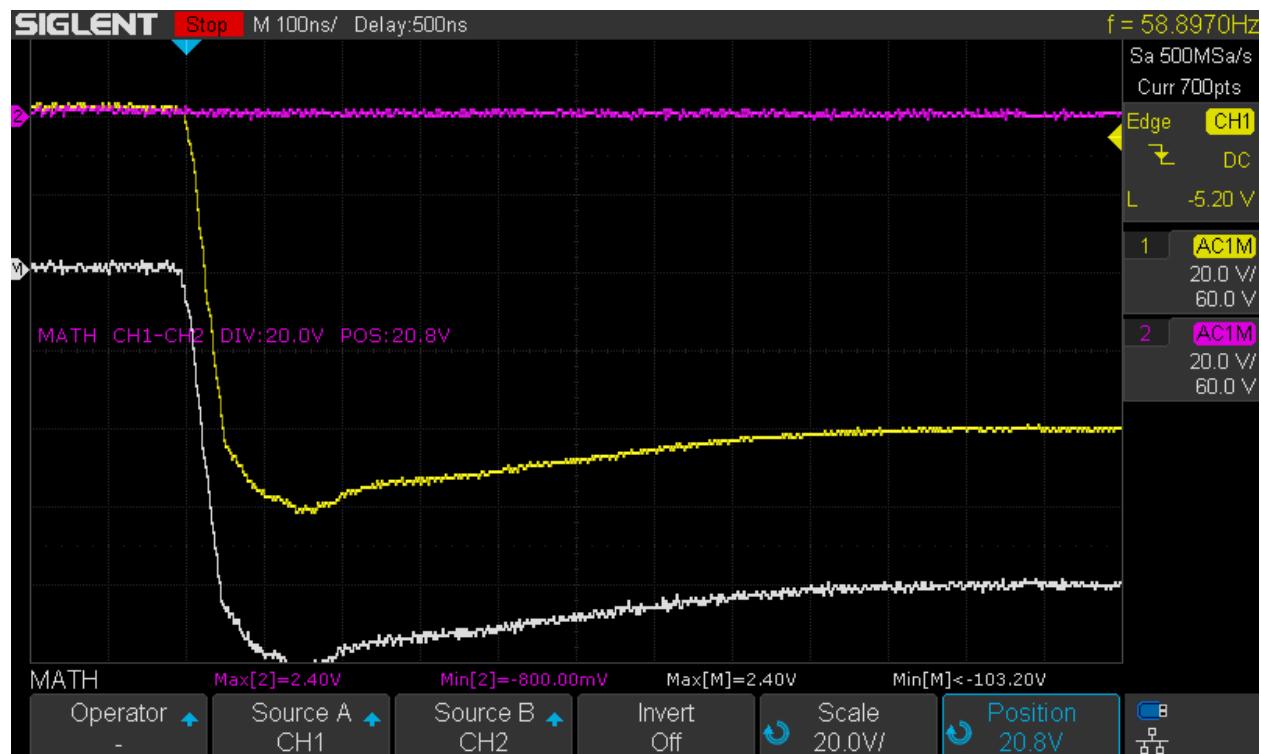
104

GATE: 8V

CAP ANODE: 120V

SERIES RESISTOR: R5

DURATION: 1us



Removed flyback diode, added 2R gate resistor

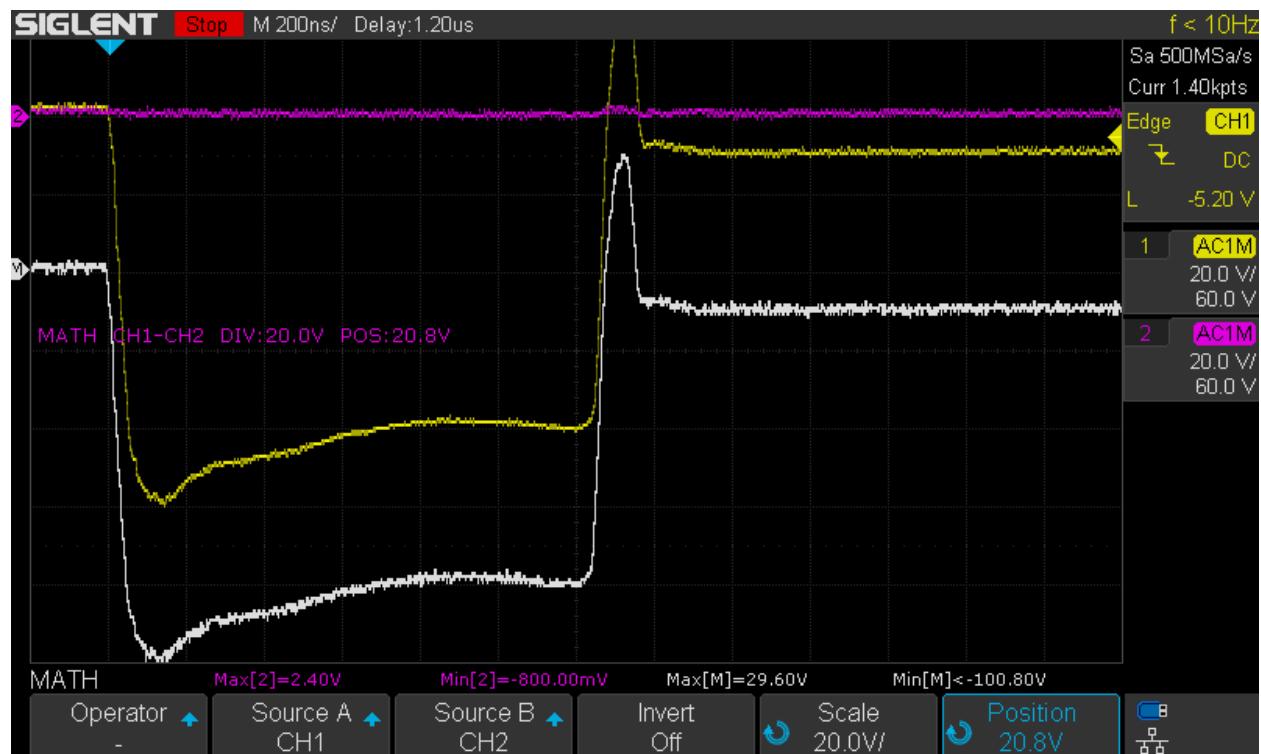
105

GATE: 8V

CAP ANODE: 120V

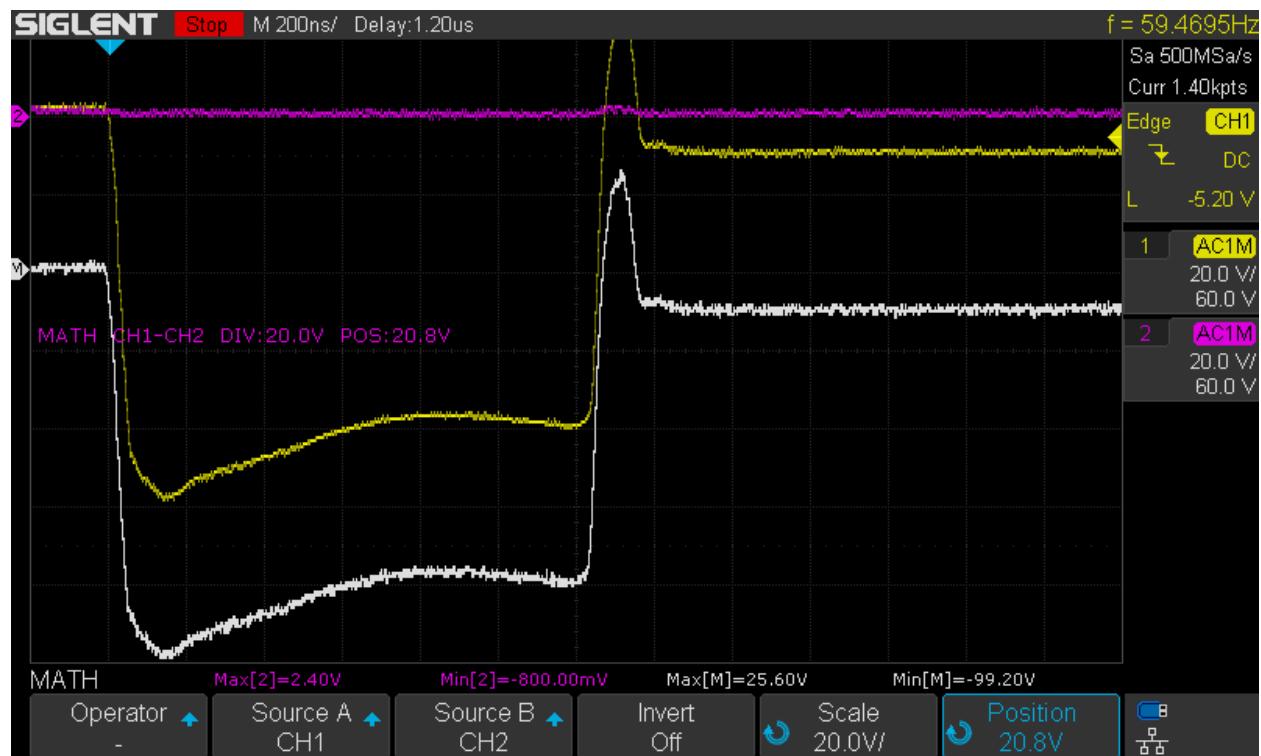
SERIES RESISTOR: R5

DURATION: 1us



No Change

106 GATE: 8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Removed gate wire, soldered ferrite bead directly to control board

Series 5 – LED Repetitive Strobe Testing #1

Overview:

Purpose:

- Testing the effect of repetitive high-voltage strobing on the Cree CXA2530 LED

Equipment:

- E2 Prototype with three banks of LED's in various states of damage, anode voltage limited to 120V
- Single Cree LED switched with IRFB4332 MOSFET, no limit on anode voltage, TC4452 voltage at 12.8V
- Integrating sphere and active light probe measuring output of single LED

Procedure

- Firmware modified to execute 1,000 consecutive 1-microsecond strobes at 8Hz.
- Oscilloscope is not capable of recording data automatically at that rate, so the screen is recorded using a DSLR

Results:

- Because of a bug in the firmware (which was also present in all previous Edgerton firmware), occasionally the microcontroller will enter an interrupt routine while the LED is on, resulting in a long strobe. This occurs several times every 1,000 strobes.
- Strobe duration seems to be a significant factor in LED damage. The firmware issue was corrected following these test series.
- Damage to the LED occurred at 100V, which is unacceptably low. This damage was likely due to the long duration strobes. Testing continued as the LED's damage seemed to be intermittent and functioned correctly, at times, at much higher voltages.
- MVI_9227_80V.mp4 – Firmware issue causes long pulses
- MVI_9229_100V.crop – Started off with signs of damage, after a long pulse it seems to have self-repaired, another long pulse didn't cause damage, all subsequent tests start off with fluctuations but seem to normalize after several
- MVI_9230_110V.crop – Multiple long pulses
- MVI_9237_170V – Eventual decrease in power

Test Data:

- See Appendix A

Series 6 – LED Repetitive Strobe Testing #2

Overview:

Purpose:

- Testing the effect of repetitive high-voltage strobing on the Cree CXA2530 LED

Equipment:

- E2 Prototype with three banks of LED's in various states of damage, anode voltage limited to 120V
- Single Cree LED switched with IRFB4332 MOSFET, no limit on anode voltage, TC4452 voltage at 12.8V
- Integrating sphere and active light probe measuring output of single LED

Procedure

- Firmware modified to execute 1,000 consecutive 4-microsecond strobes at 8Hz.
- Oscilloscope is not capable of recording data automatically at that rate, so the screen is recorded using a DSLR

Results:

- MVI_9245_143V.crop.mp4 – Noise in some frames, nothing wrong with LED strobing
- MVI_9246_161V.crop.mp4 – Slight decrease in power after several hundred strobes, Significant decrease after several more

Test Data:

- See Appendix B

Series 7 – LED Repetitive Strobe Testing #3

Overview:

Purpose:

- Testing the effect of repetitive high-voltage strobing on the Cree CXA2530 LED

Equipment:

- E2 Prototype with three banks of LED's in various states of damage, anode voltage limited to 120V
- Single Cree LED switched with IRFB4332 MOSFET, no limit on anode voltage, TC4452 voltage at 12.8V
- Integrating sphere and active light probe measuring output of single LED

Procedure

- Firmware modified to execute 1,000 consecutive strobos at 10Hz.
- Oscilloscope is not capable of recording data automatically at that rate, so the screen is recorded using a DSLR
- 1000x cycles @ 10Hz, 4x strobos per cycle @ 50us between strobos, 4us strobe
- Each set increments 10V, starting at 80V and ending at partial failure at 150V
- Partial Failure @ 150V (MVI_9259.MOV)
- Frame 881 / 0:36.7
- tail ends of Strobes 3, 4 fall off rapidly
-
- Frame 1929 / 1:20.5
- Strobes 3, 4 drop
- Strobe 2 appears to drop faster?
-
- Frame 1945 / 1:21.1
- Strobe 4 doesn't start at full power
-

- After that, power drops here and there
-
- Starting voltage is consistent throughout run
- Ending voltage is higher at end of run

Test Data:

- See Appendix C

Series 8 – LED Current Testing

Overview:

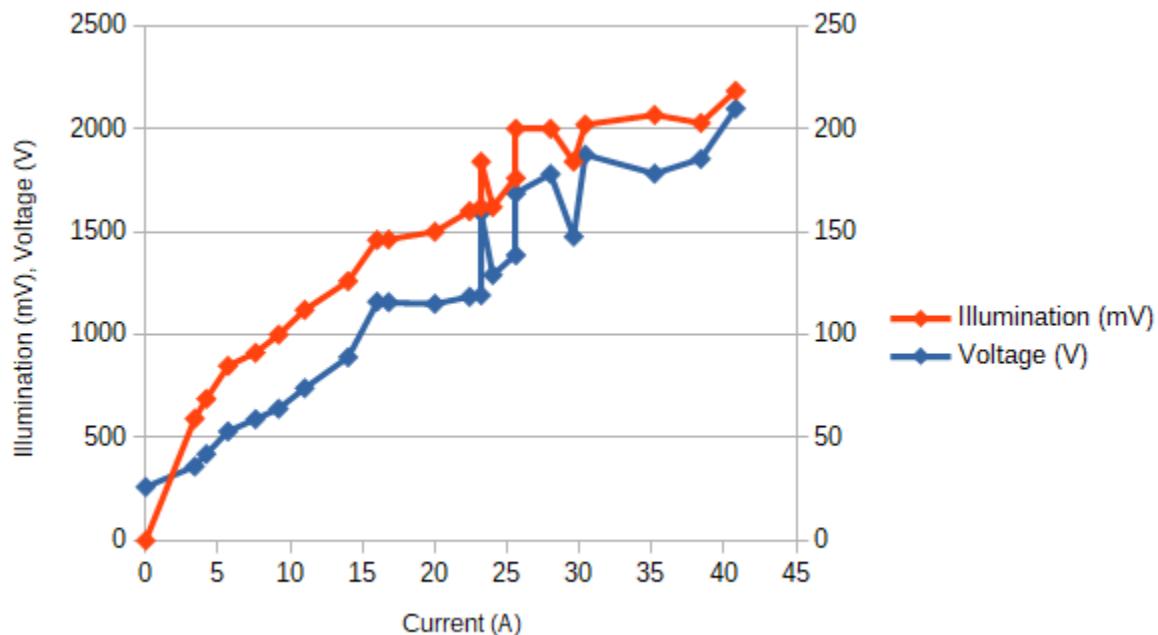
Purpose:

- To measure the Current-Voltage relationship of the Cree CXA2530 LED
- To measure the Current-Light Output relationship of the Cree CXA2530 LED

Equipment:

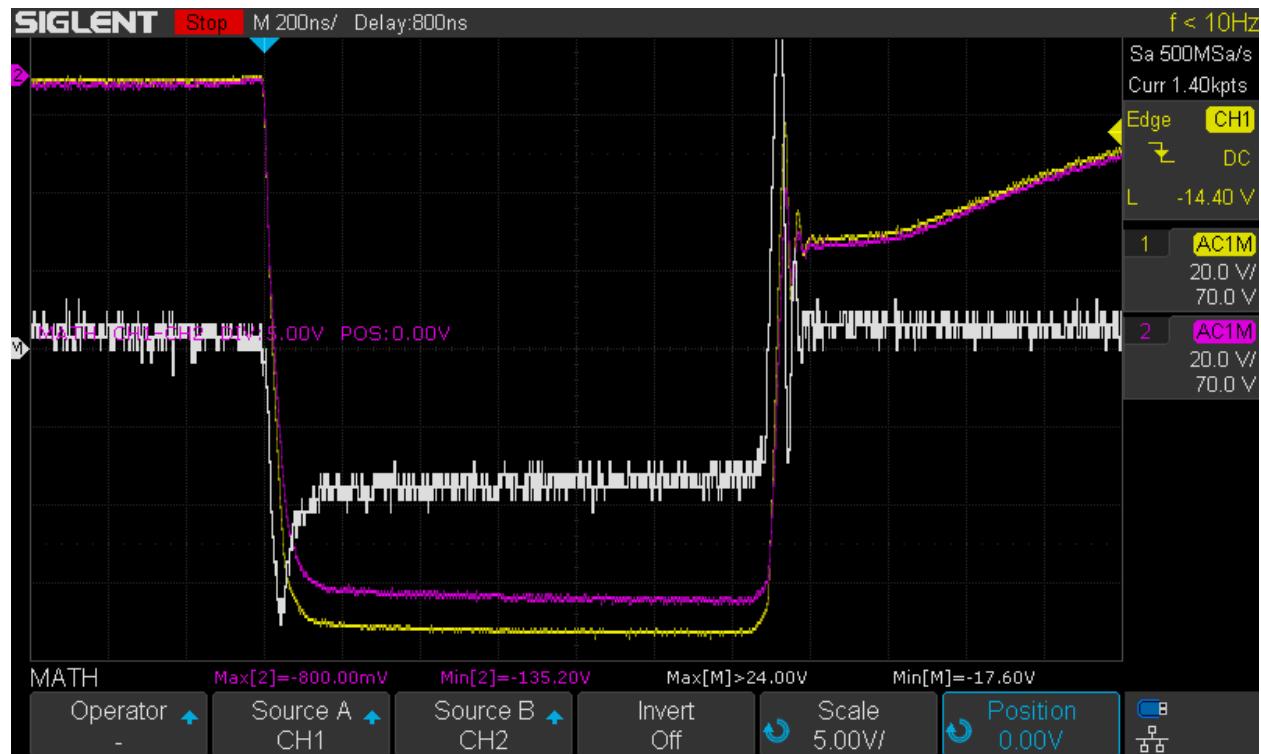
- E2 Prototype with four banks of LED's in various states of damage
 - IPPR60 MOSFET's

Results:



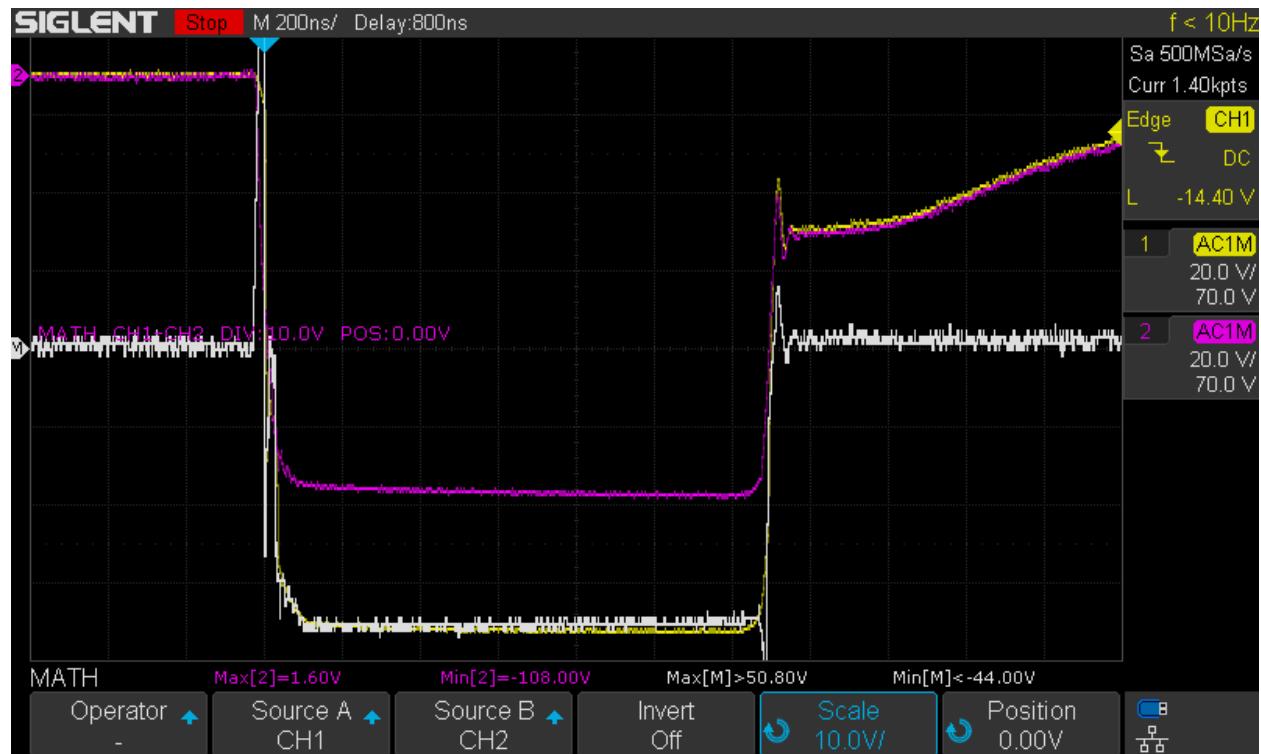
Test Data:

107, 108 (dup) GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: R5 DURATION: 1us



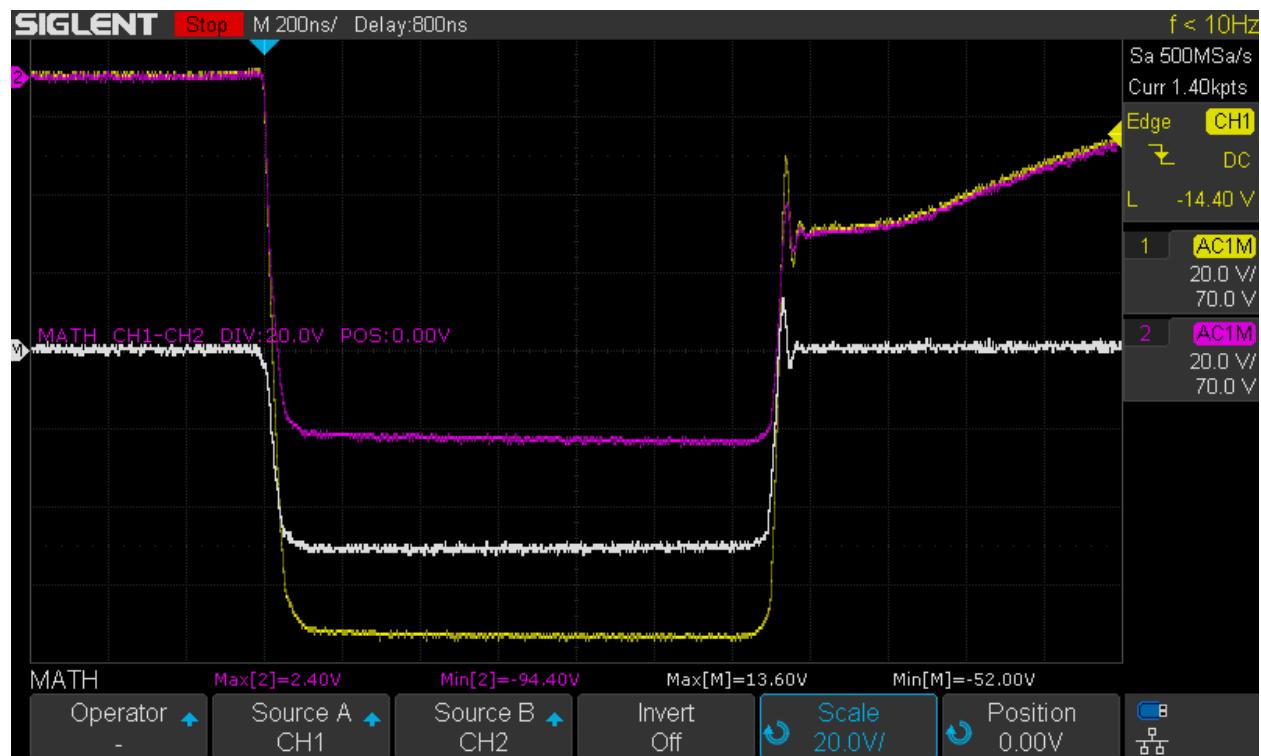
Current Test

109, 110 (dup) GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 2R5 DURATION: 1us



Current Test

111 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 4R5 DURATION: 1us



Current Test

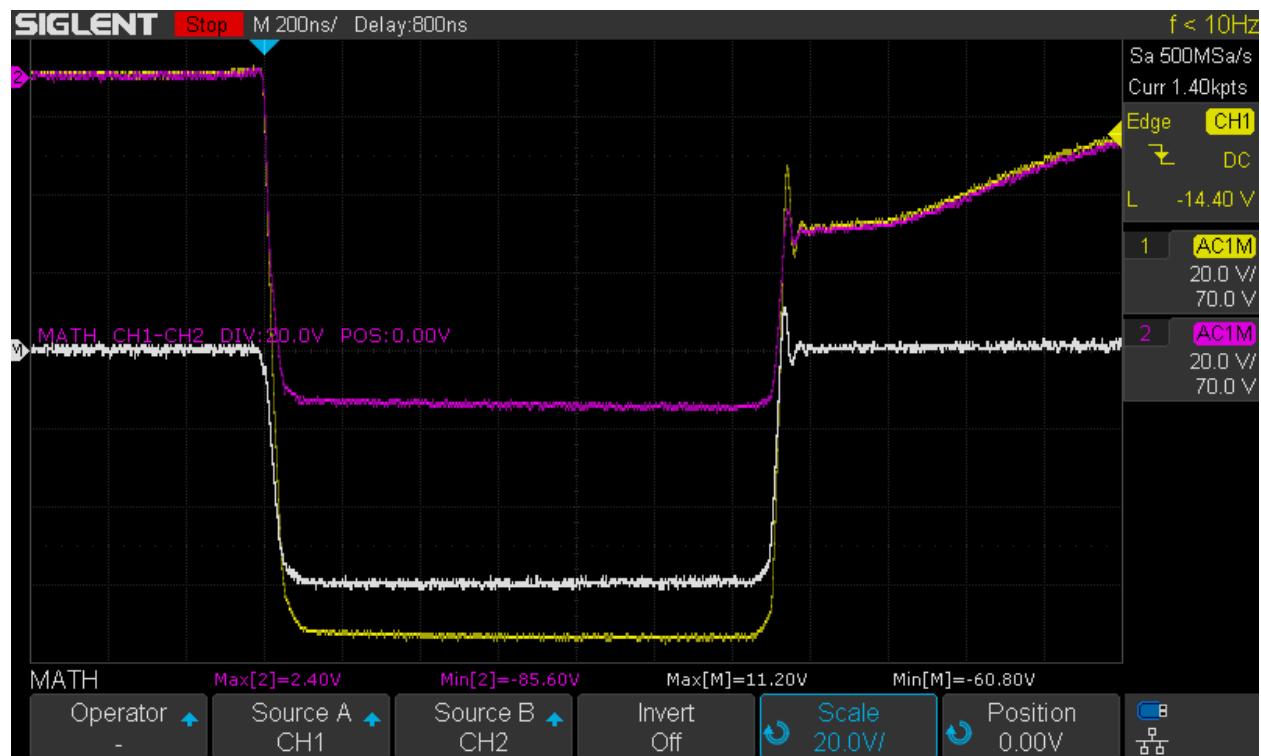
112

GATE: 12.8V

CAP ANODE: 124V

SERIES RESISTOR: 6R5

DURATION: 1us



Current Test

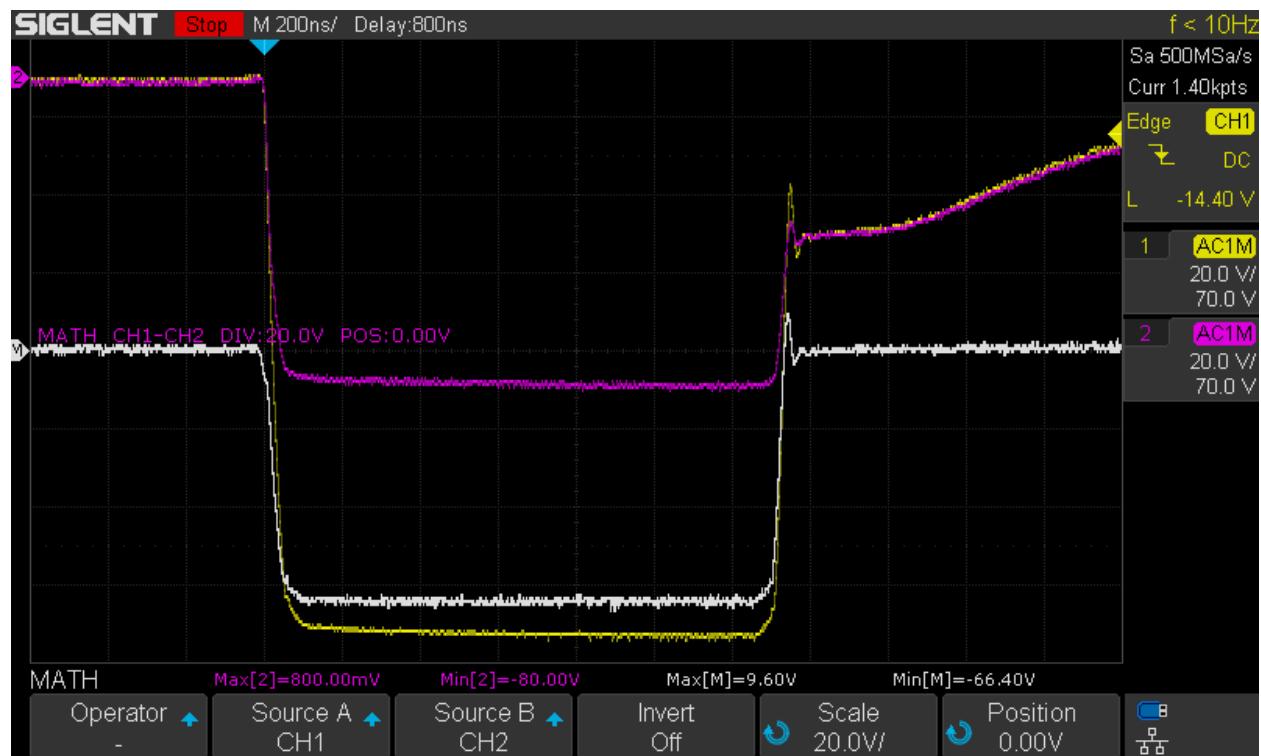
113

GATE: 12.8V

CAP ANODE: 124V

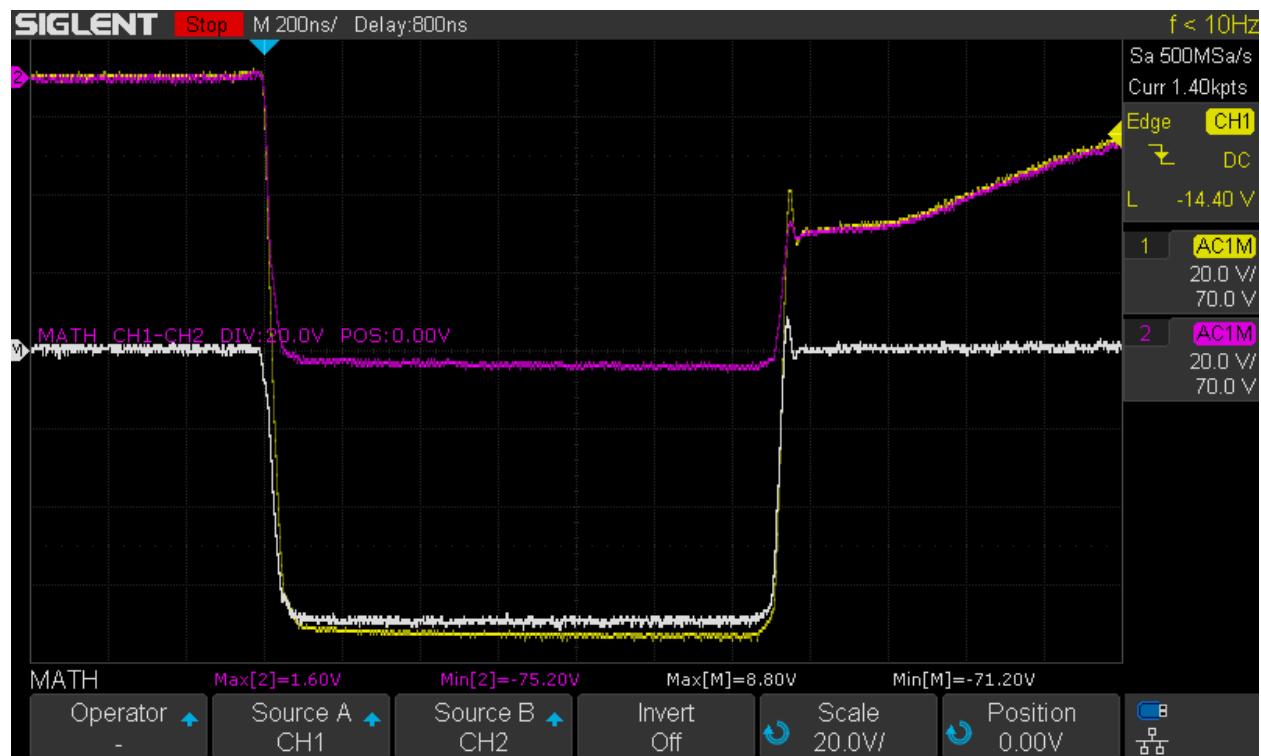
SERIES RESISTOR: 8R5

DURATION: 1us



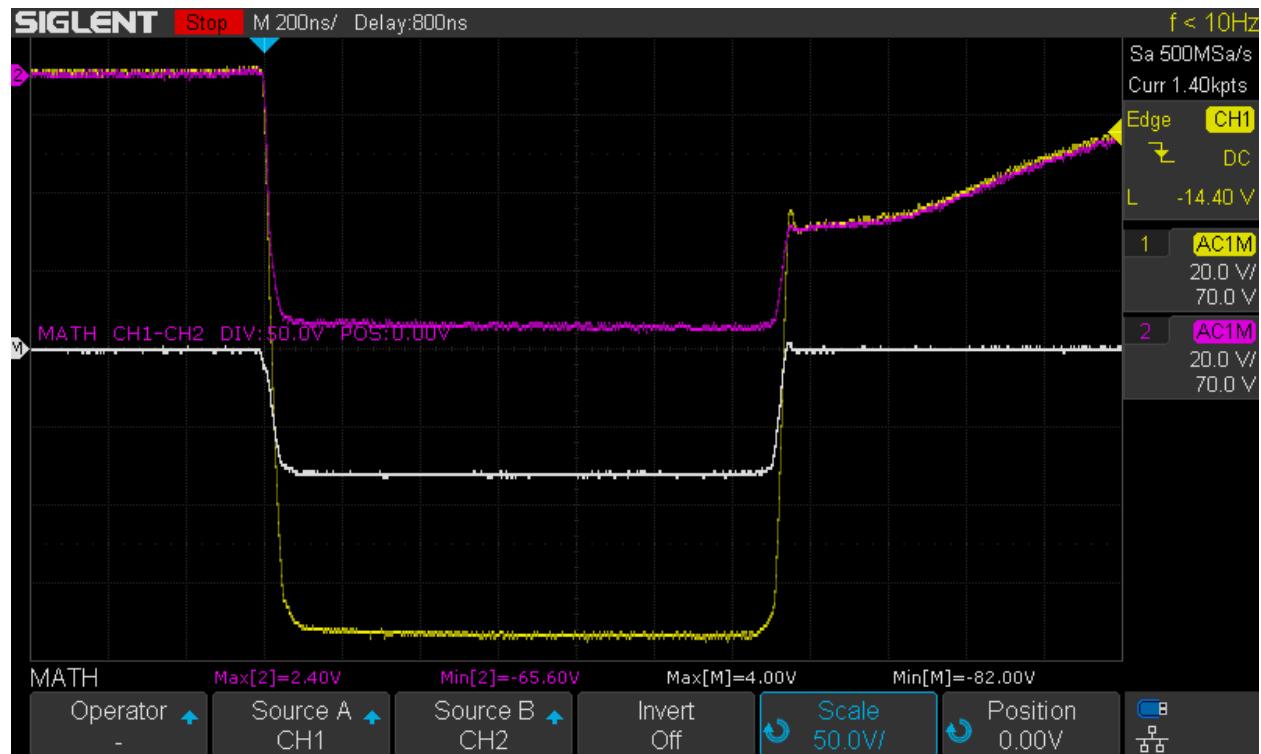
Current Test

114 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 10R5 DURATION: 1us



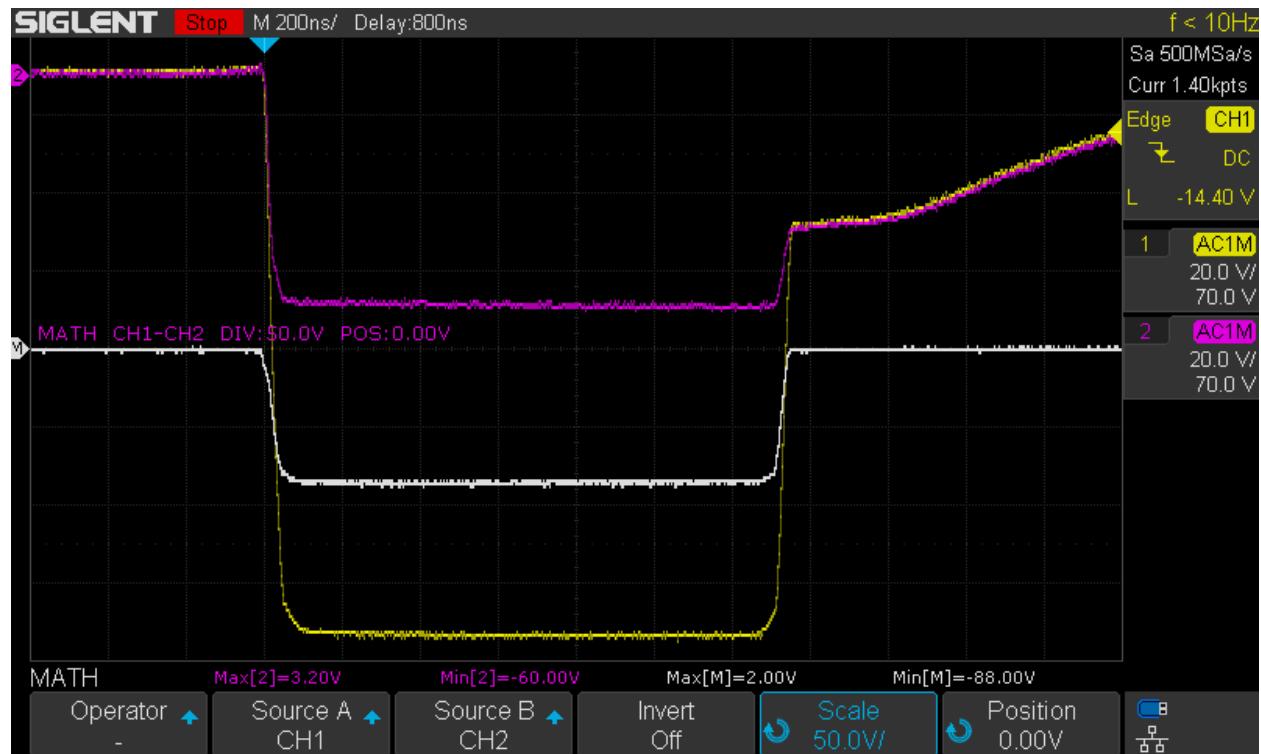
Current Test

115, 116 (dup) GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 19R3 DURATION: 1us



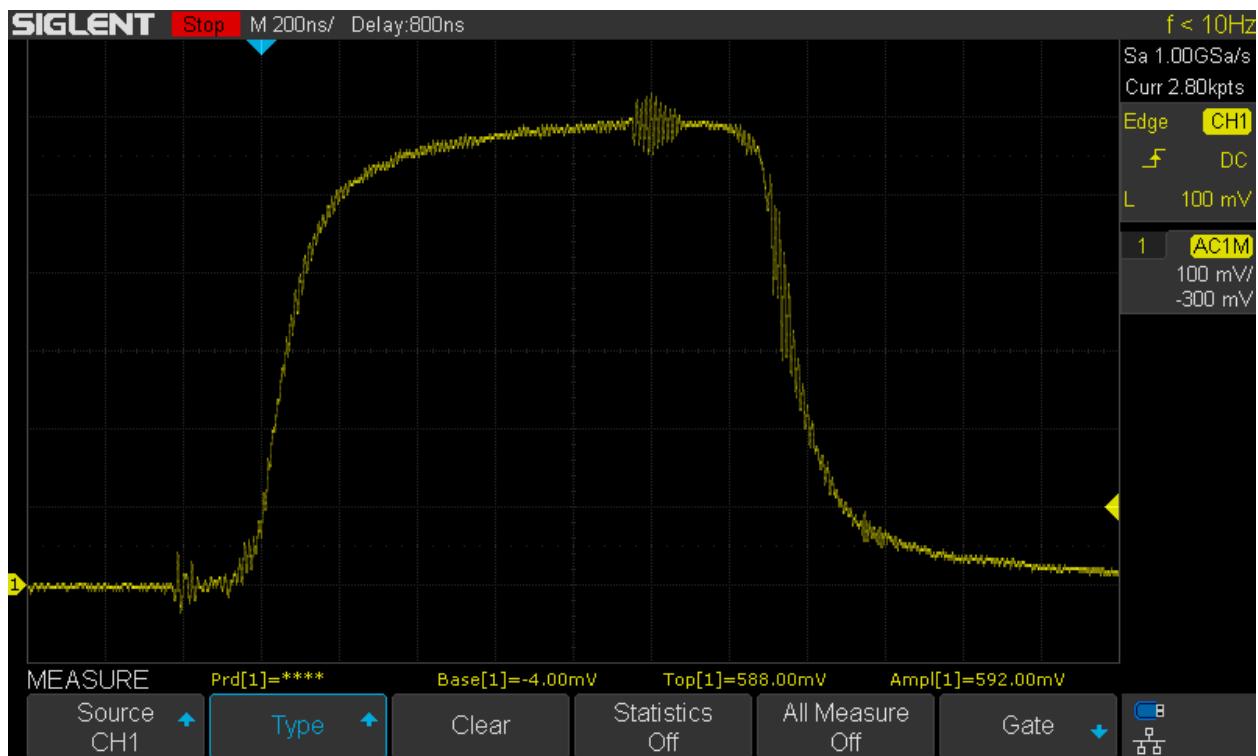
Current Test

117, 118 (dup) GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 26R1 DURATION: 1us



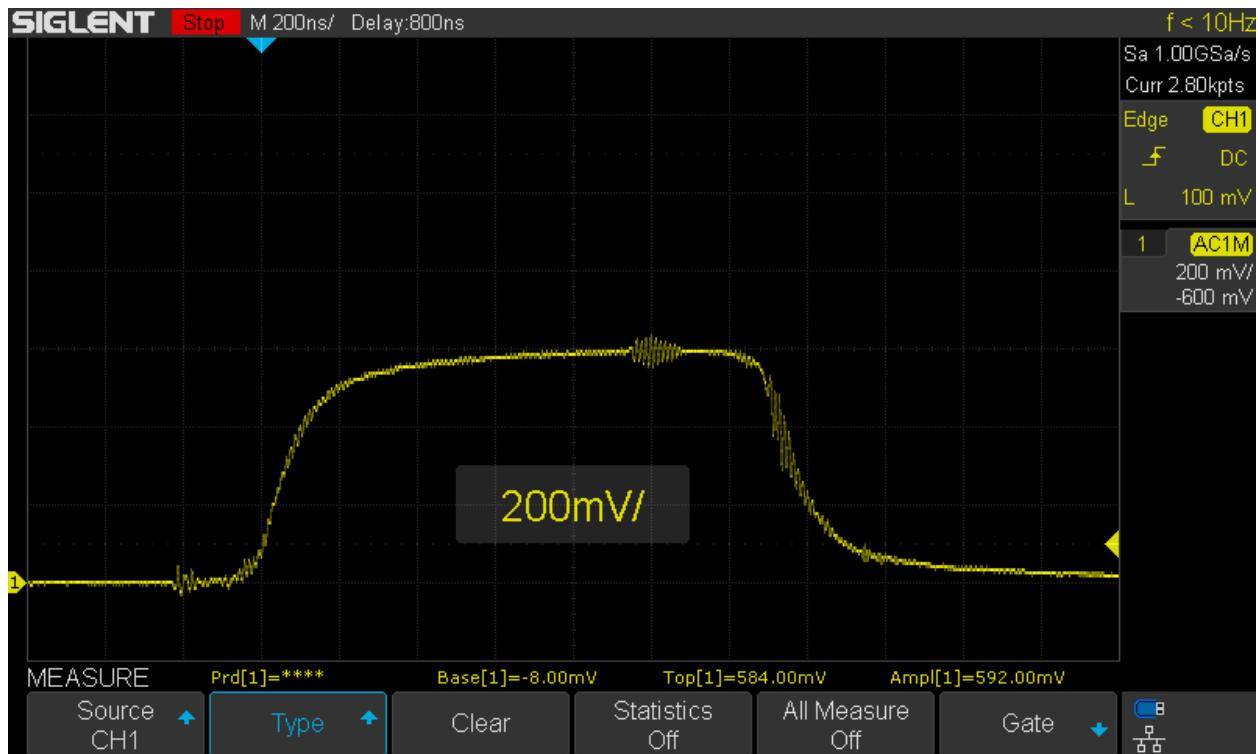
Current Test

119 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 26R1 DURATION: 1us



Light Output Test

120 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 26R1 DURATION: 1us



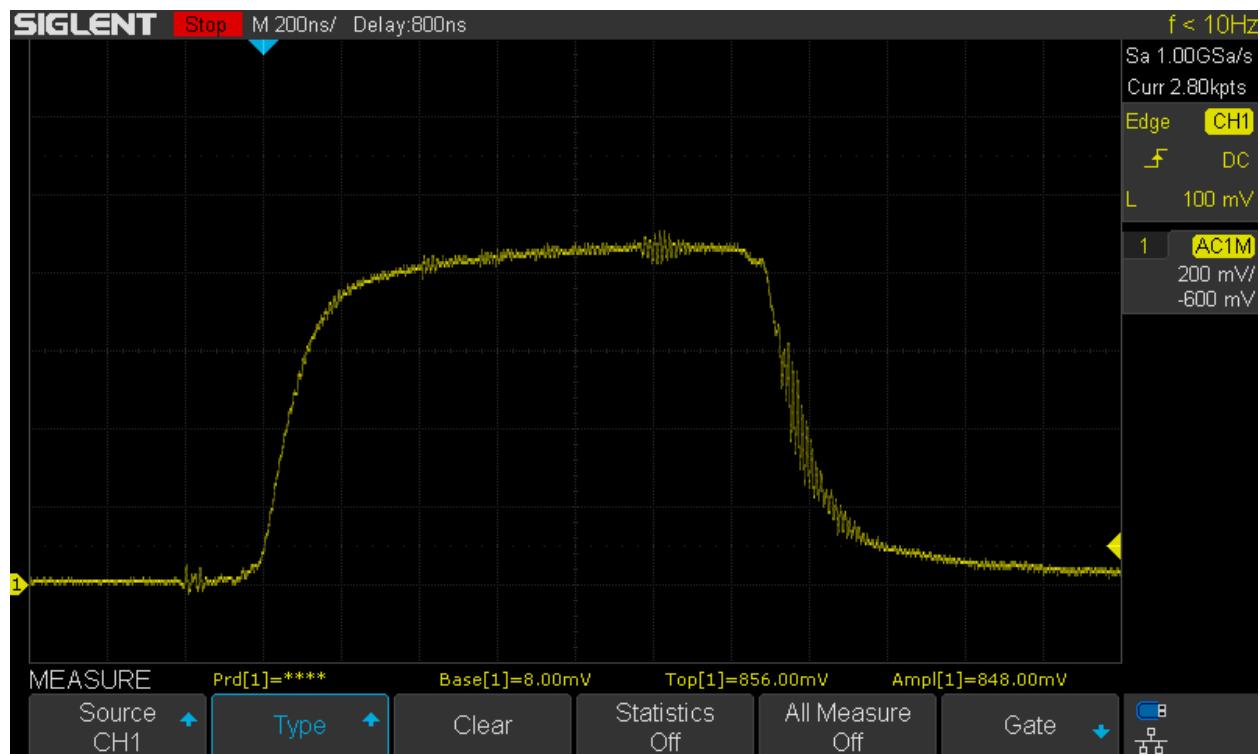
Light Output Test

121 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 19R3 DURATION: 1us



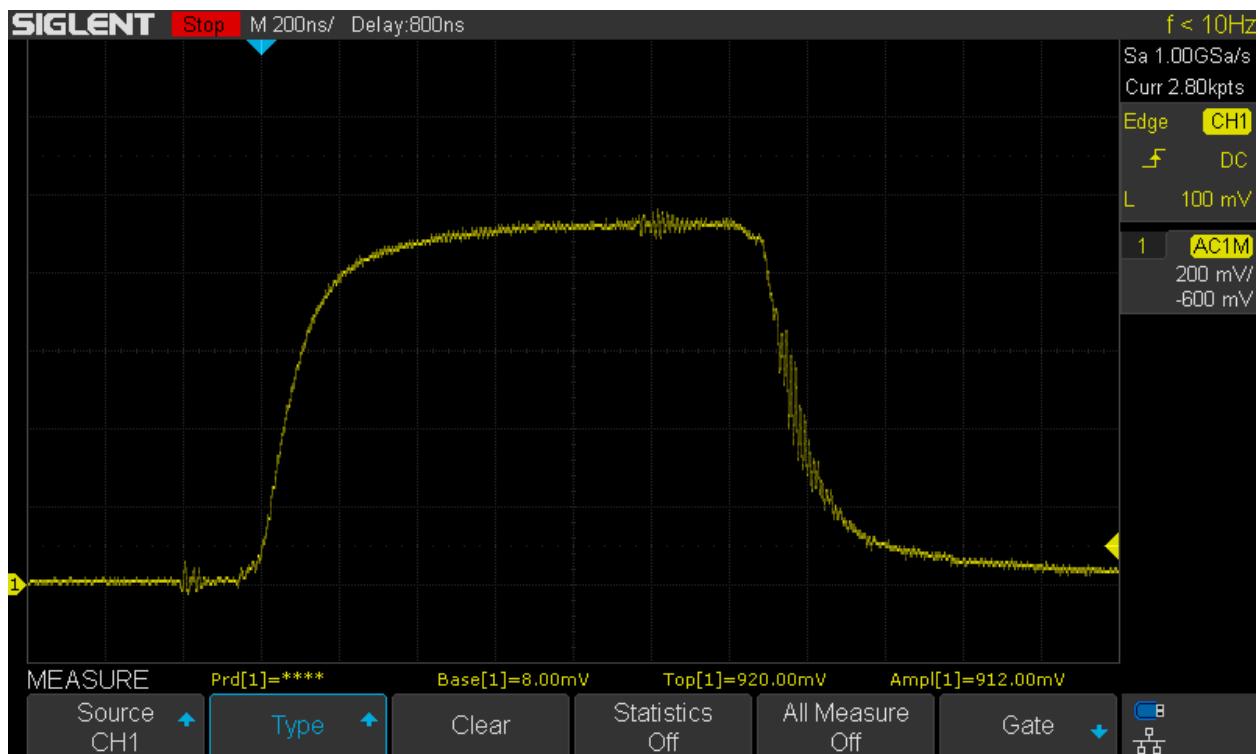
Light Output Test

122 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 12R5 DURATION: 1us



Light Output Test

123 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 8R5 DURATION: 1us



Light Output Test

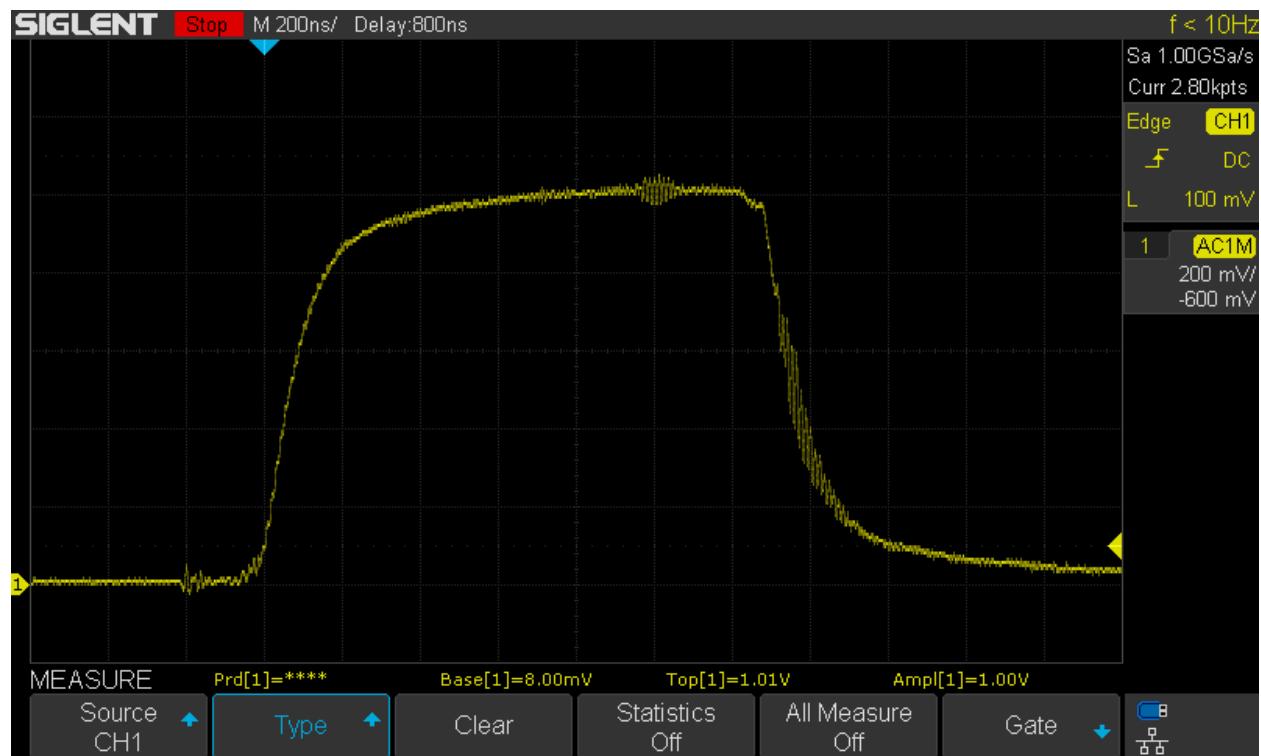
124

GATE: 12.8V

CAP ANODE: 124V

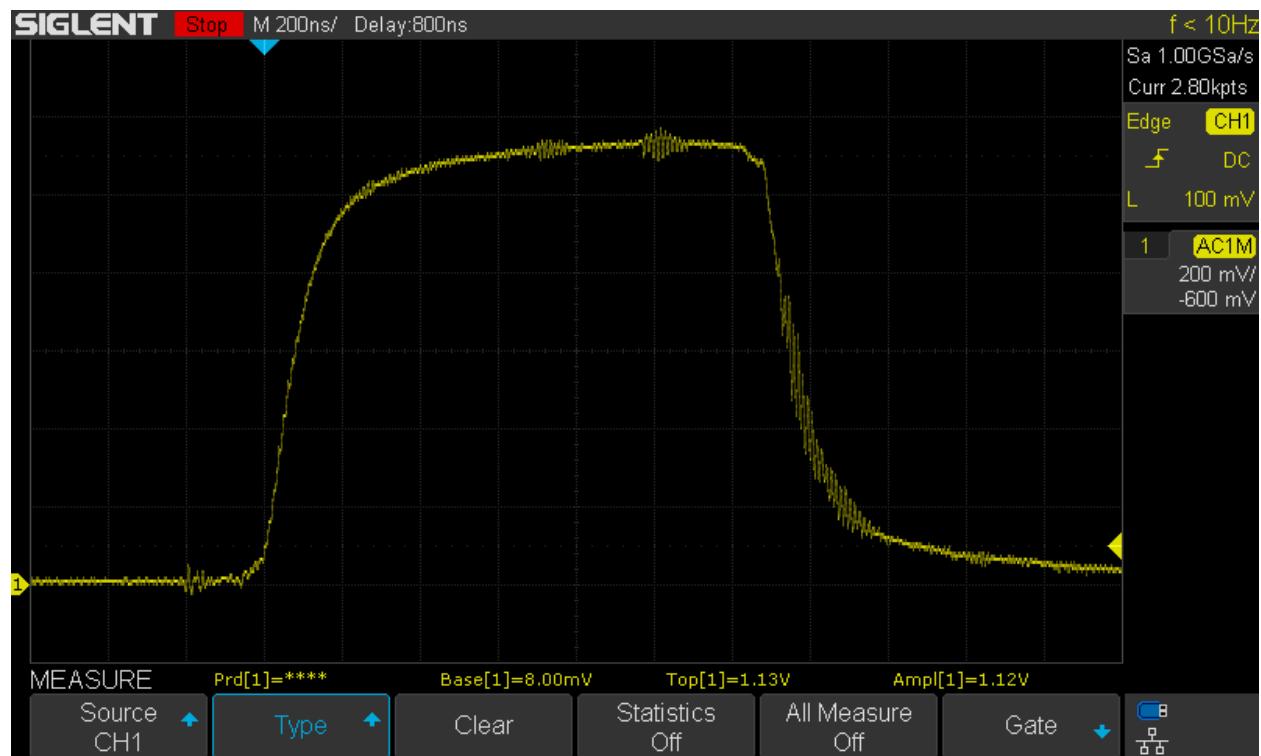
SERIES RESISTOR: 6R5

DURATION: 1us



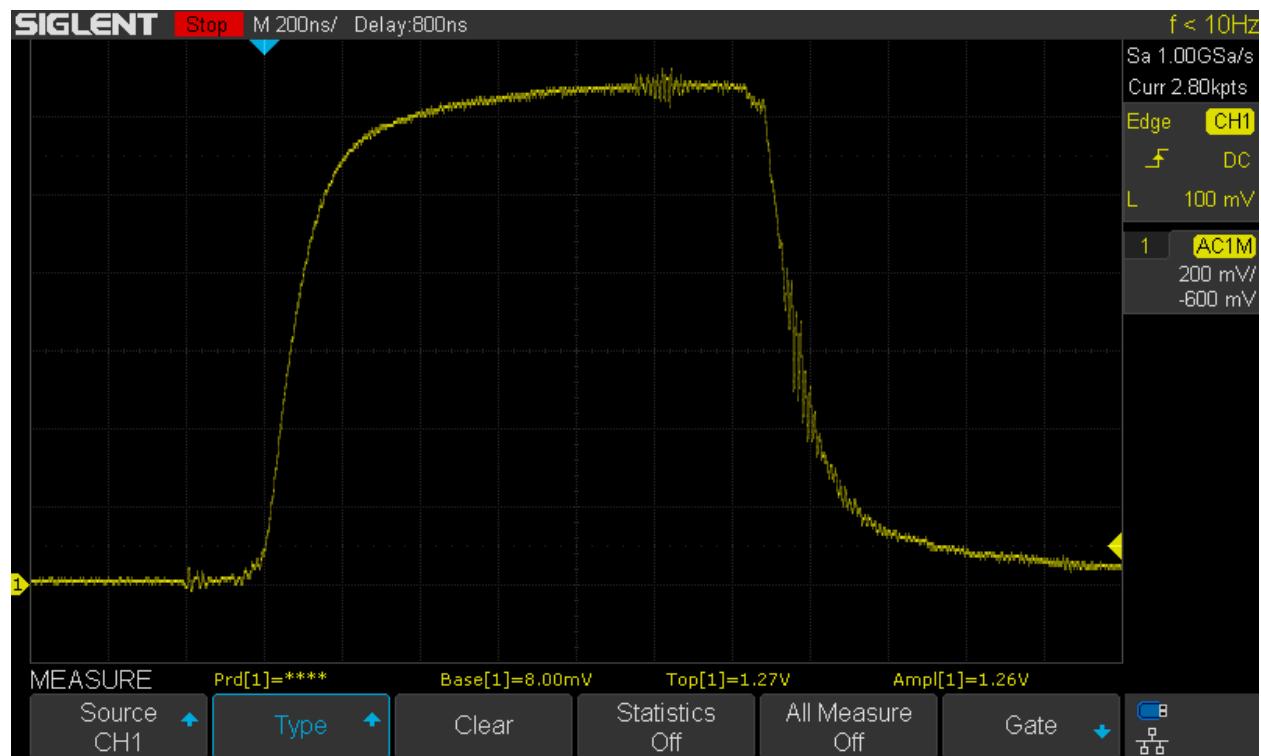
Light Output Test

125 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 4R5 DURATION: 1us



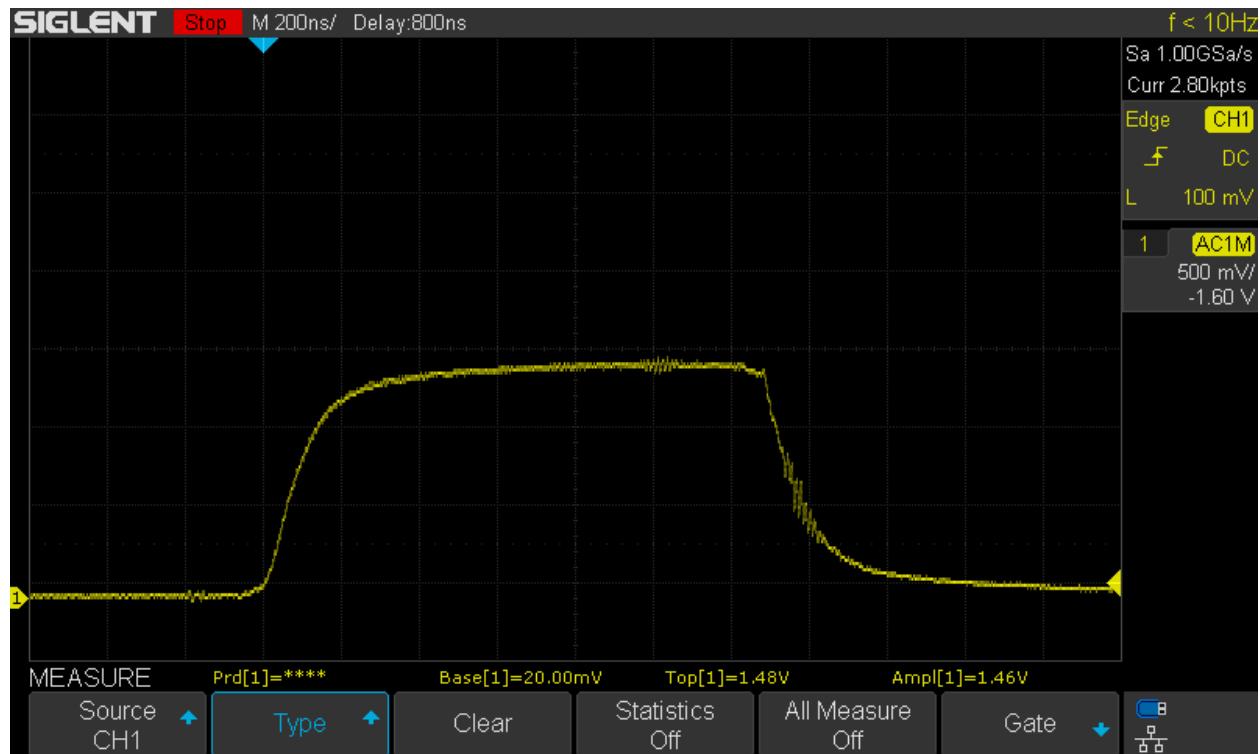
Light Output Test

126 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 2R5 DURATION: 1us



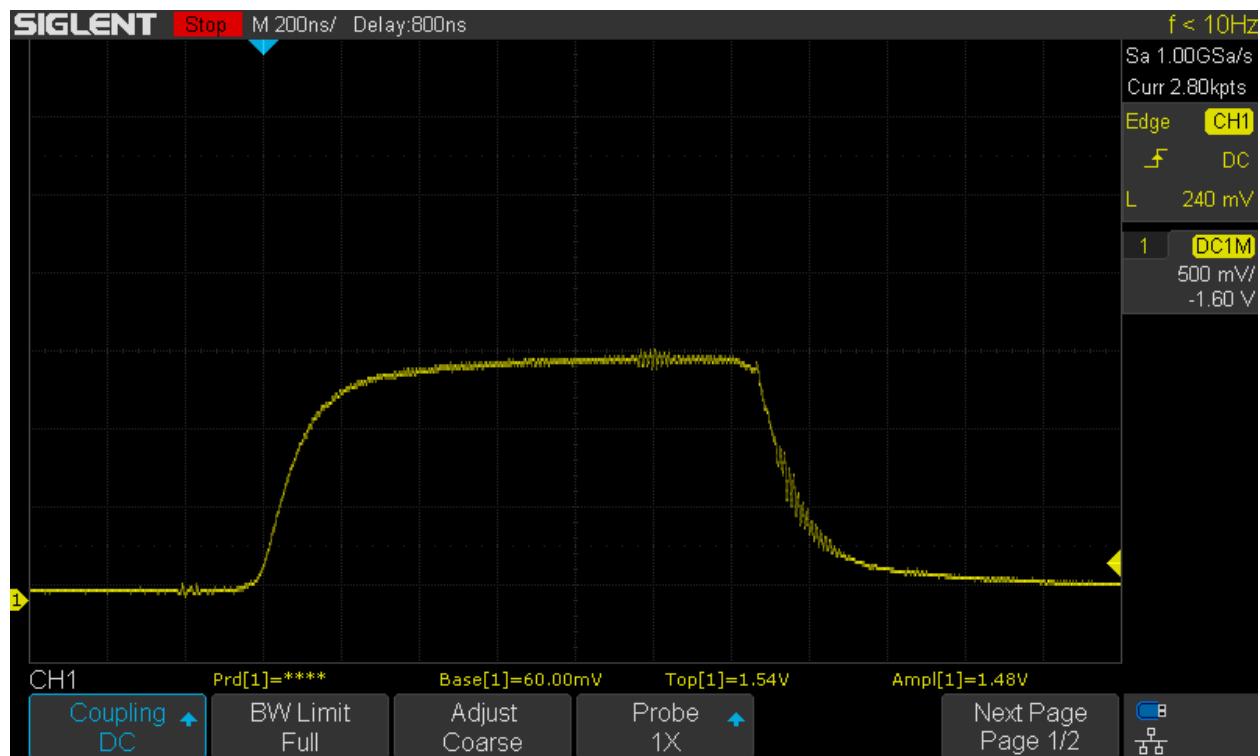
Light Output Test

127, 128 (dup) GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: 0R5 DURATION: 1us



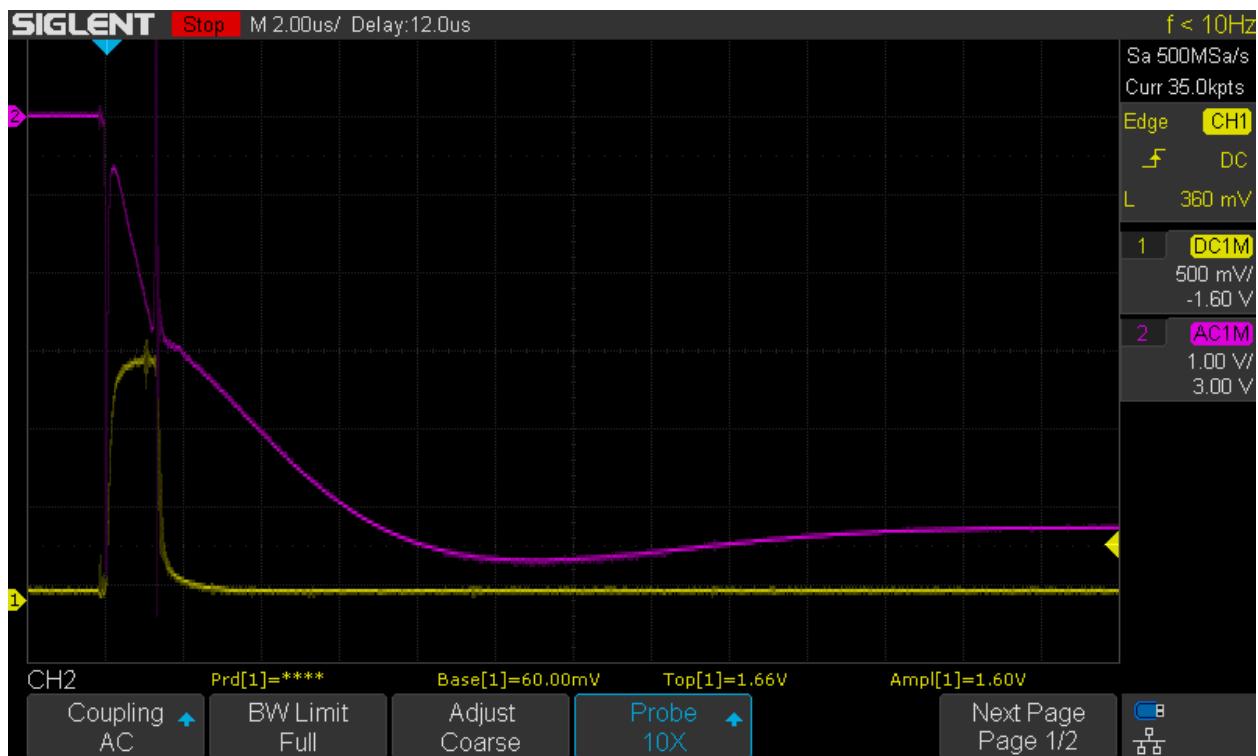
Light Output Test

129 GATE: 12.8V CAP ANODE: 124V SERIES RESISTOR: OR25 DURATION: 1us

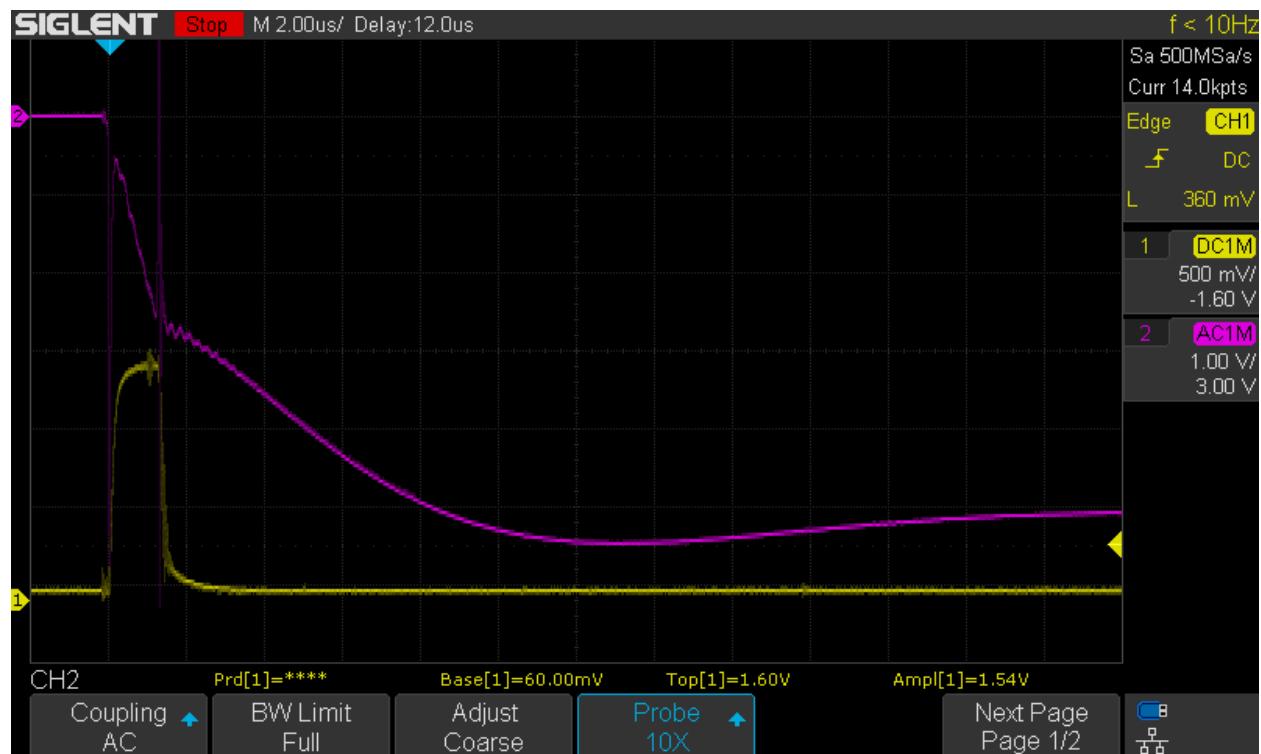


Light Output Test

130 GATE: 12.8V CAP ANODE: 120V? SERIES RESISTOR: R25 DURATION: 1us



131 GATE: 12.8V CAP ANODE: 125V? SERIES RESISTOR: R25 DURATION: 1us



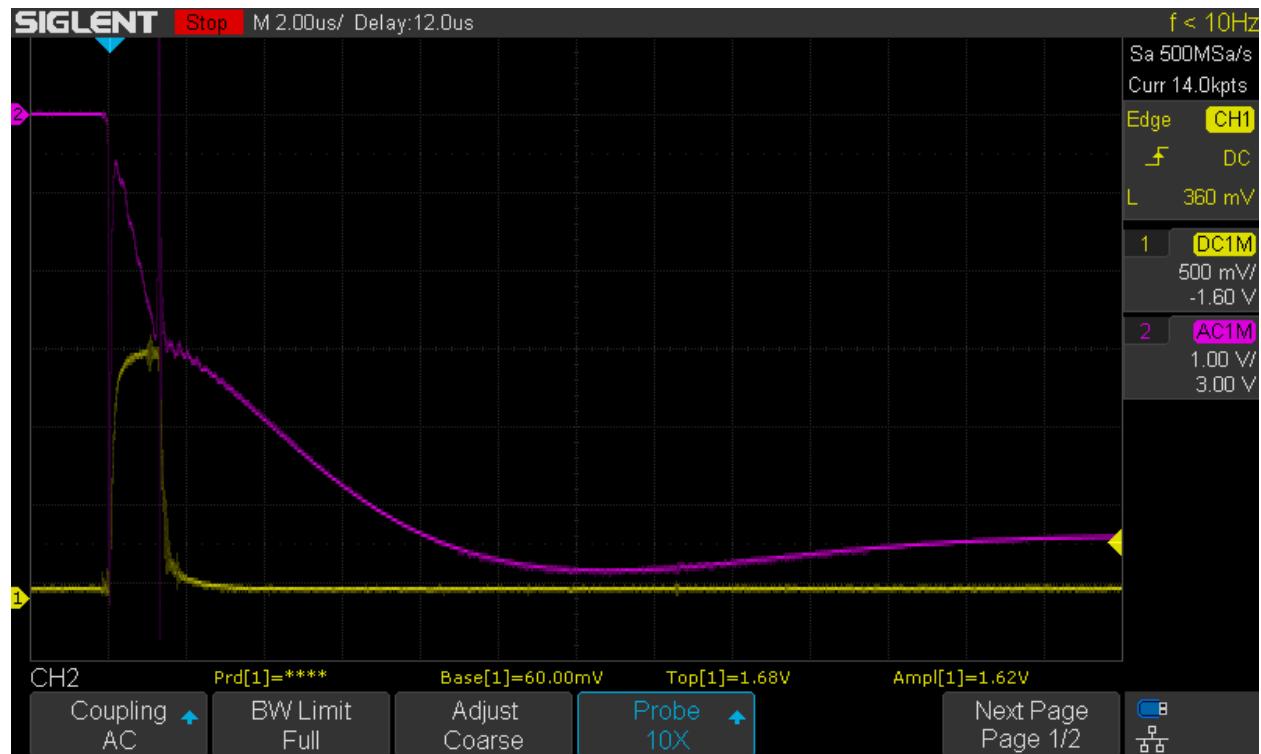
132

GATE: 12.8V

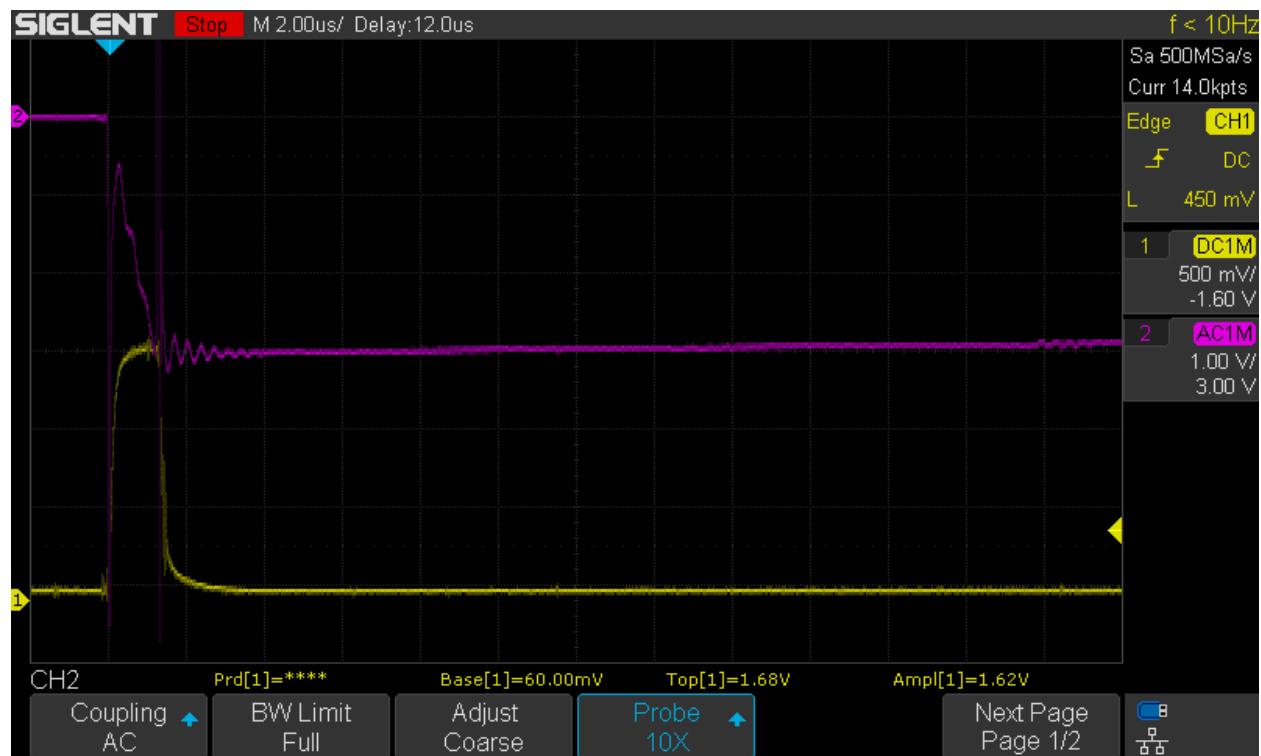
CAP ANODE: 125V

SERIES RESISTOR: R25

DURATION: 1us



133 GATE: 12.8V CAP ANODE: 135V SERIES RESISTOR: R25 DURATION: 1us



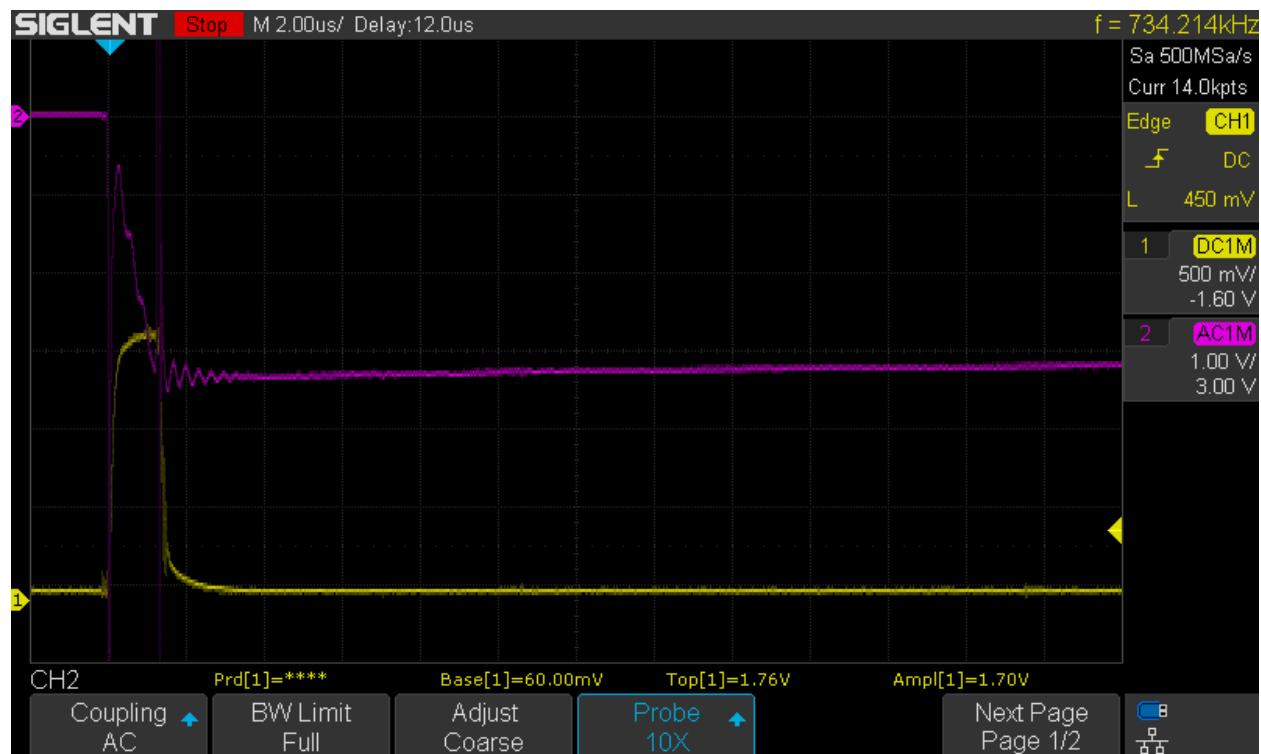
134

GATE: 12.8V

CAP ANODE: 145V

SERIES RESISTOR: R25

DURATION: 1us



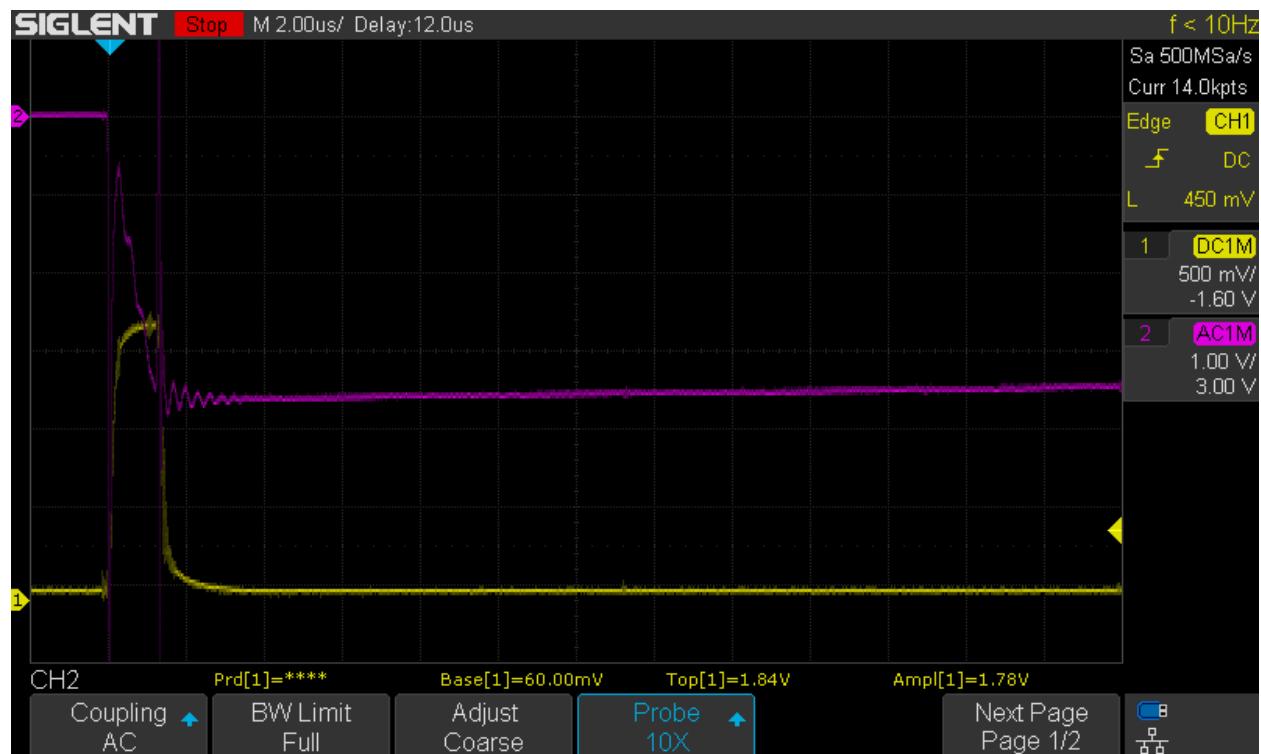
135

GATE: 12.8V

CAP ANODE: 155V

SERIES RESISTOR: R25

DURATION: 1us



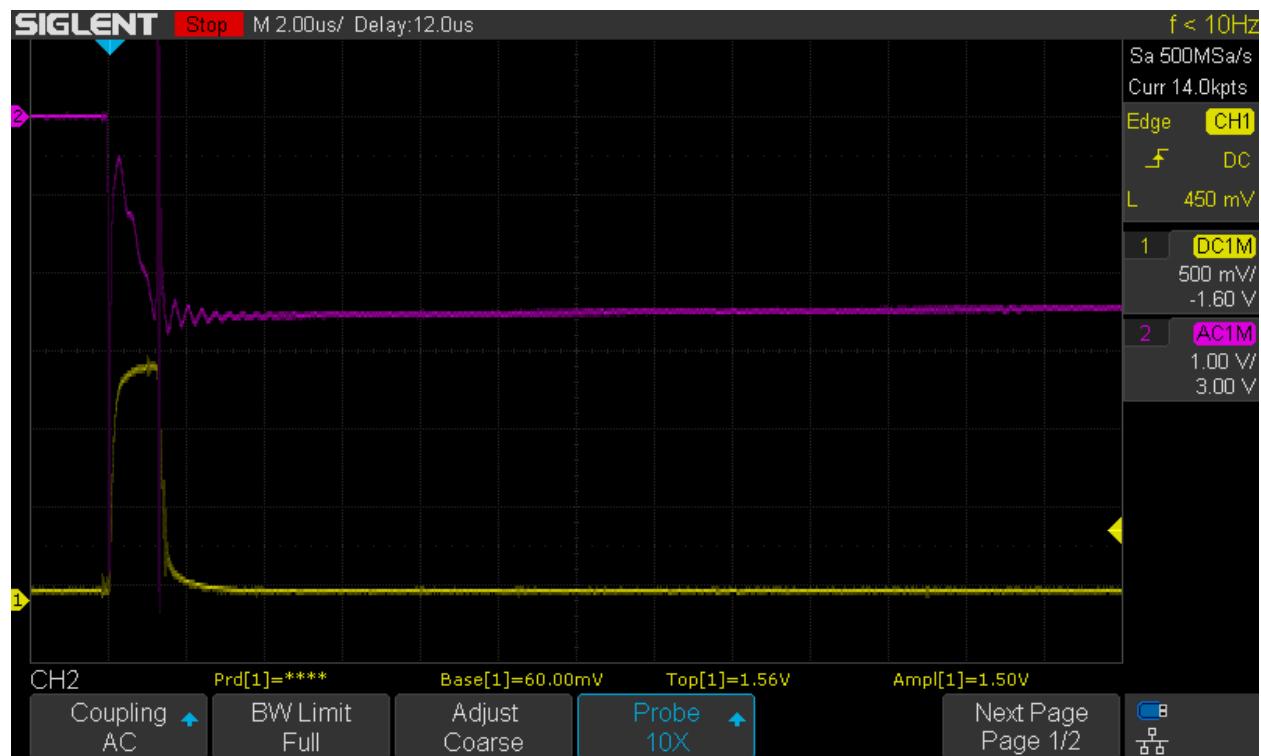
136

GATE: 12.8V

CAP ANODE: 120V

SERIES RESISTOR: R25

DURATION: 1us



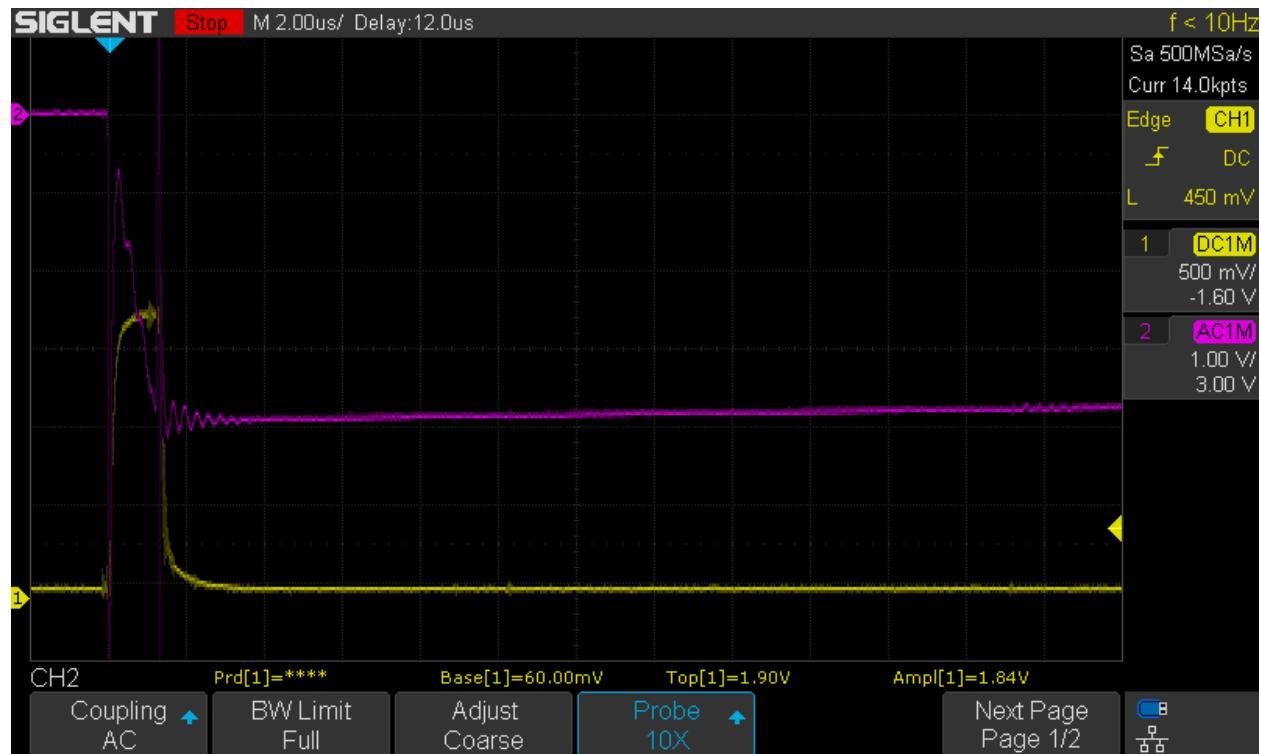
137

GATE: 12.8V

CAP ANODE: 165V

SERIES RESISTOR: R25

DURATION: 1us



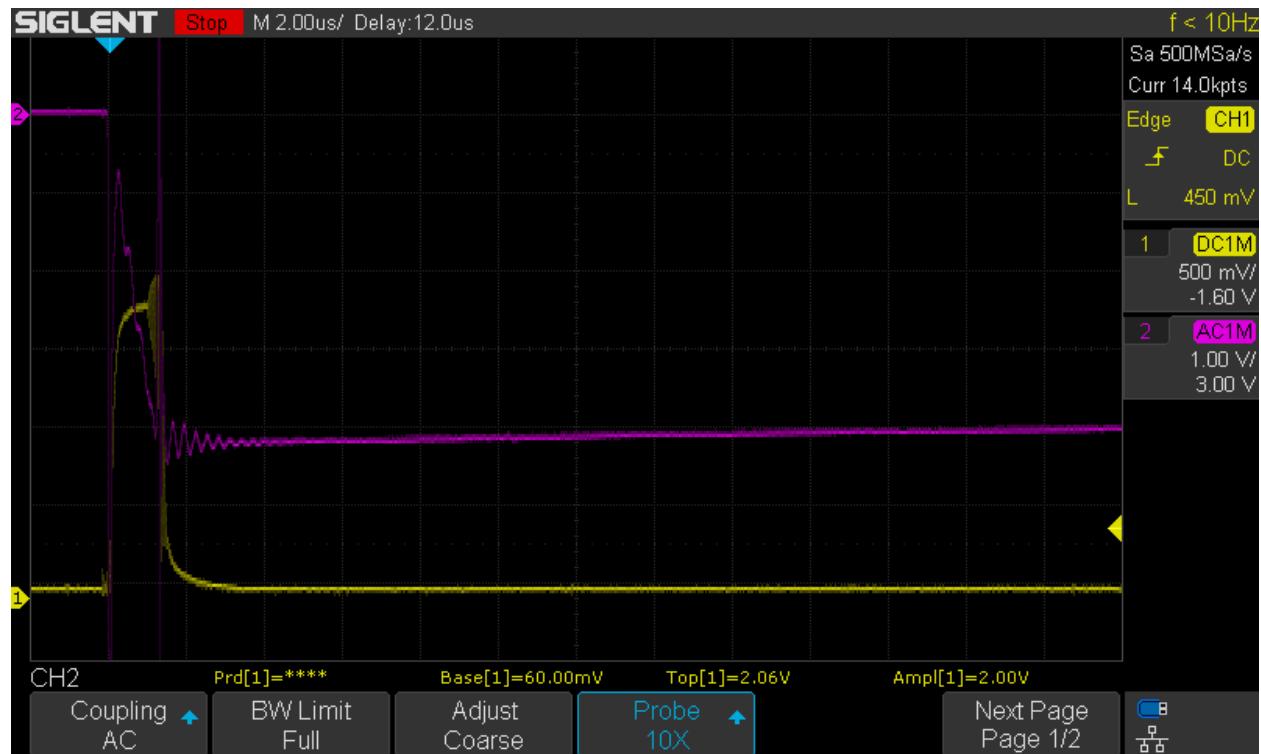
138

GATE: 12.8V

CAP ANODE: 175V

SERIES RESISTOR: R25

DURATION: 1us



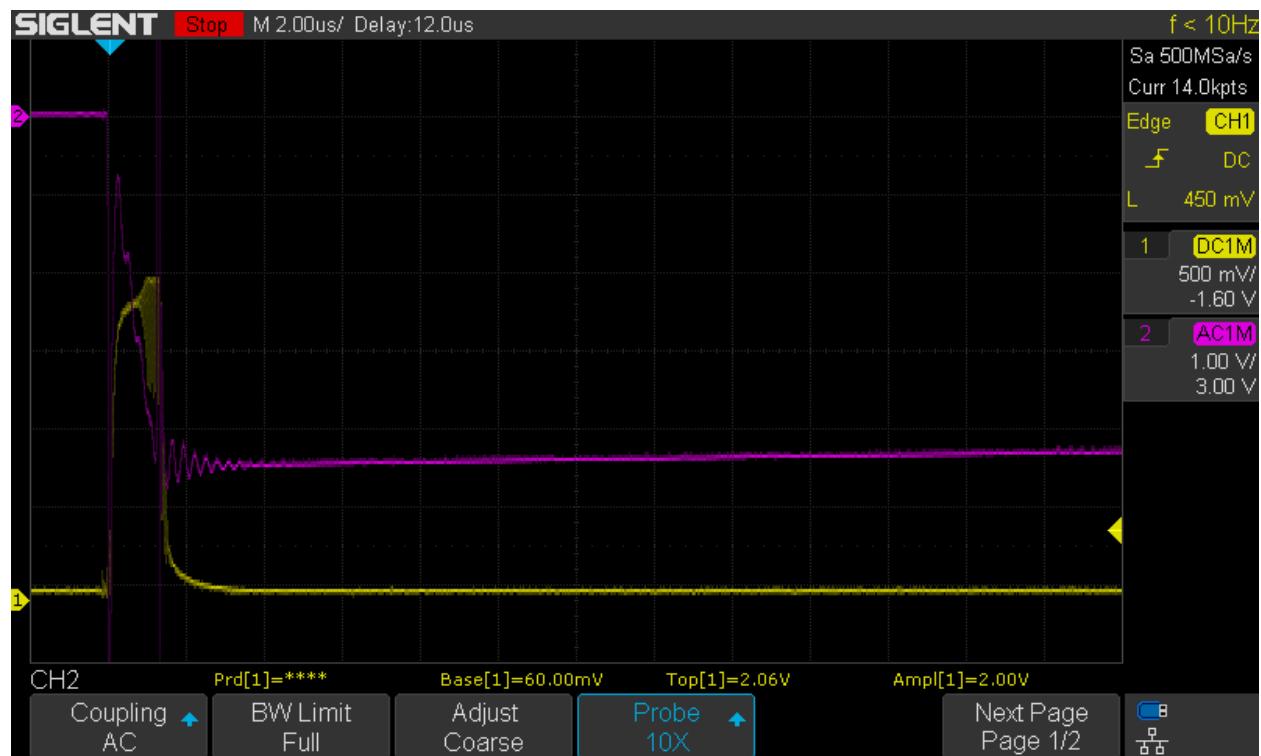
139

GATE: 12.8V

CAP ANODE: 185V

SERIES RESISTOR: R25

DURATION: 1us



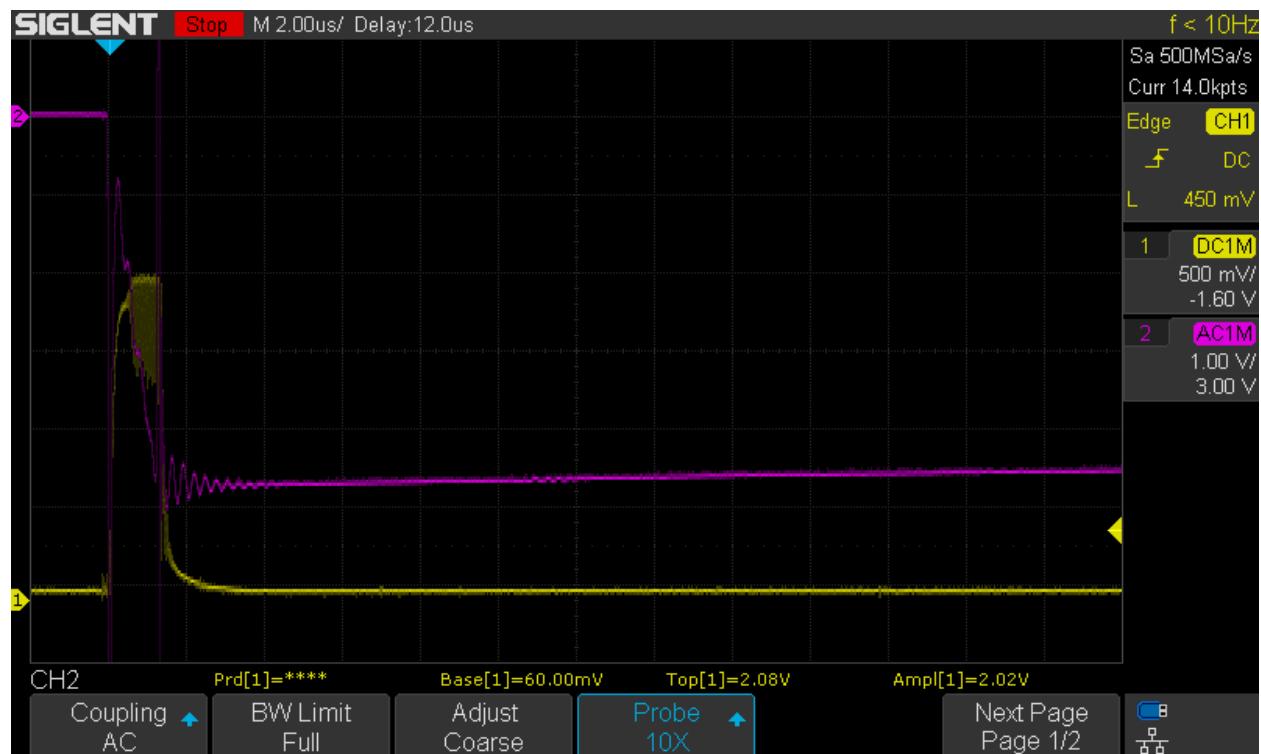
140

GATE: 12.8V

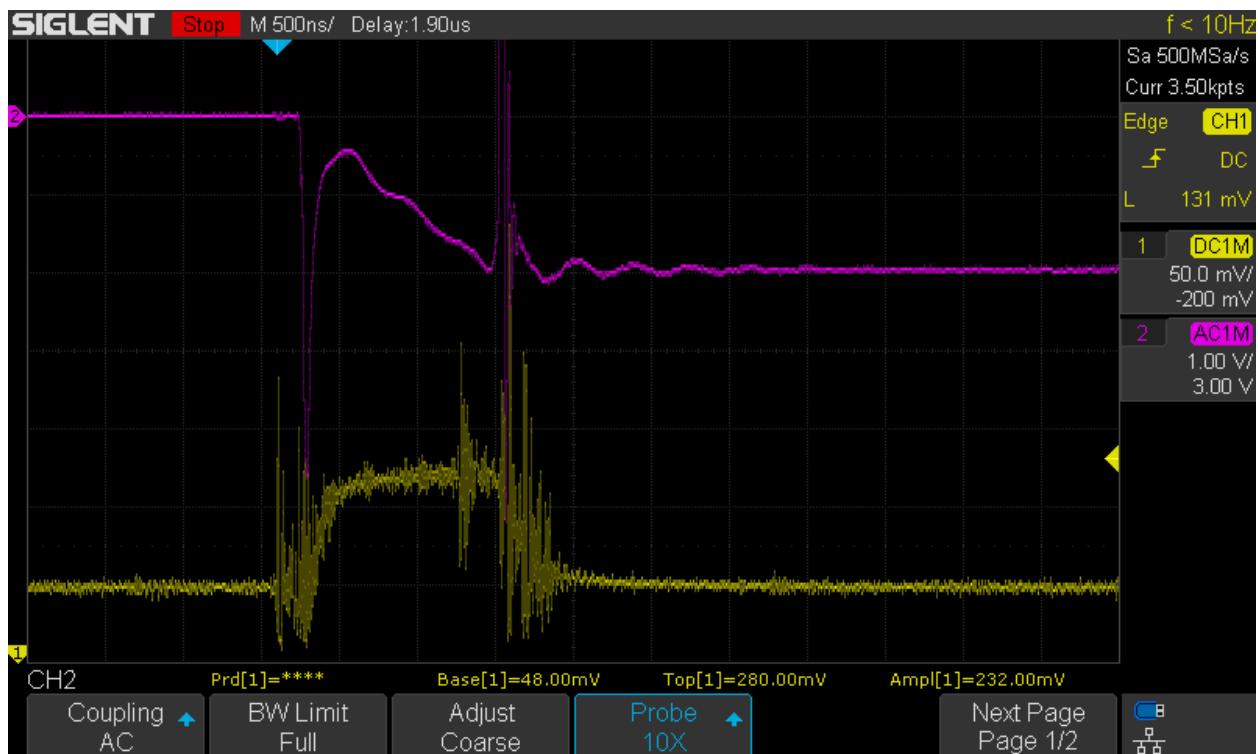
CAP ANODE: 195V

SERIES RESISTOR: R25

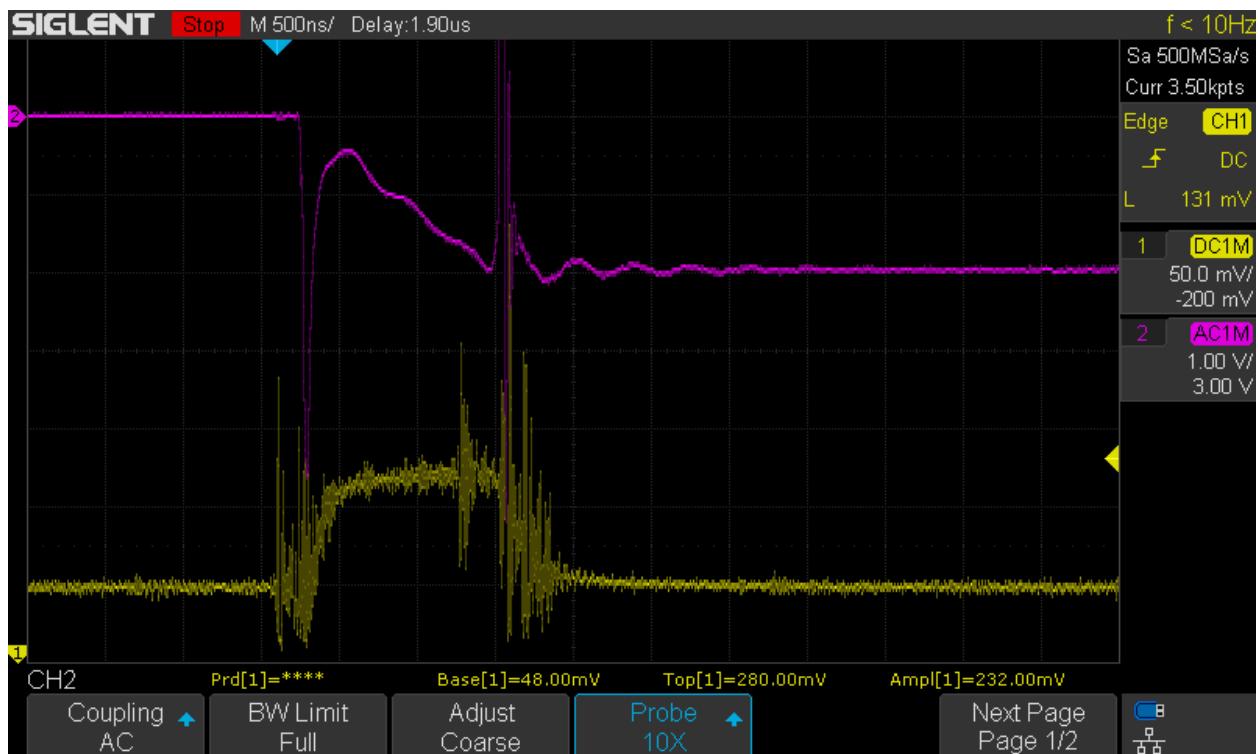
DURATION: 1us



141 GARBAGE



142 GARBAGE



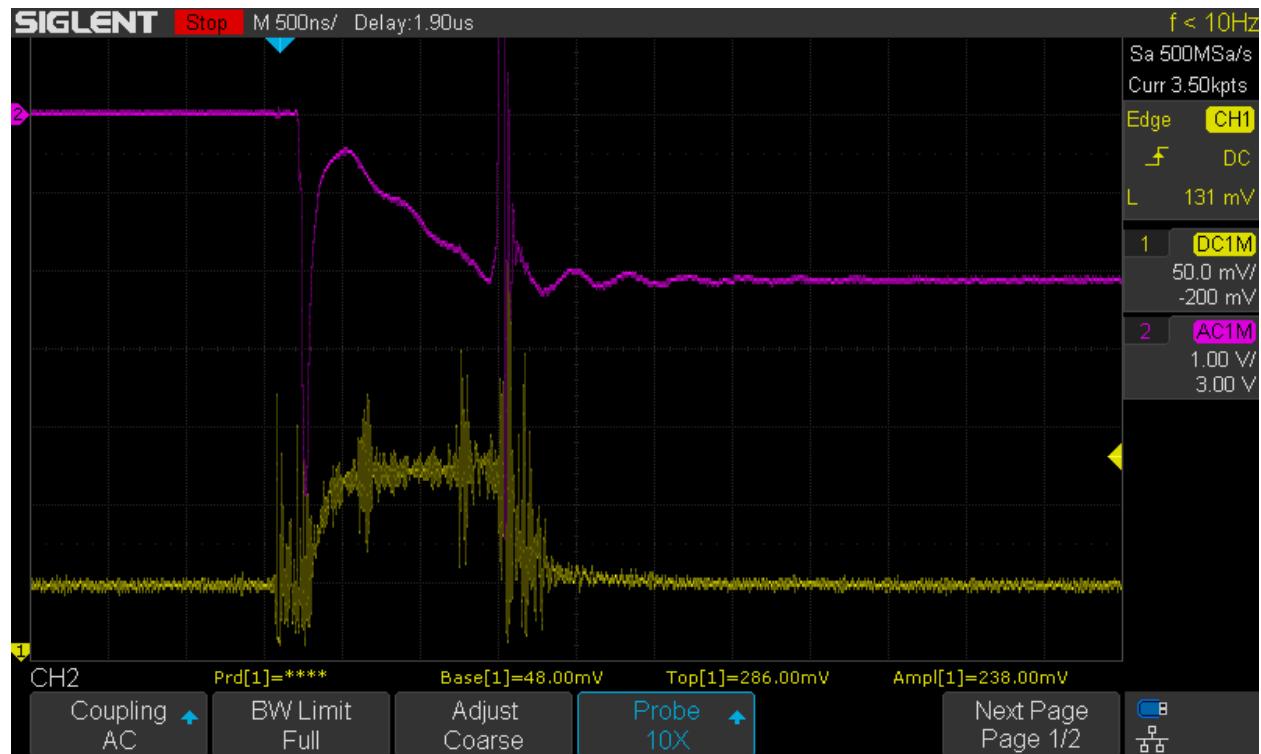
143

GATE: 12.8V

CAP ANODE: 120V

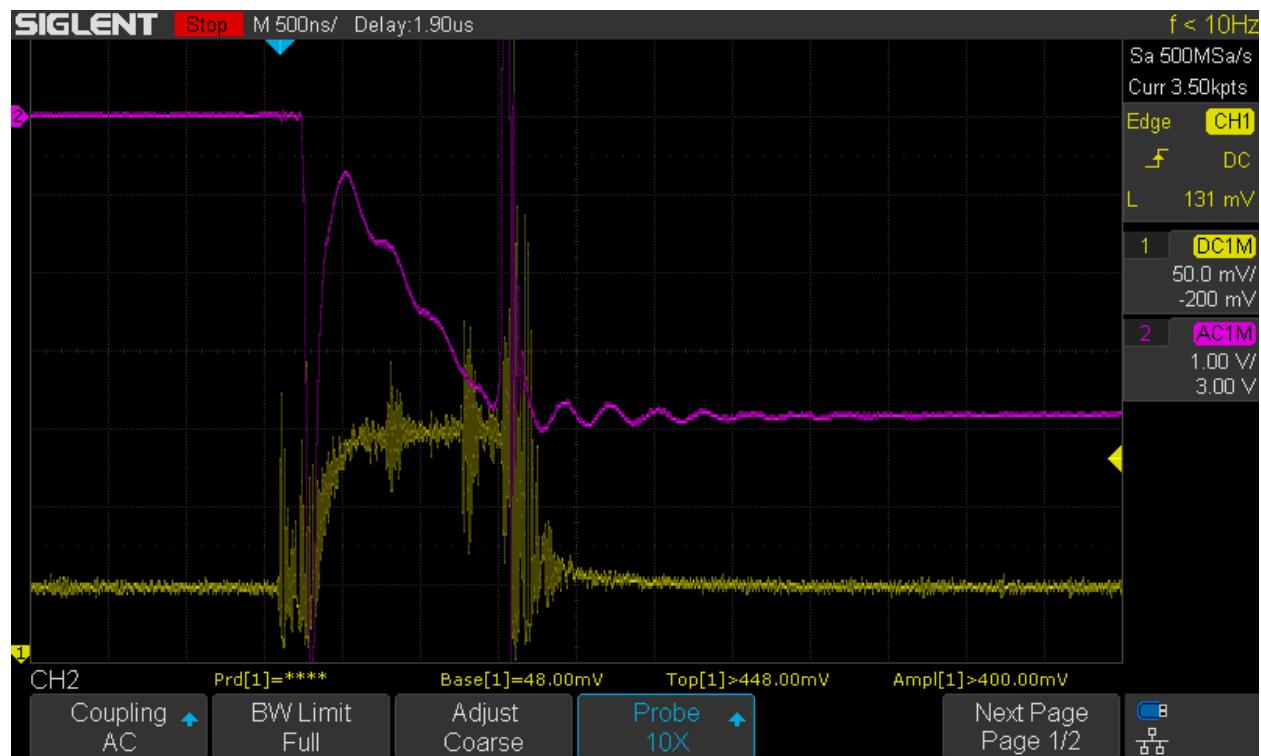
SERIES RESISTOR: R25

DURATION: 1us



Added 6-stop ND Filter to optical train

144

GARBAGE

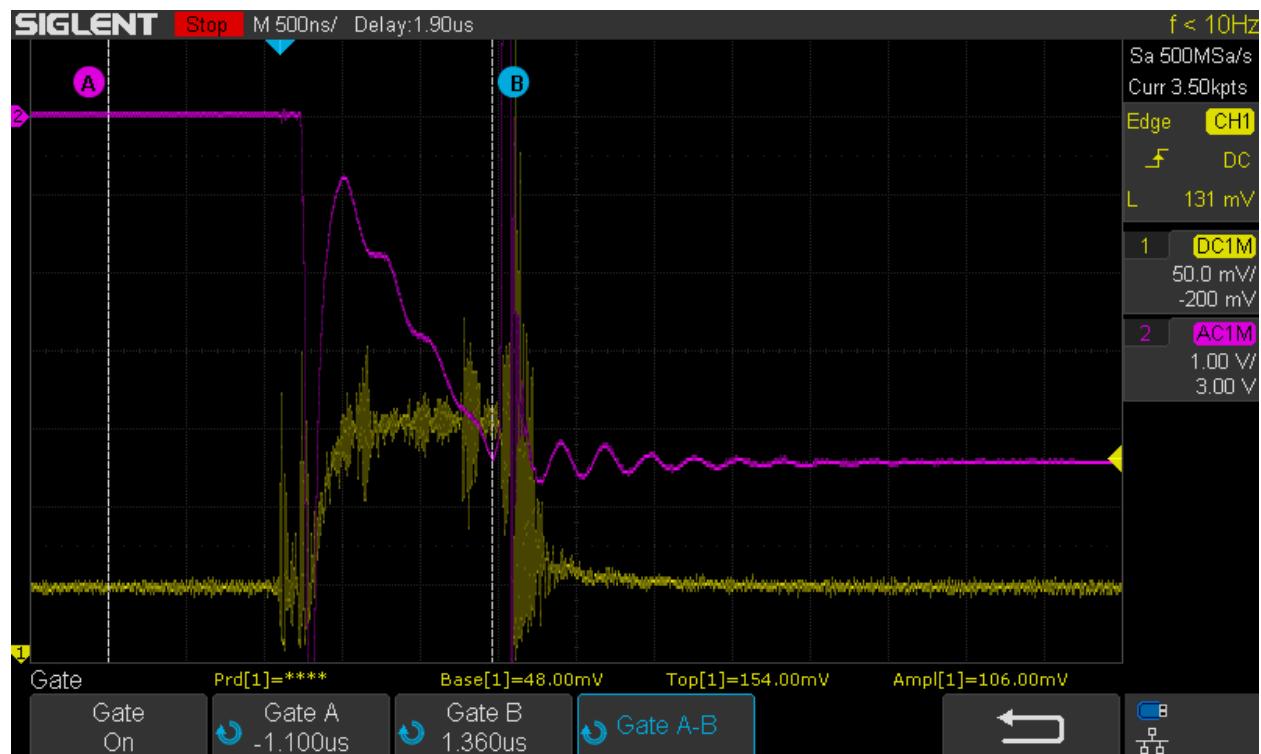
145

GATE: 12.8V

CAP ANODE: 187V

SERIES RESISTOR: R25

DURATION: 1us



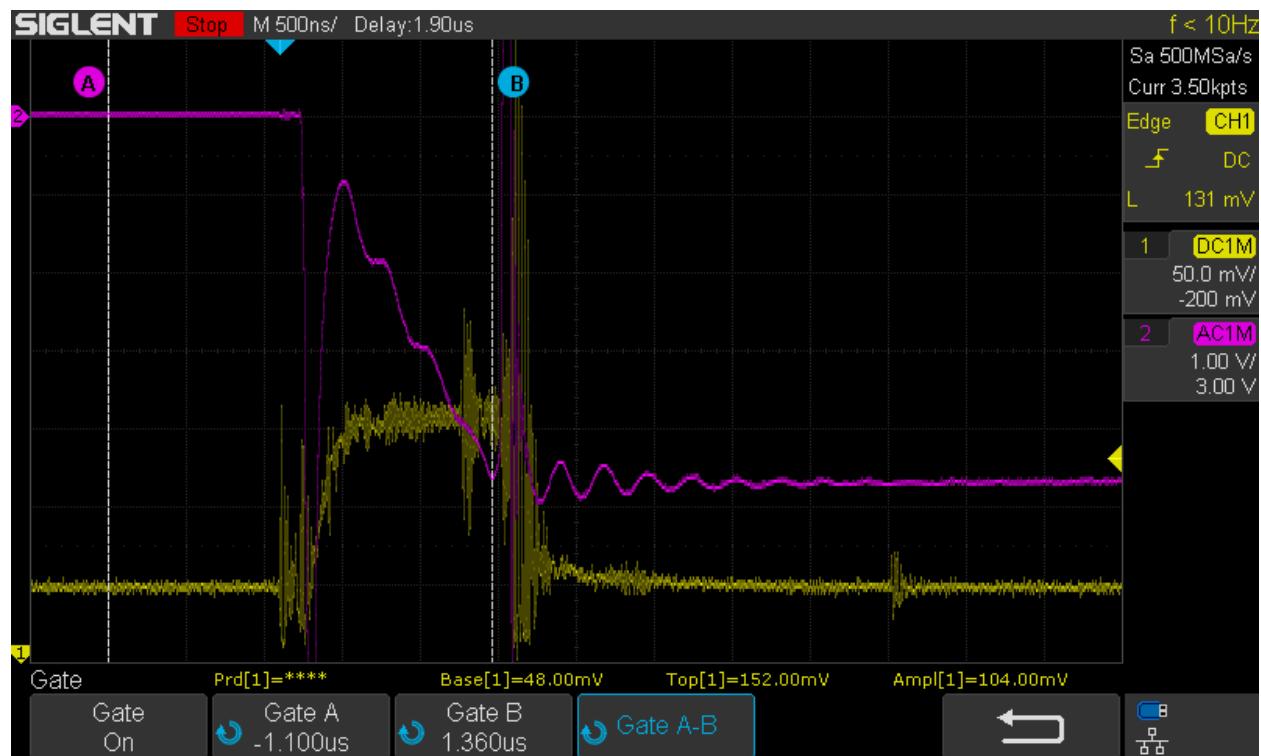
146

GATE: 12.8V

CAP ANODE: 195V

SERIES RESISTOR: R25

DURATION: 1us



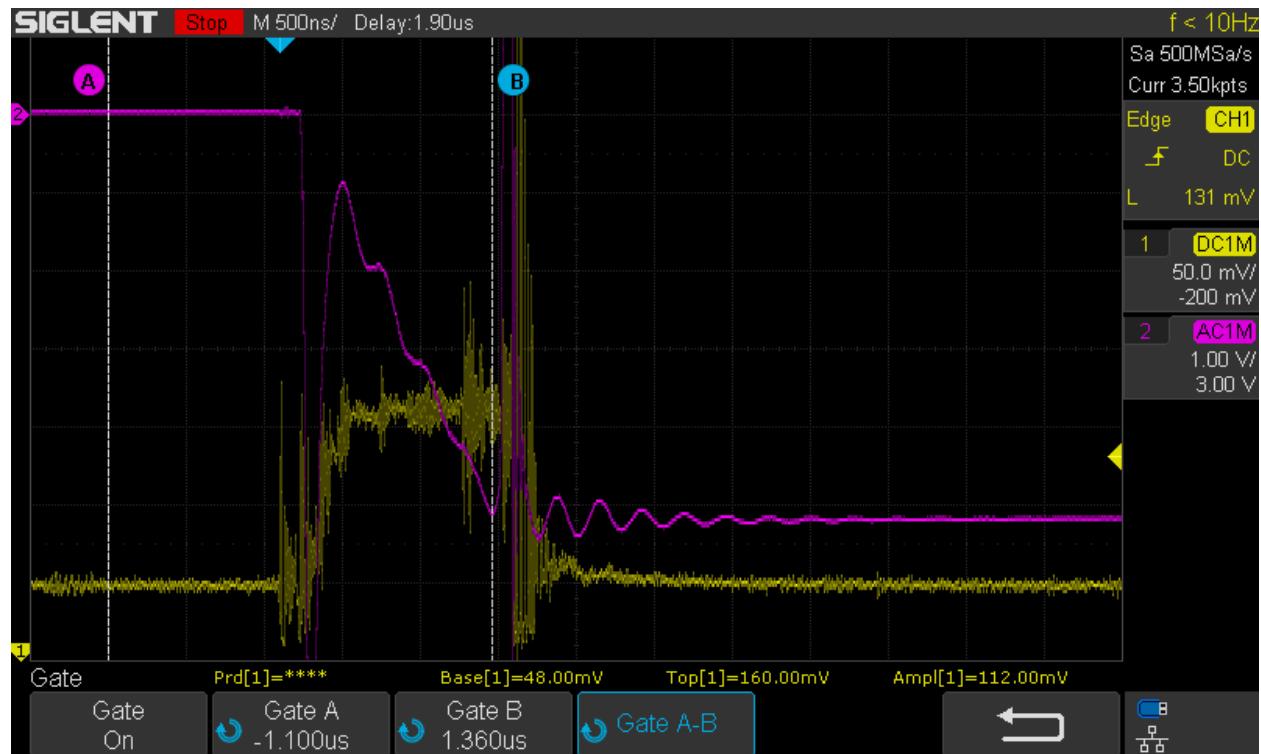
147

GATE: 12.8V

CAP ANODE: 220V

SERIES RESISTOR: R25

DURATION: 1us



Series 9 – Multi-Strobe Testing

Overview:

Purpose: To test the effect of multi-strobing on the Cree CXA2530 LED and determine the safe limits of operation

Equipment:

- E2 Prototype with four banks of LED's in various states of damage
 - IPPR60 MOSFET's

Test Data:

Series 10 – IGBT Testing

Overview:

Purpose: To test the I_e / V_{ge} relationship of two select IGBT transistors

Equipment:

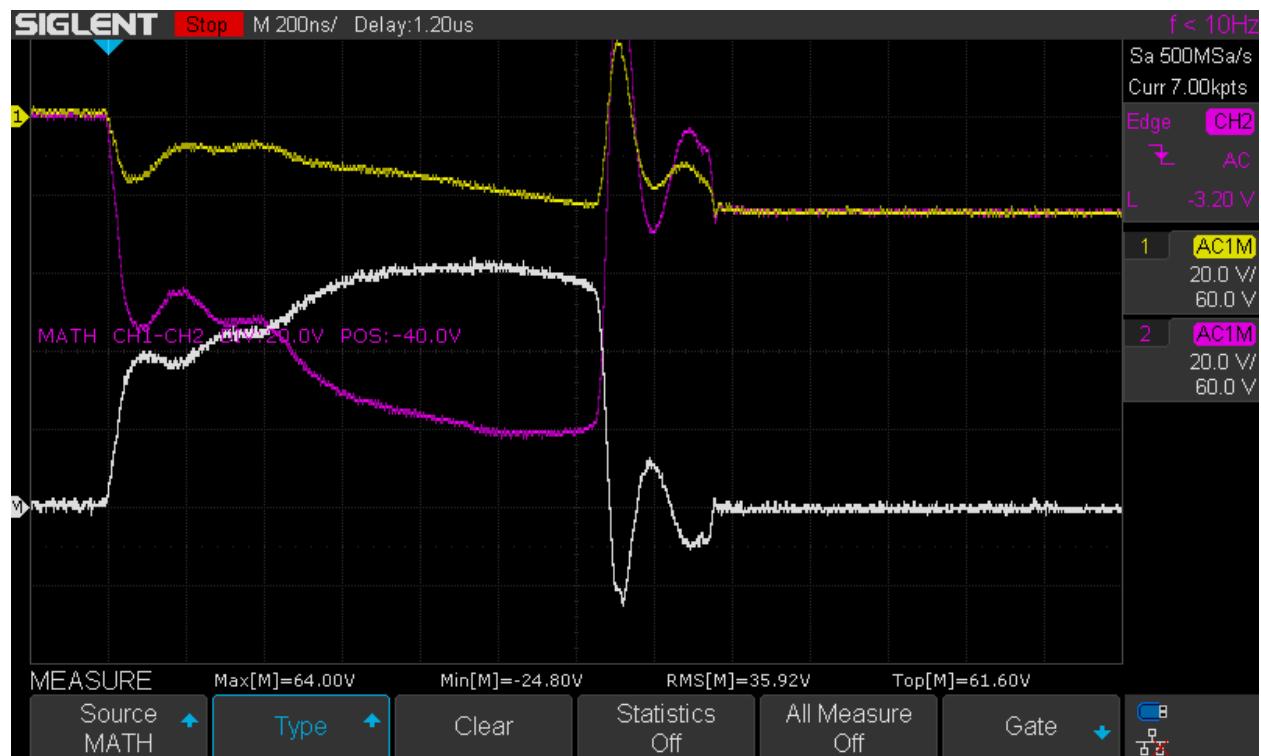
- E2 Prototype with four banks of LED's in various states of damage
 - STGP40V60F IGBT
 - FGAF40N60UFTU IGBT

Results:

- No advantage was found in using an IGBT over the established MOSFET transistors

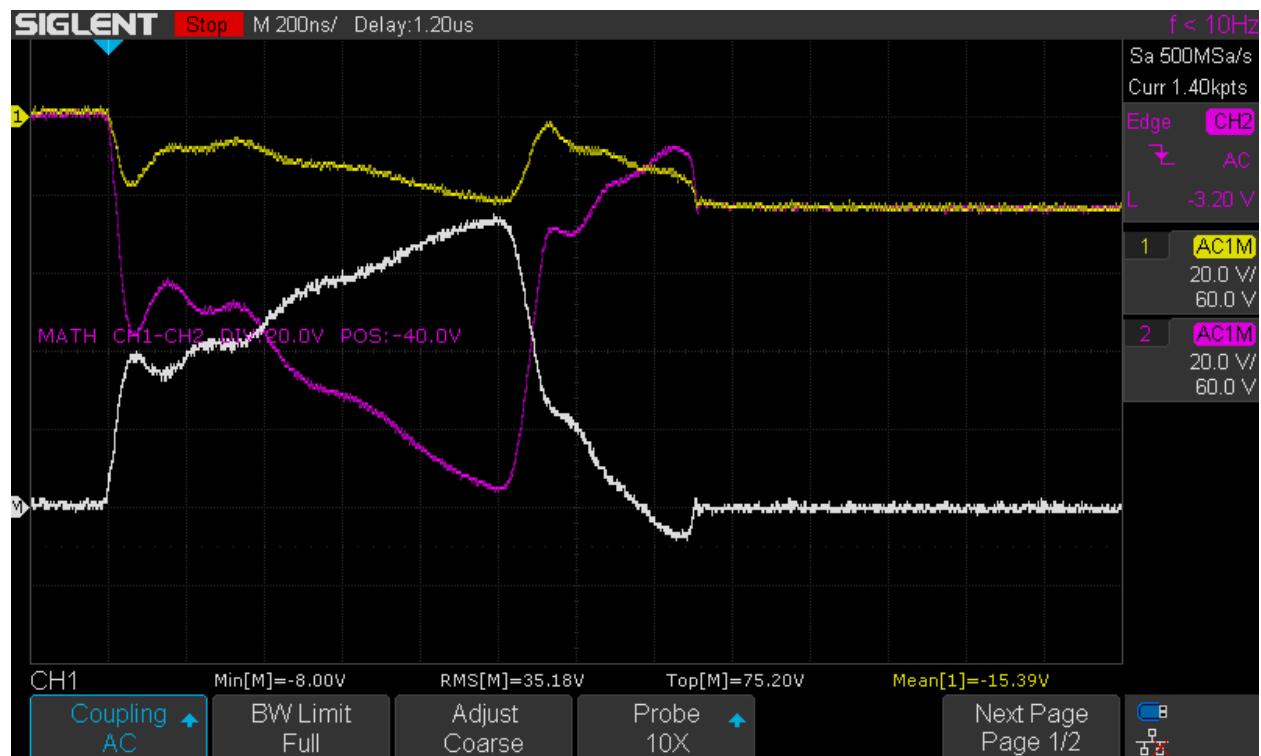
Test Data:

1 GATE: 12.8V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 1us



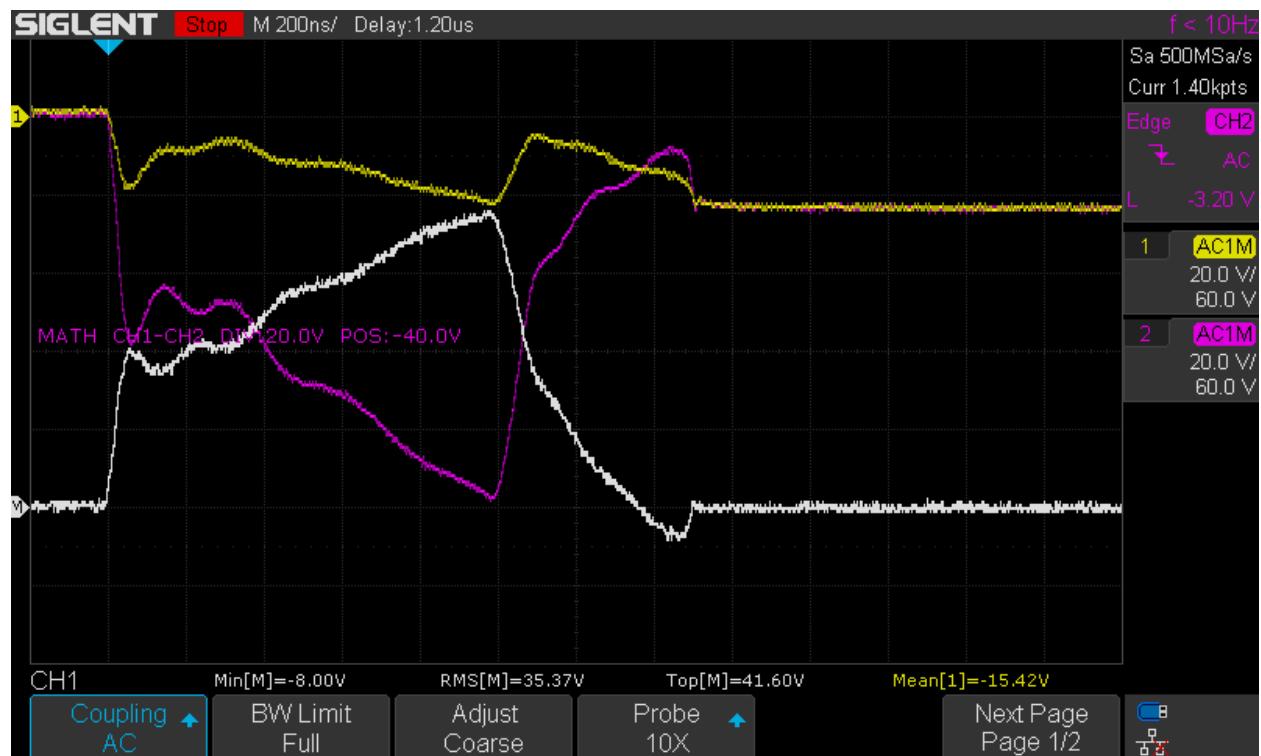
STGP40V60F

2 GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



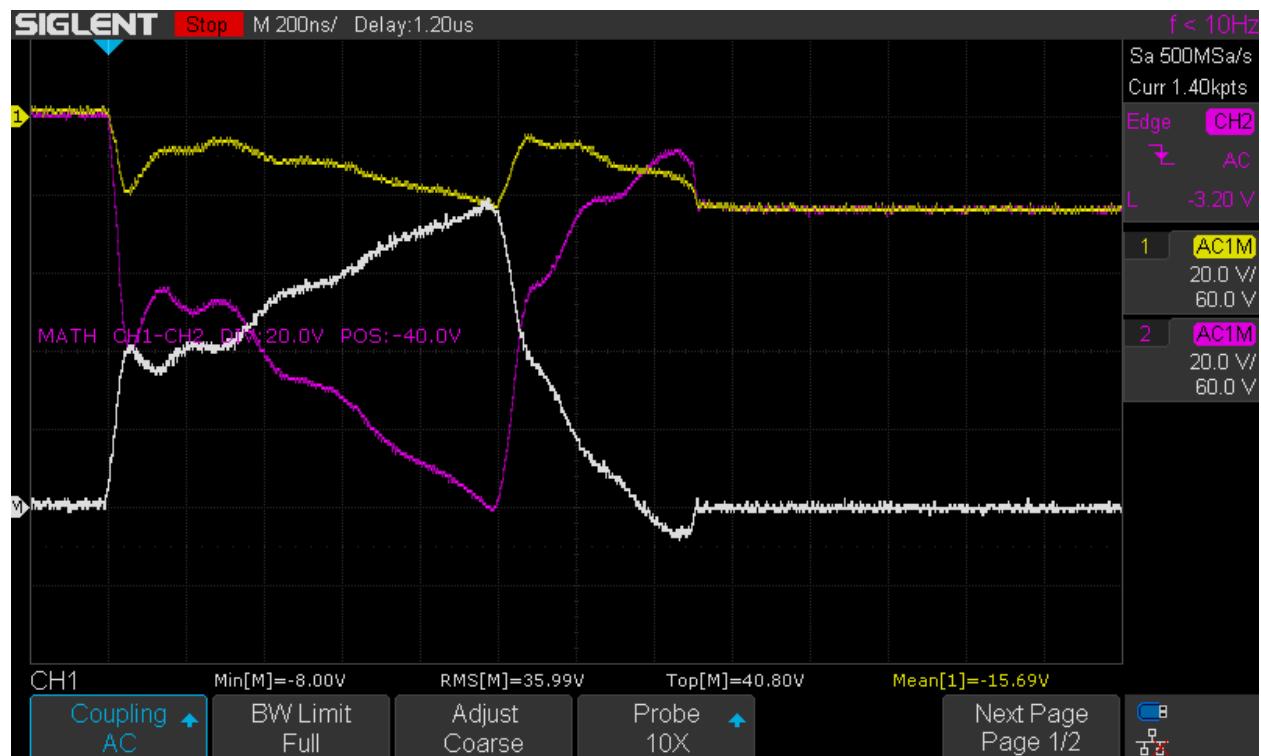
STGP40V60F

3 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



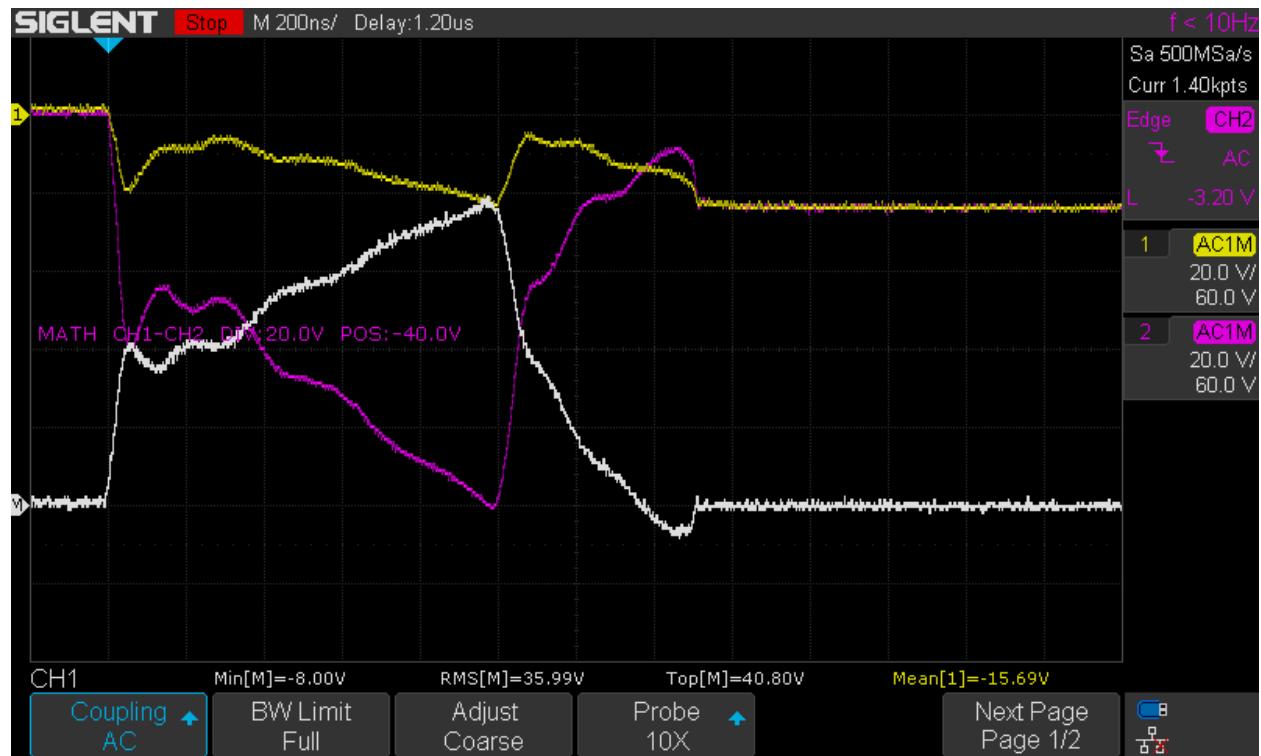
STGP40V60F

4 GATE: 12.8V CAP ANODE: 140V SERIES RESISTOR: R25 DURATION: 1us



STGP40V60F

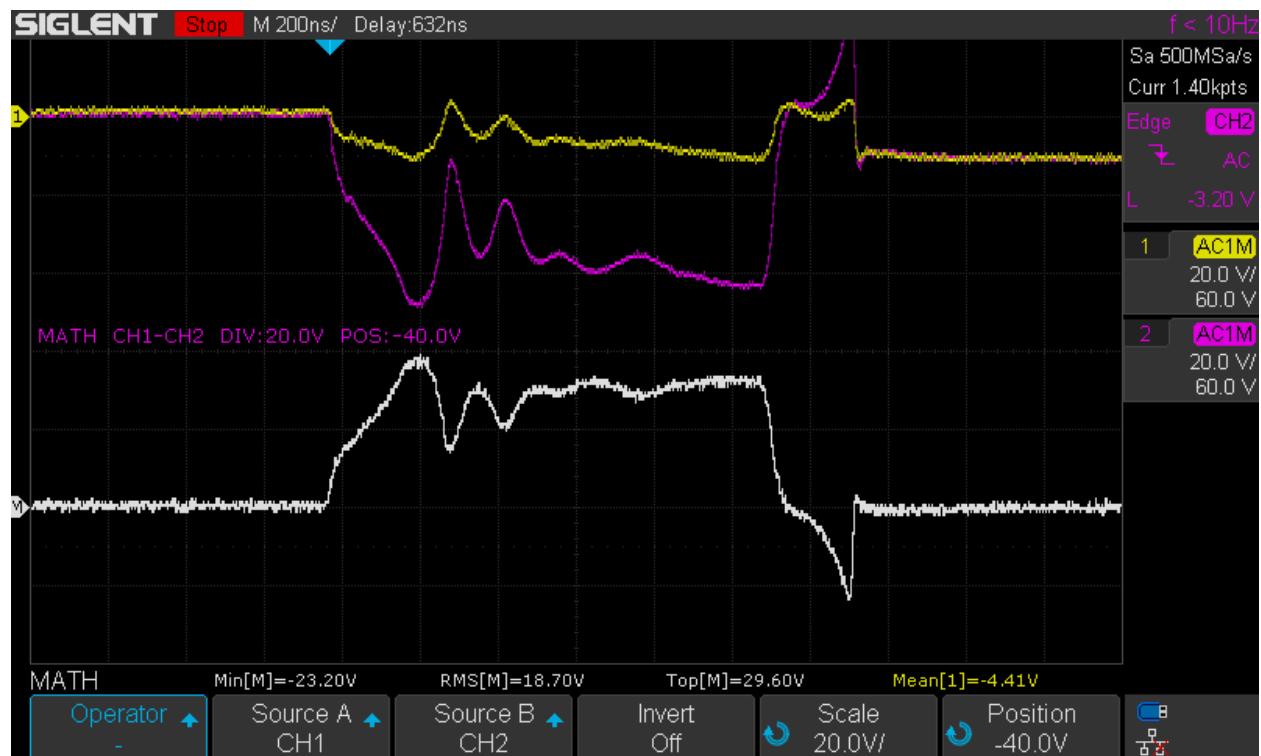
5 GATE: 12.8V CAP ANODE: 140V SERIES RESISTOR: R25 DURATION: 1us



STGP40V60F

Removed gate resistor

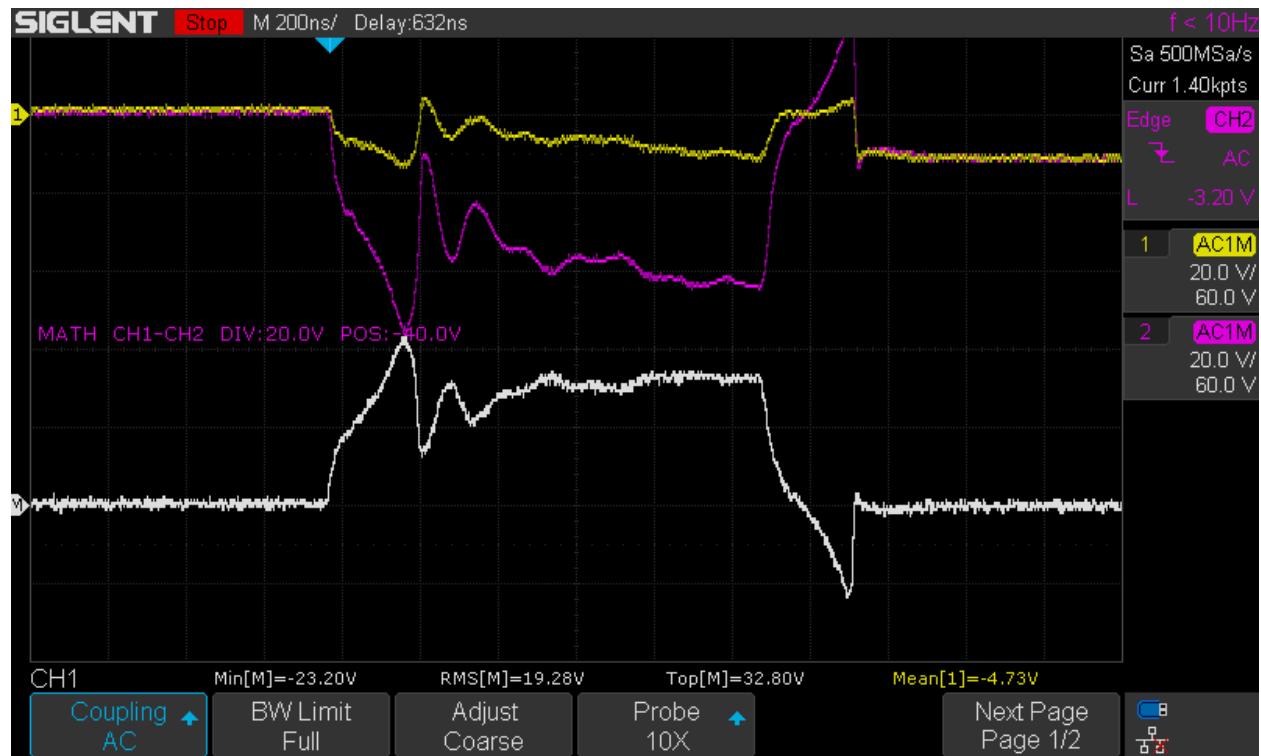
6 GATE: 12.8V CAP ANODE: 80V SERIES RESISTOR: R25 DURATION: 1us



FGAF40N60UFTU

No gate resistor

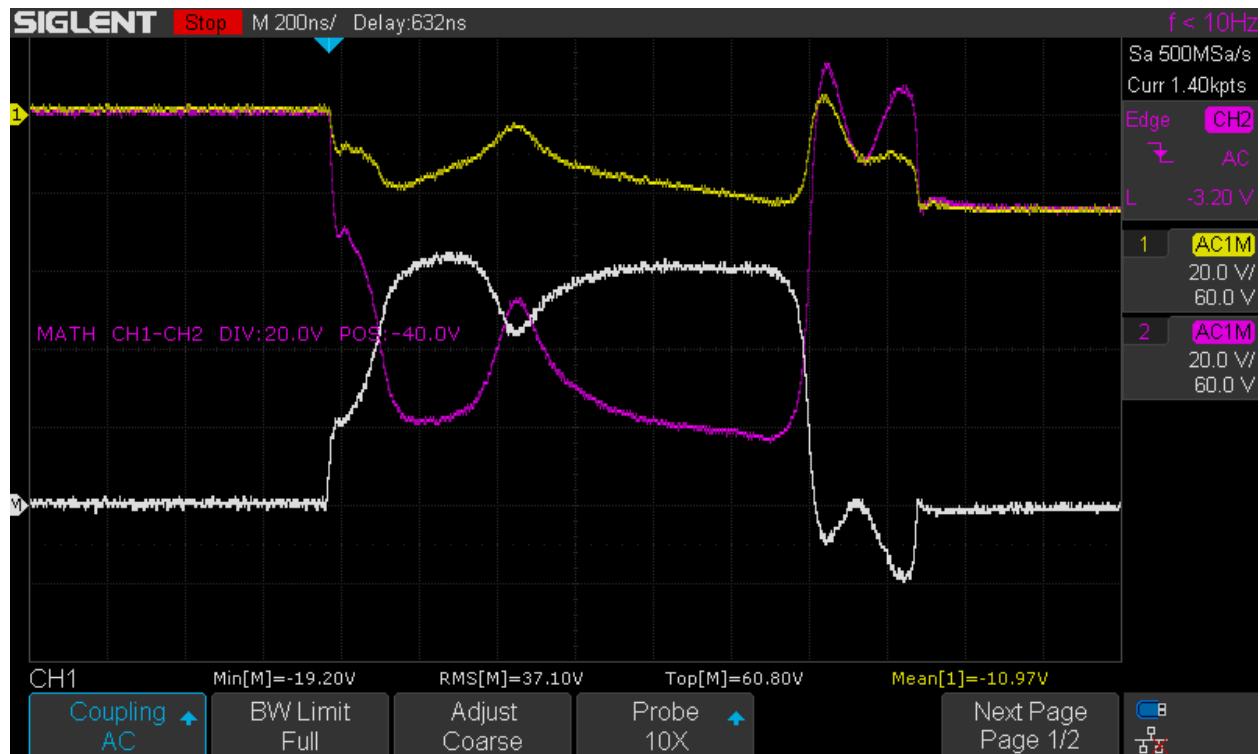
7 GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



FGAF40N60UFTU

No gate resistor

8, 9 (dup) GATE: 18V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us

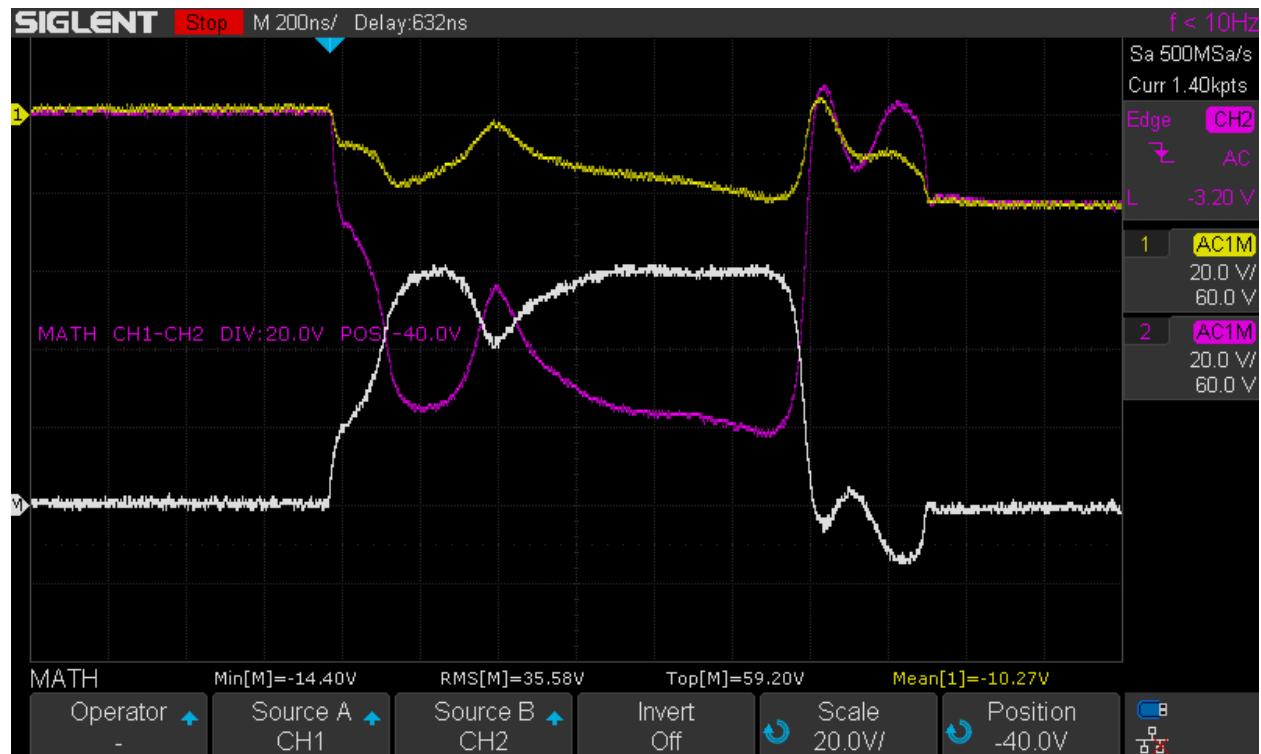


FGAF40N60UFTU

Increased TC4452 Voltage

No gate resistor

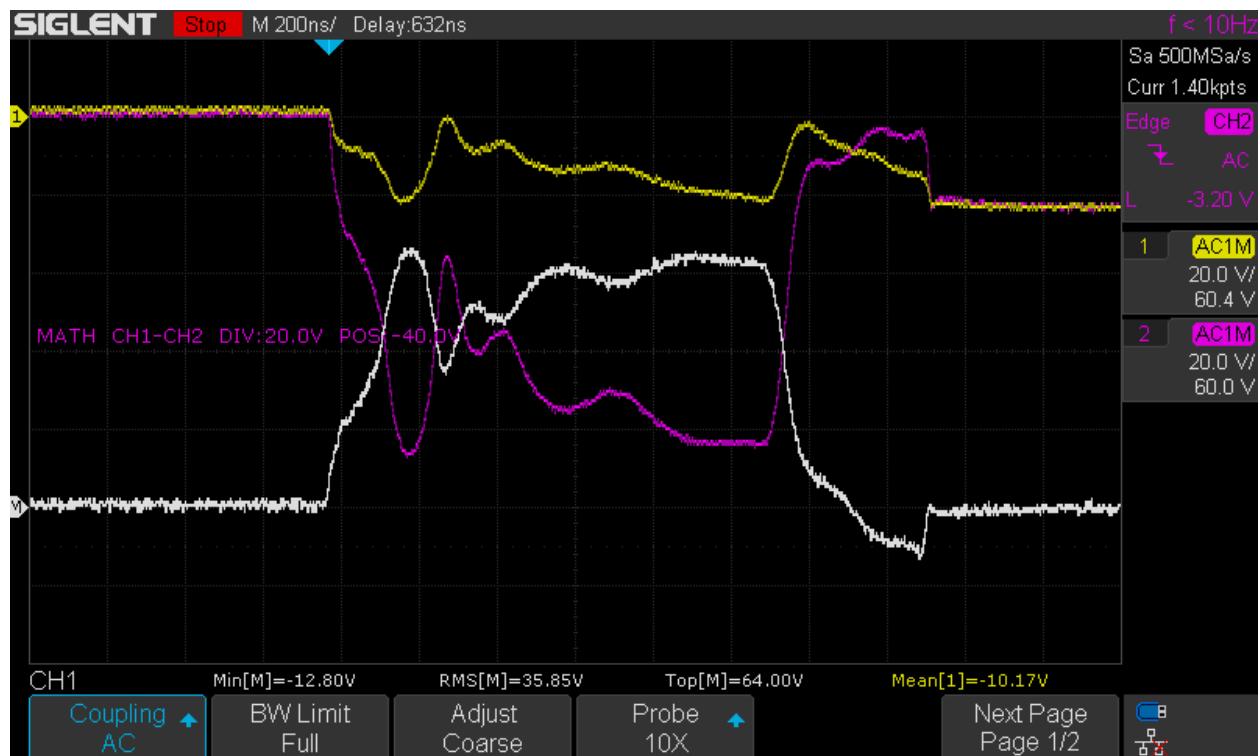
10 GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R25 DURATION: 1us



FGAF40N60UFTU

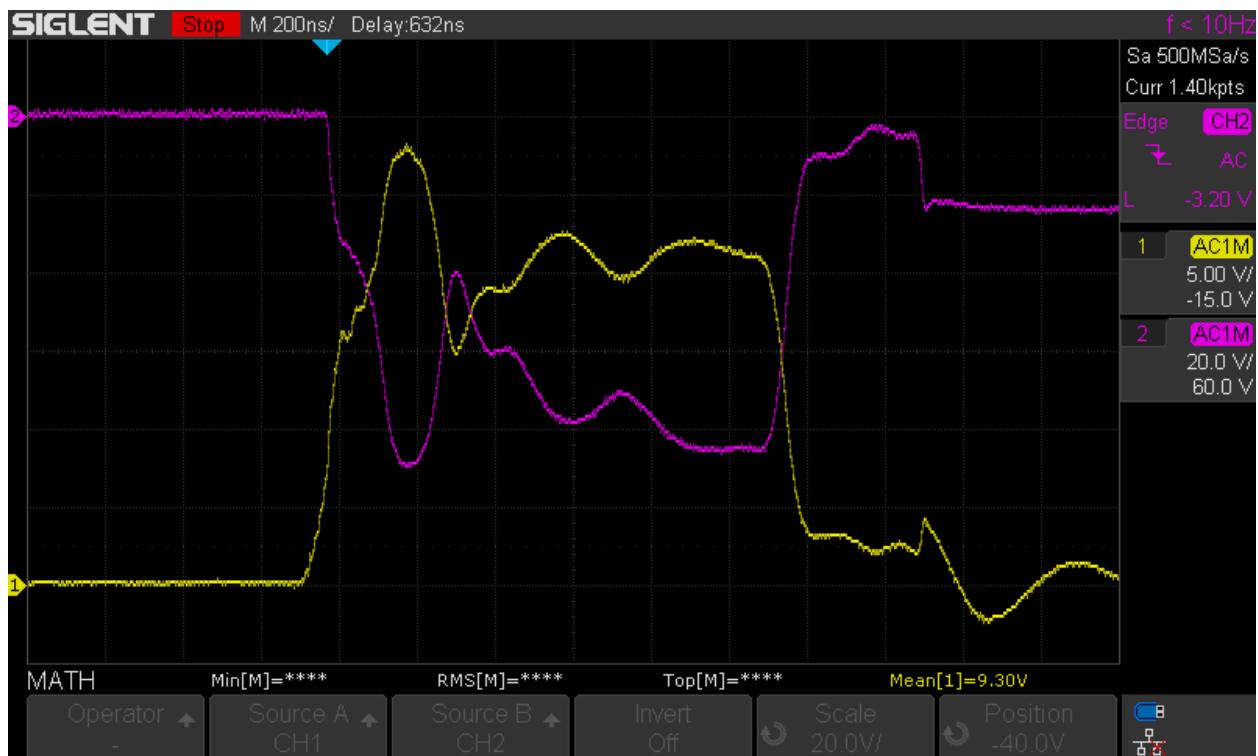
Added gate resistor

11, 12 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



FGAF40N60UFTU

13 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R25 DURATION: 1us



FGAF40N60UFTU

Ch1 – Gate Input

Series 11 – Flyback Converter Testing

Overview:

Purpose: To evaluate the MIC3172-based flyback converter

Equipment:

- E2 Prototype with four banks of LED's in various states of damage
 - IRFB4332 MOSFET's

Results:

- Order of gate filter components does not matter
- Gate overshoot is significant – 12.8V @ TC4452 = 18V max @ gate, 16.0V @ TC4452 = 24V max @ gate

Test Data:

DRAFT 2020-08-23

E2 Flash Development Testing.odt

Series 12 – Bank Testing

Overview:

Purpose: To test the effects of a full bank of LED's on the circuit

Equipment:

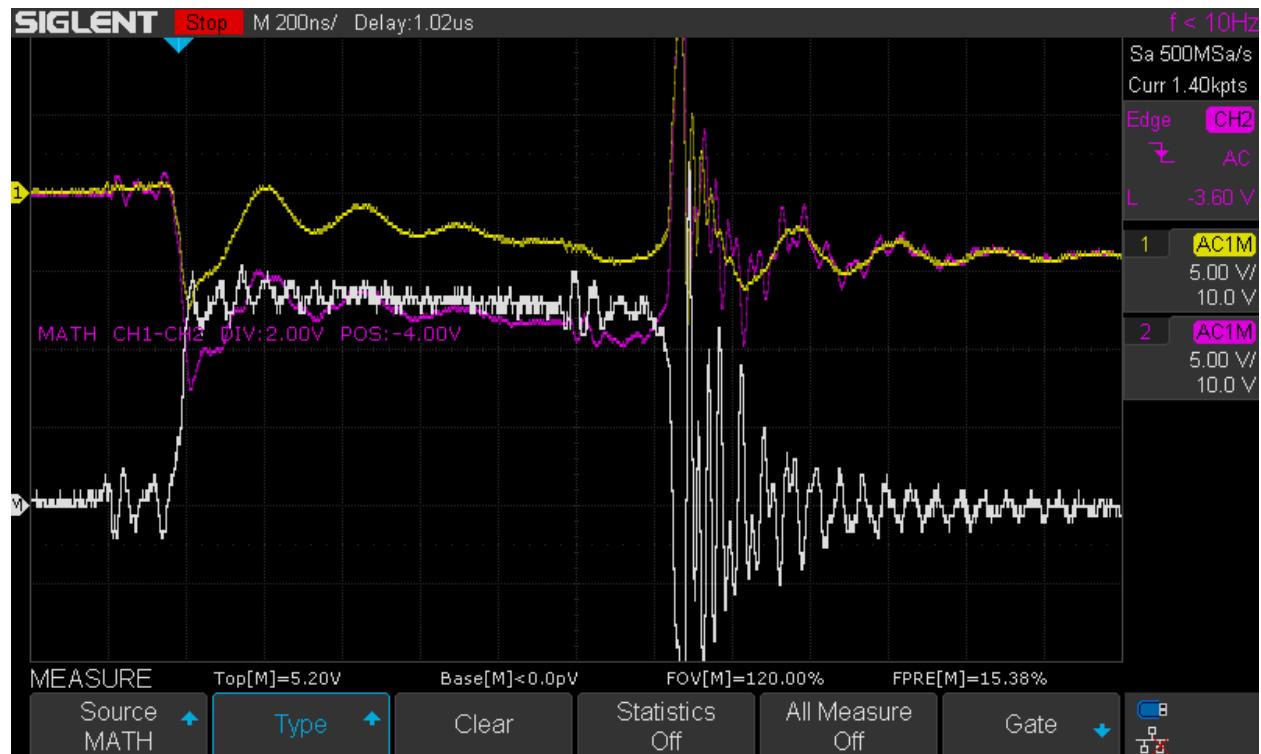
- E2 Prototype with four banks of LED's in various states of damage
 - IRFB4332 MOSFET's

Results:

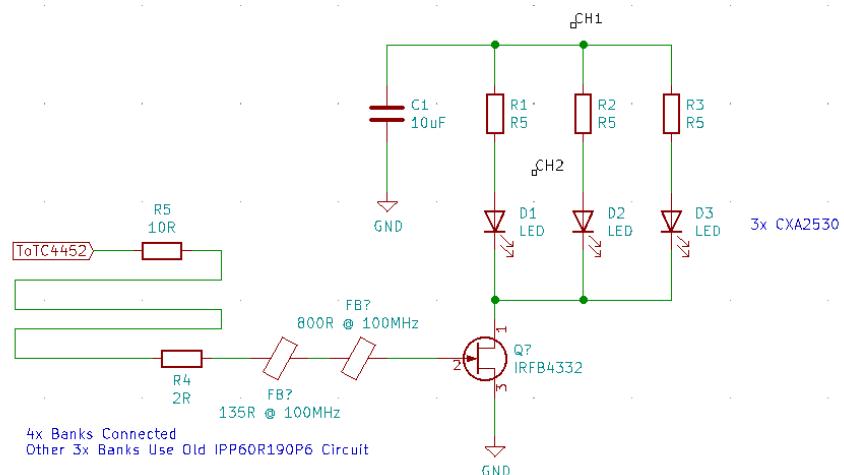
- Order of gate filter components does not matter
- Gate overshoot is significant – 12.8V @ TC4452 = 18V max @ gate, 16.0V @ TC4452 = 24V max @ gate

Test Data:

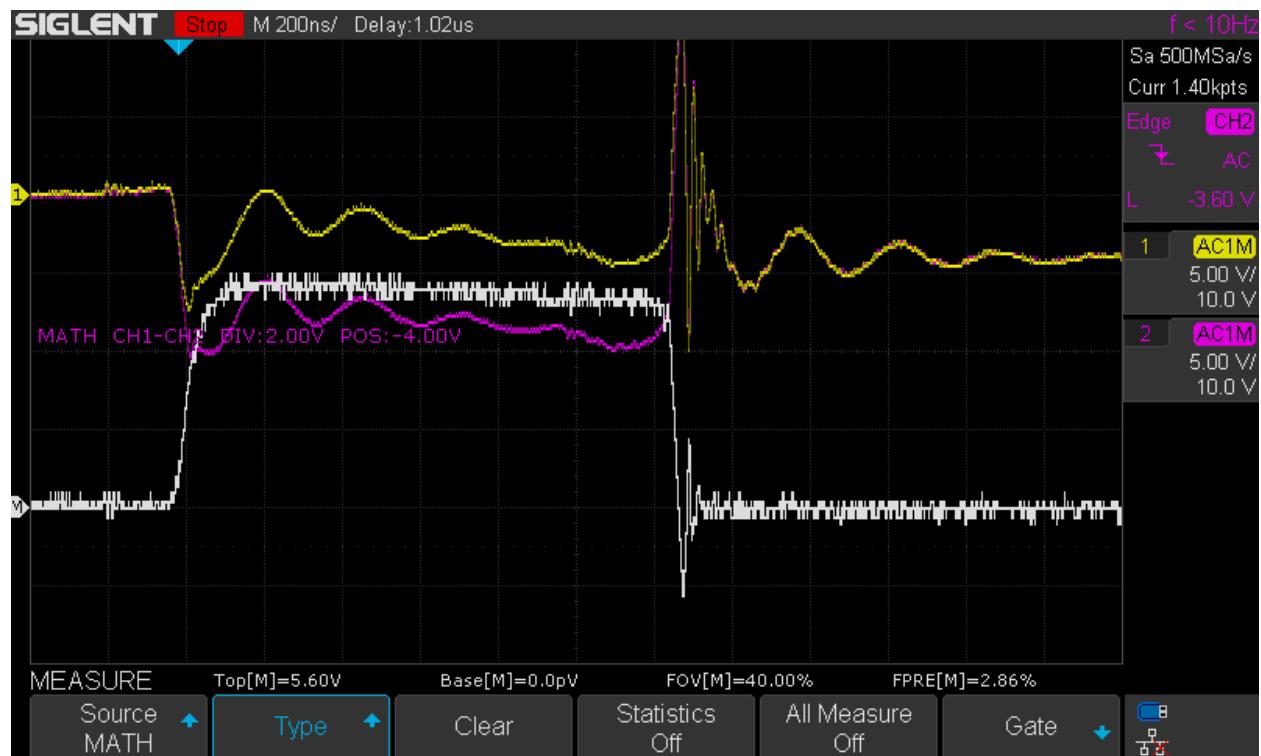
1 GATE: 12.8V CAP ANODE: 80V SERIES RESISTOR: R5 DURATION: 1us



LED 1

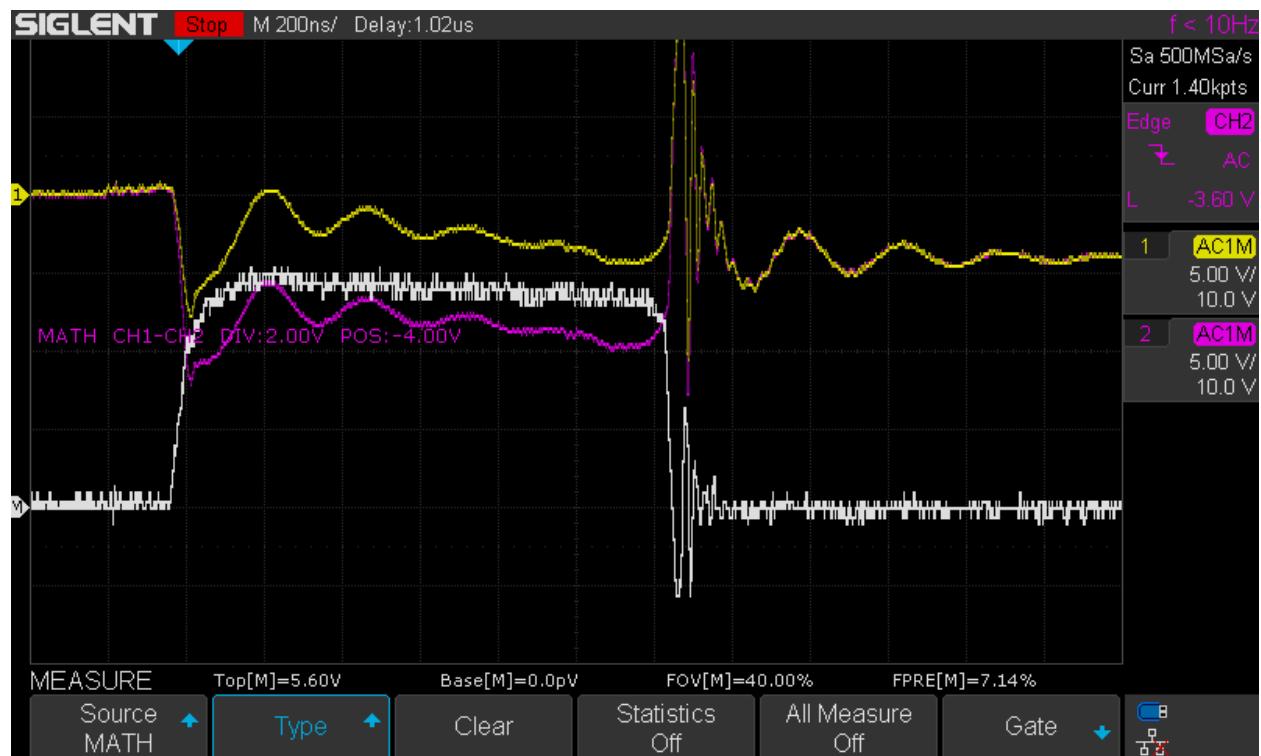


2 GATE: 12.8V CAP ANODE: 80V SERIES RESISTOR: R5 DURATION: 1us



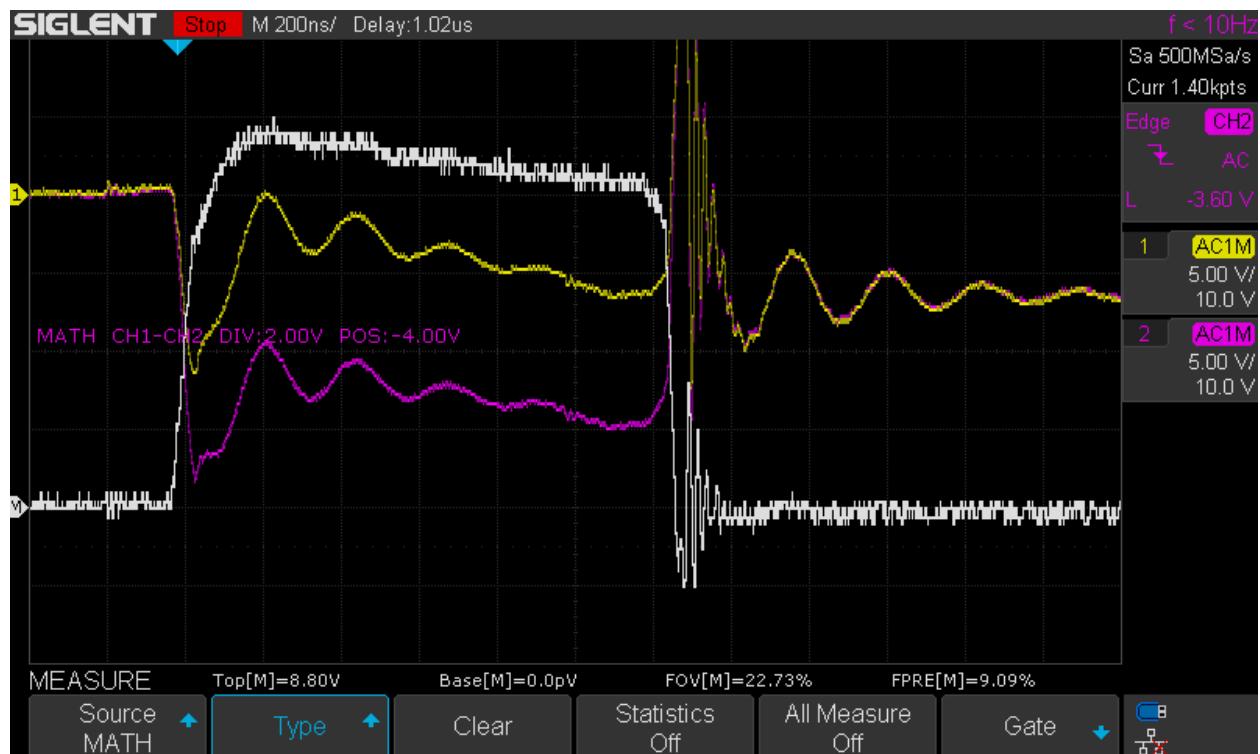
LED #3

3 GATE: 12.8V CAP ANODE: 80V SERIES RESISTOR: R5 DURATION: 1us



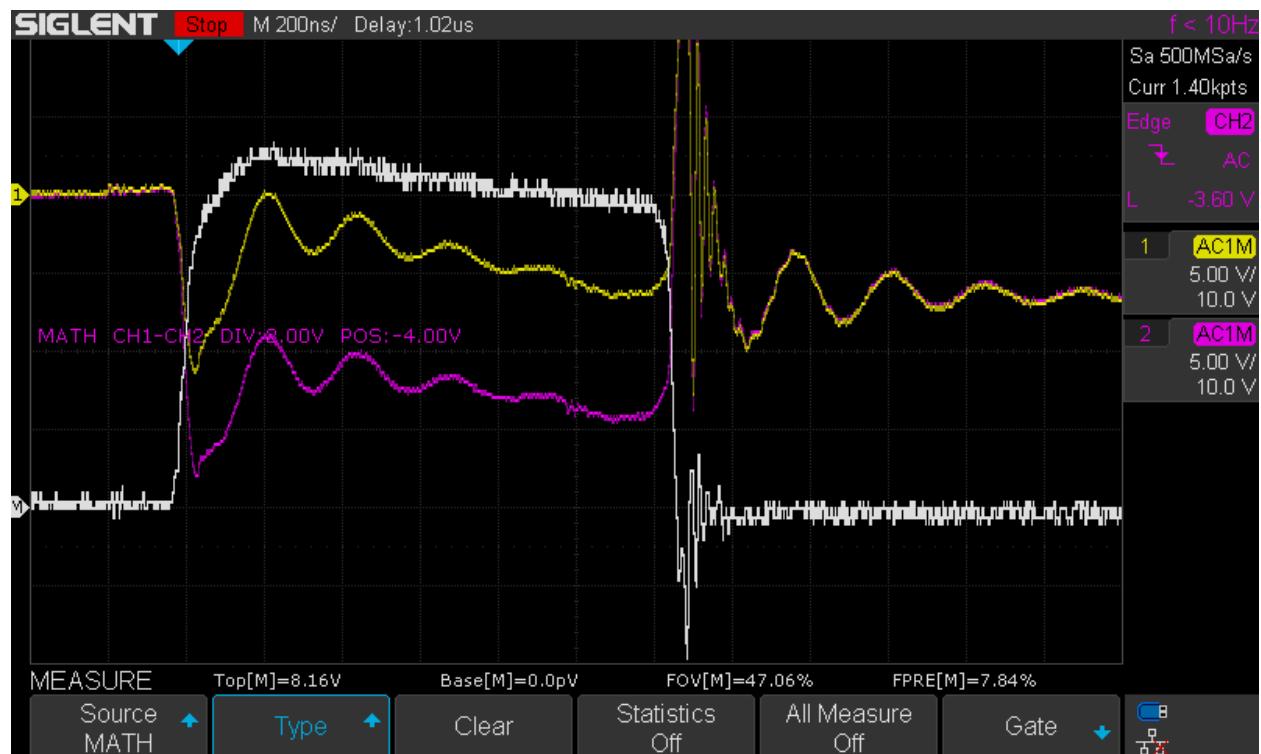
LED #2

4, 5 (dup) GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R5 DURATION: 1us



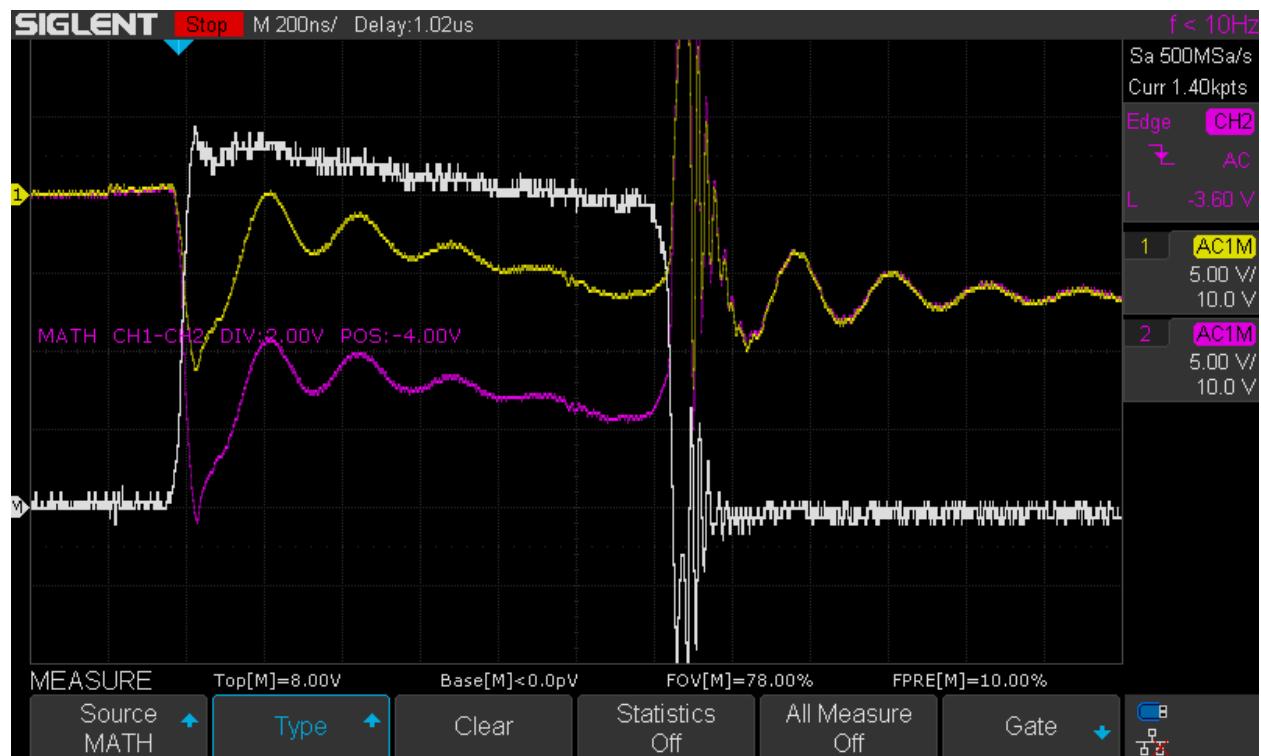
LED #2

6 GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R5 DURATION: 1us



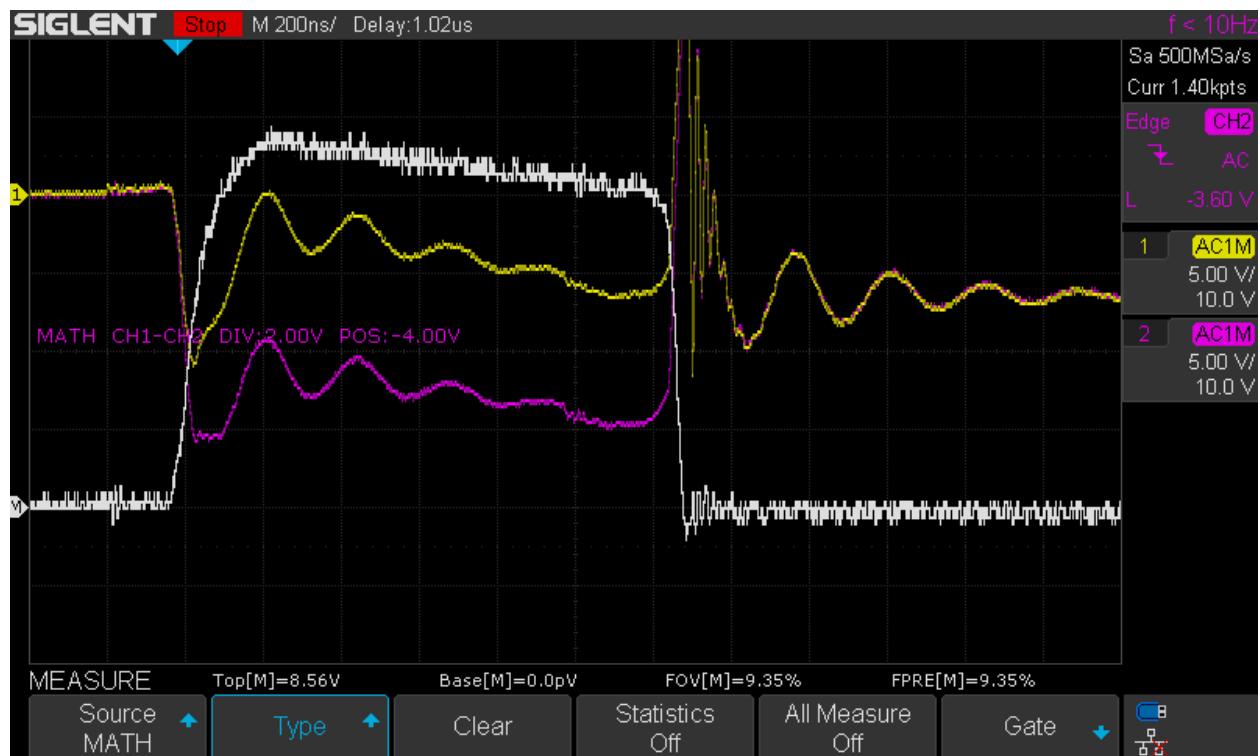
LED #1, CH2 near Resistor

7 GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R5 DURATION: 1us



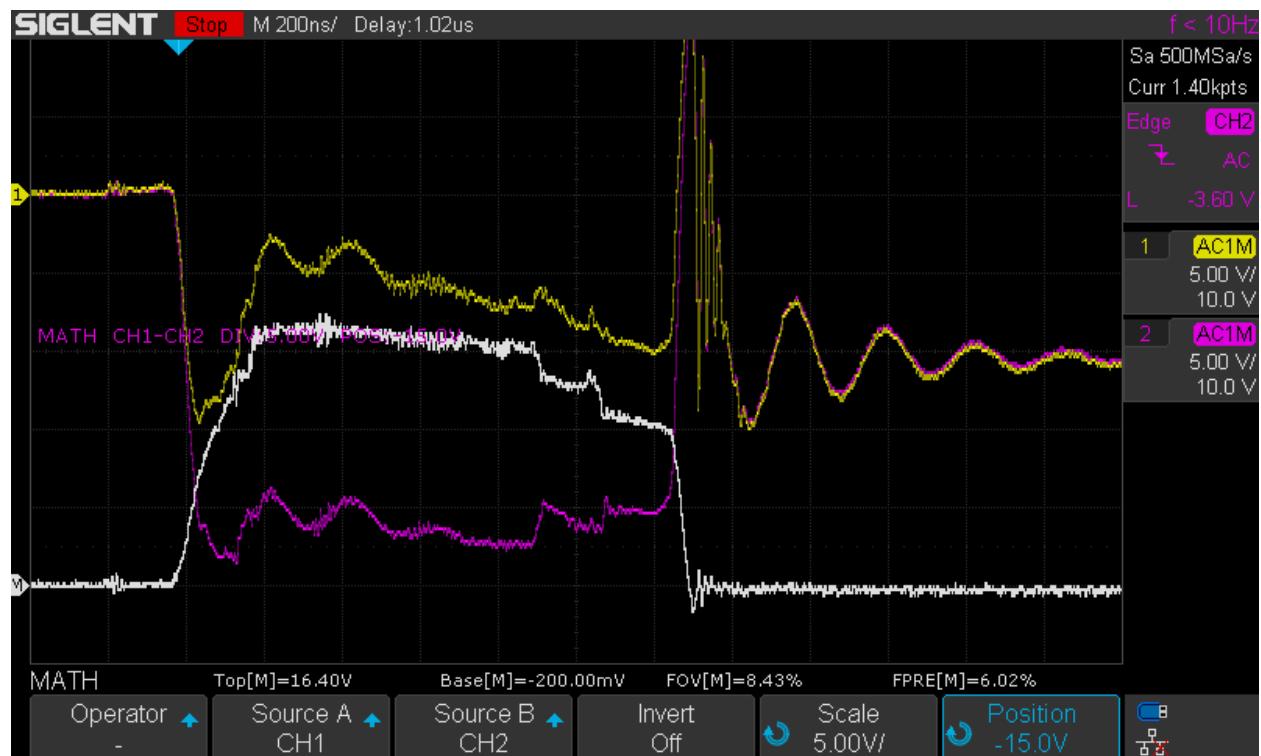
LED #1, CH2 near LED

8, 9 (dup) GATE: 12.8V CAP ANODE: 100V SERIES RESISTOR: R5 DURATION: 1us



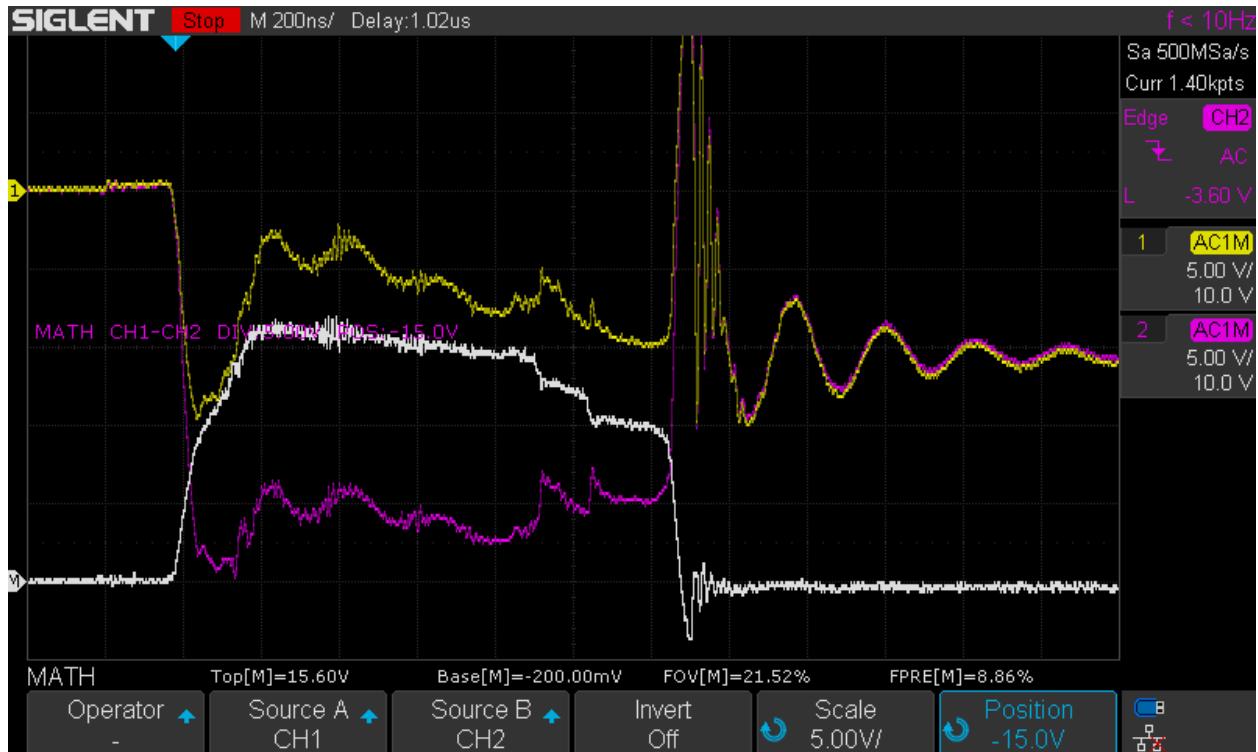
LED #3

10, 11 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



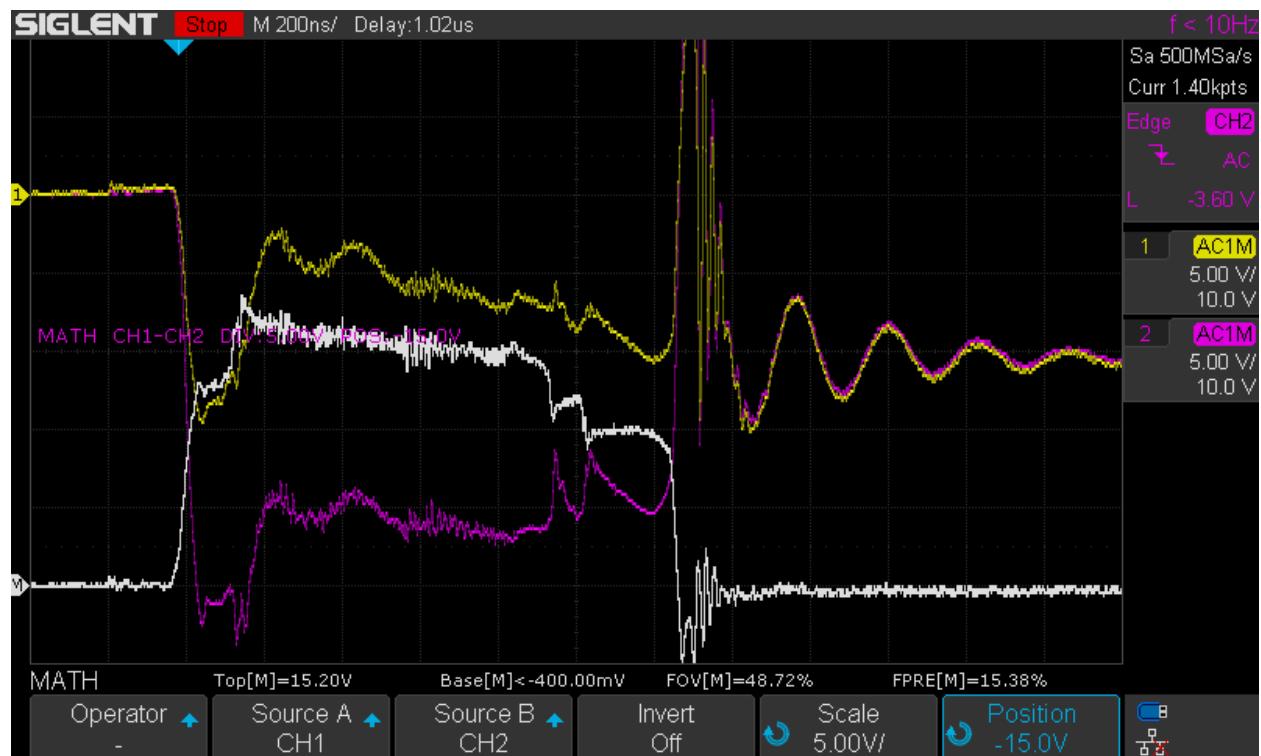
LED #3

12 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



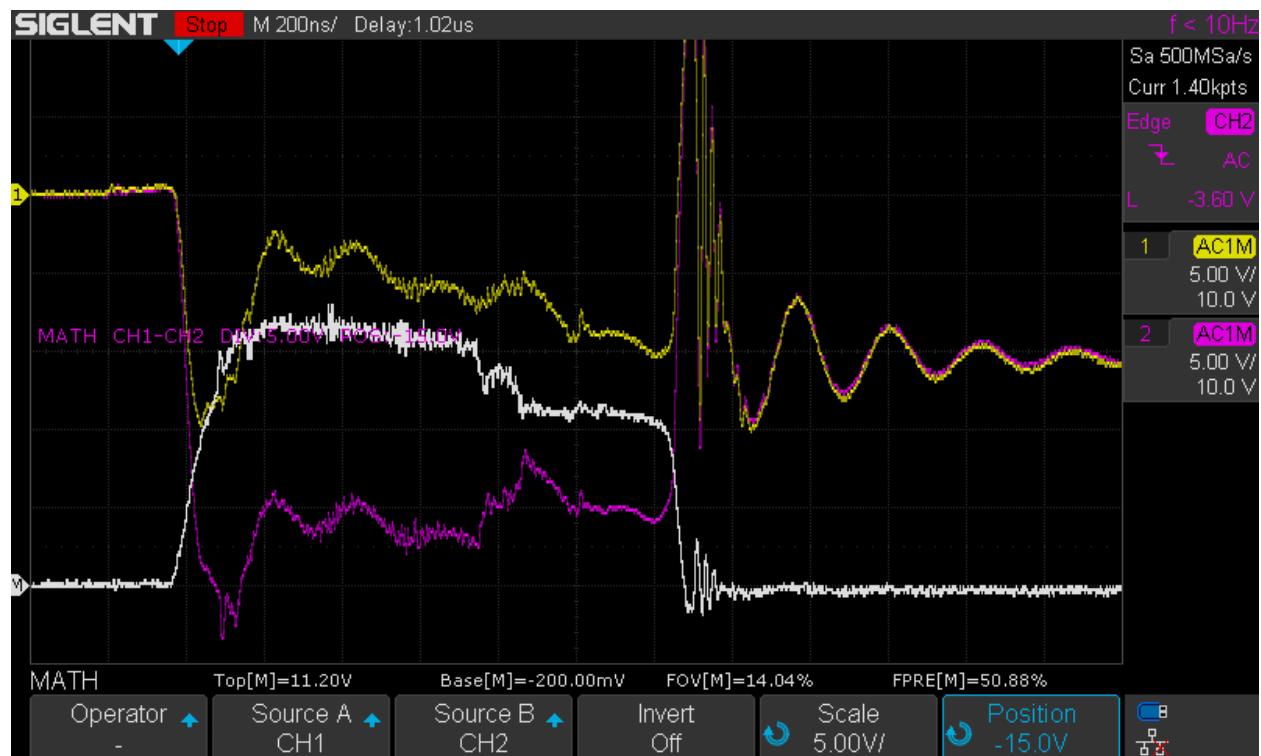
LED #1, CH2 near Resistor

13 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



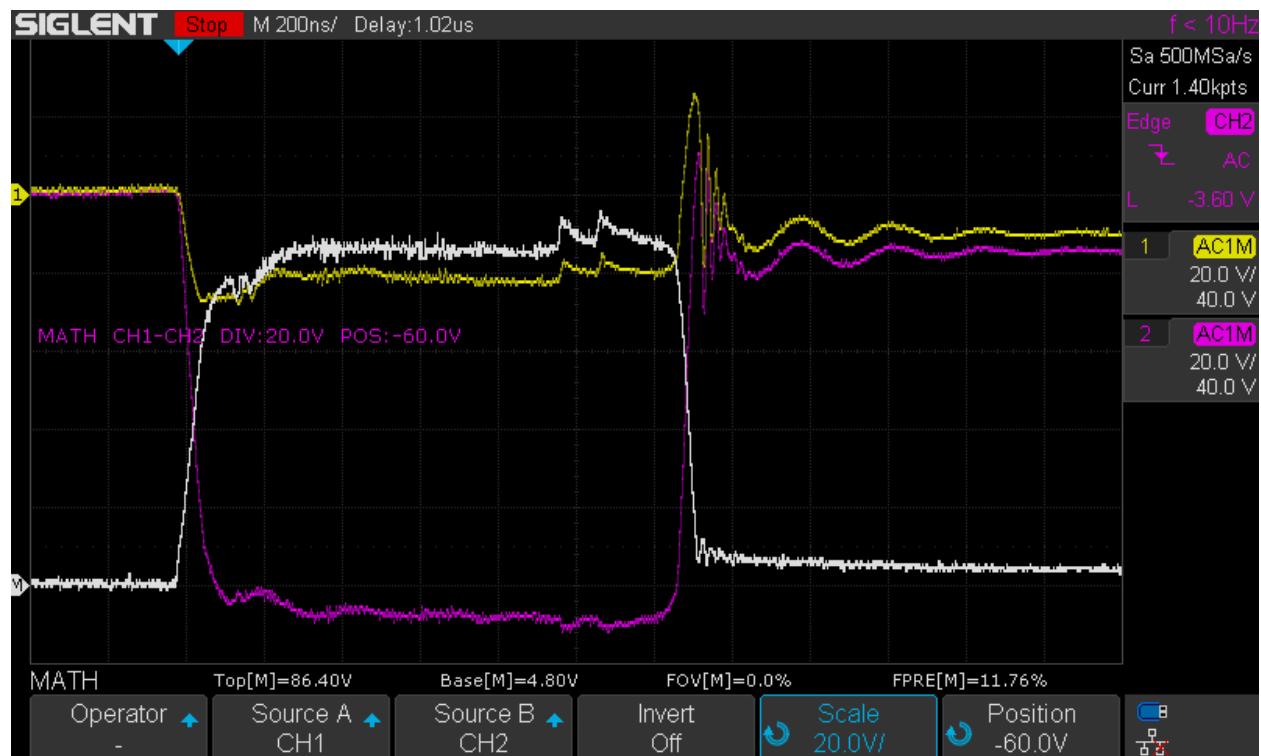
LED #1, CH2 near LED

14, 15 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

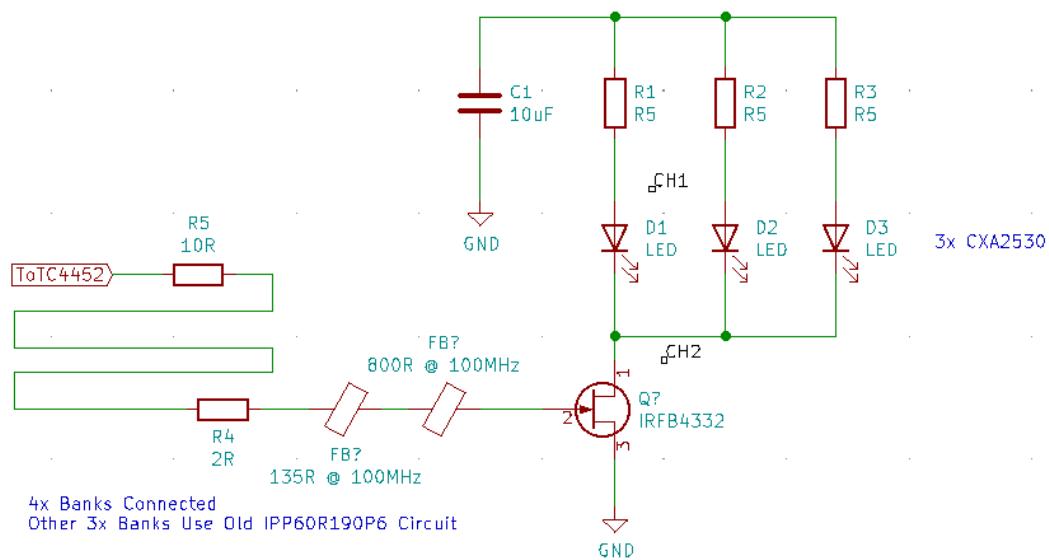


LED #2

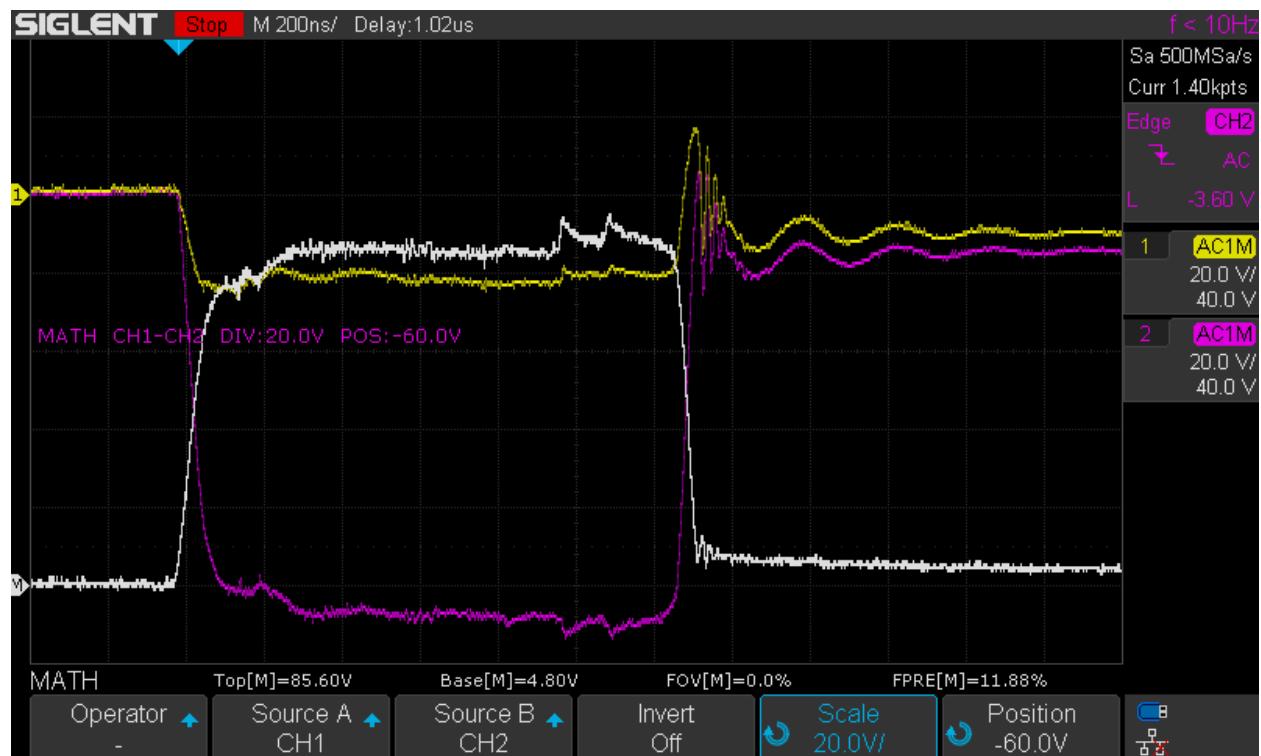
16, 17 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



LED #1, Measuring across LED

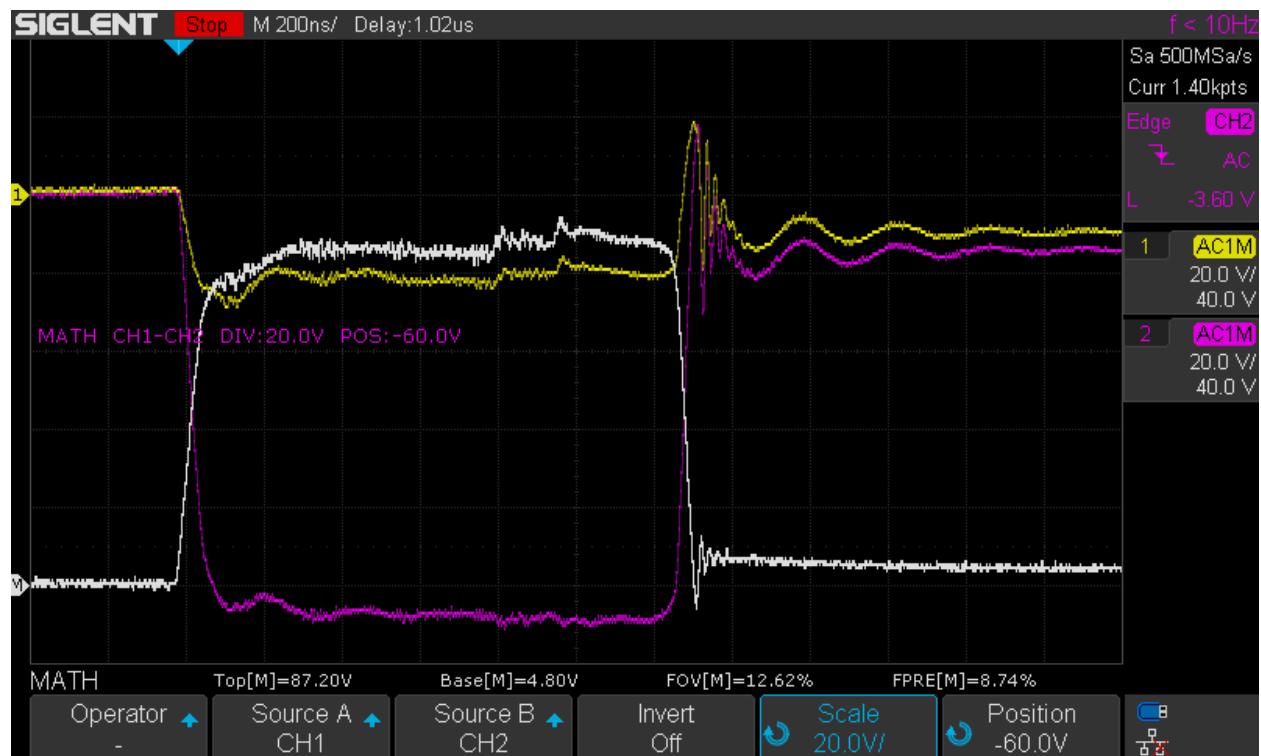


18, 19 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



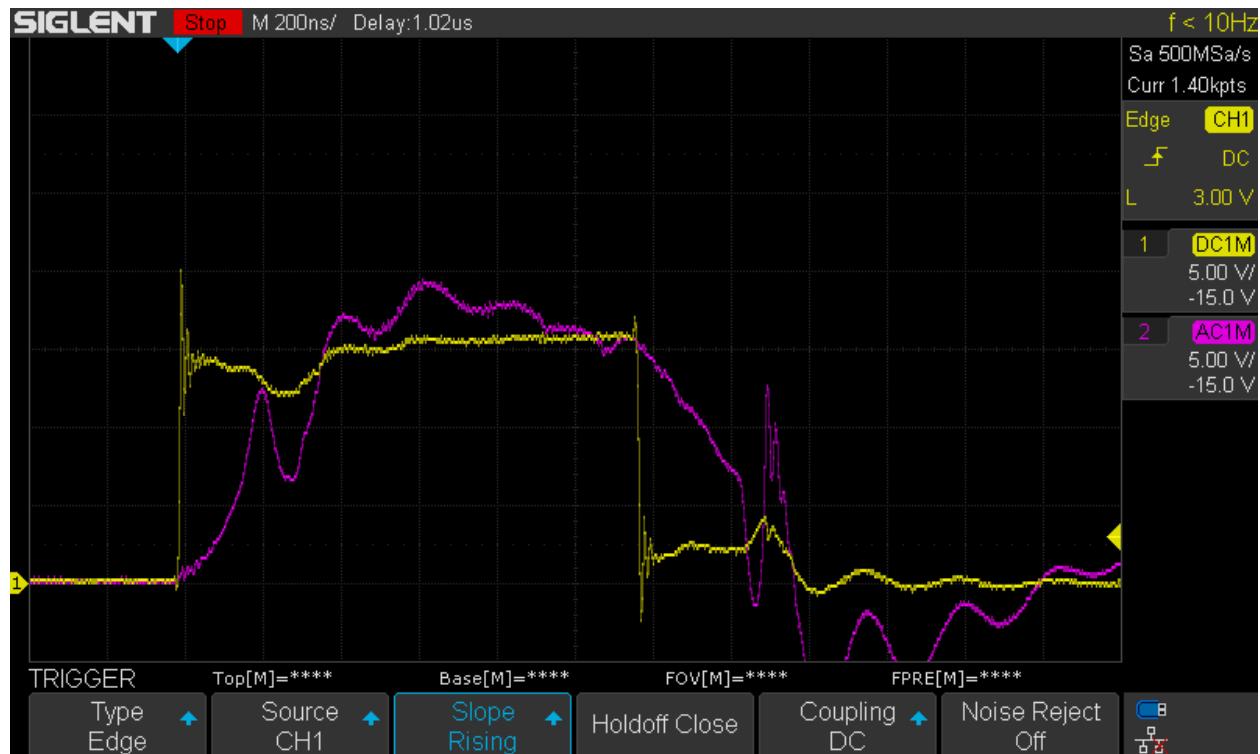
LED #3, Measuring across LED

20 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



LED #2, Measuring across LED

21, 22 (dup) GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



CH1 – Gate input, CH2 – FET Gate

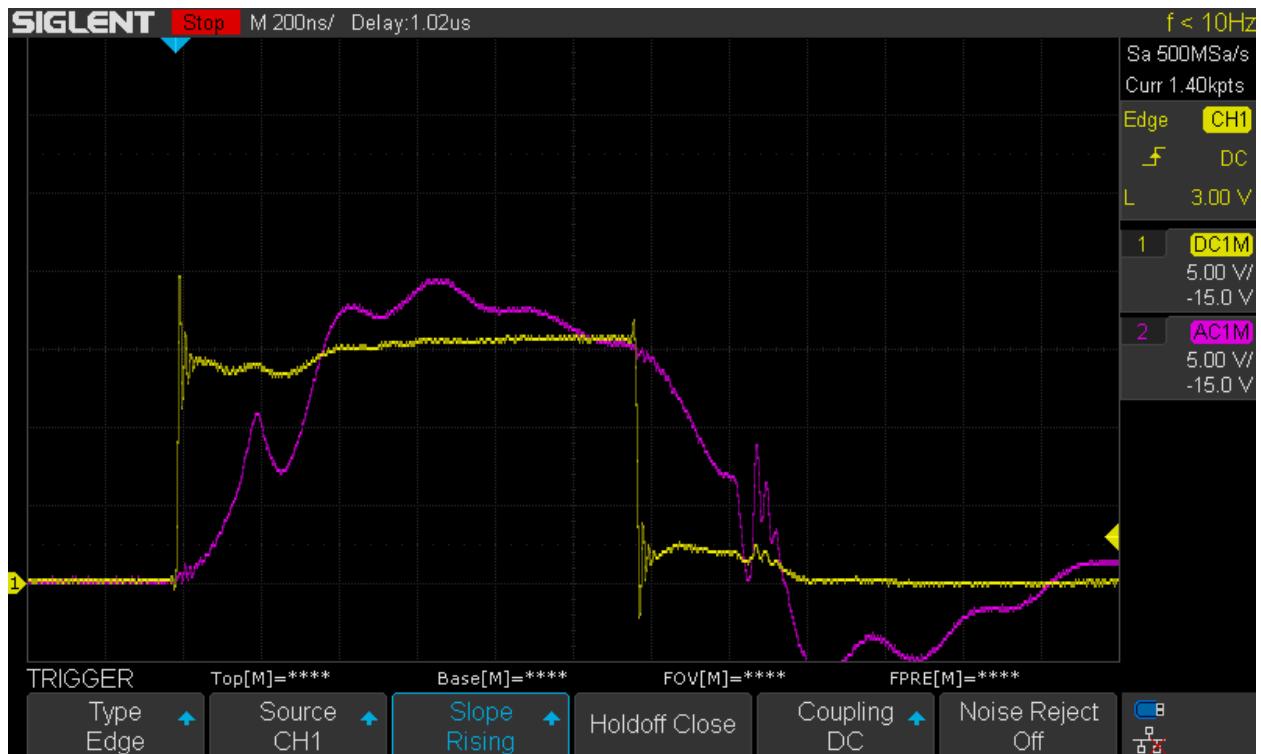
23

GATE: 12.8V

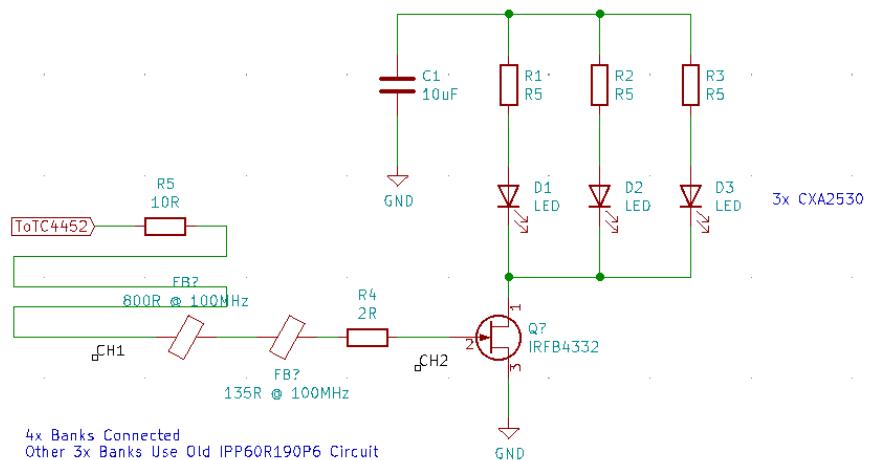
CAP ANODE: 80V

SERIES RESISTOR: R5

DURATION: 1us



Reversed gate filter circuit



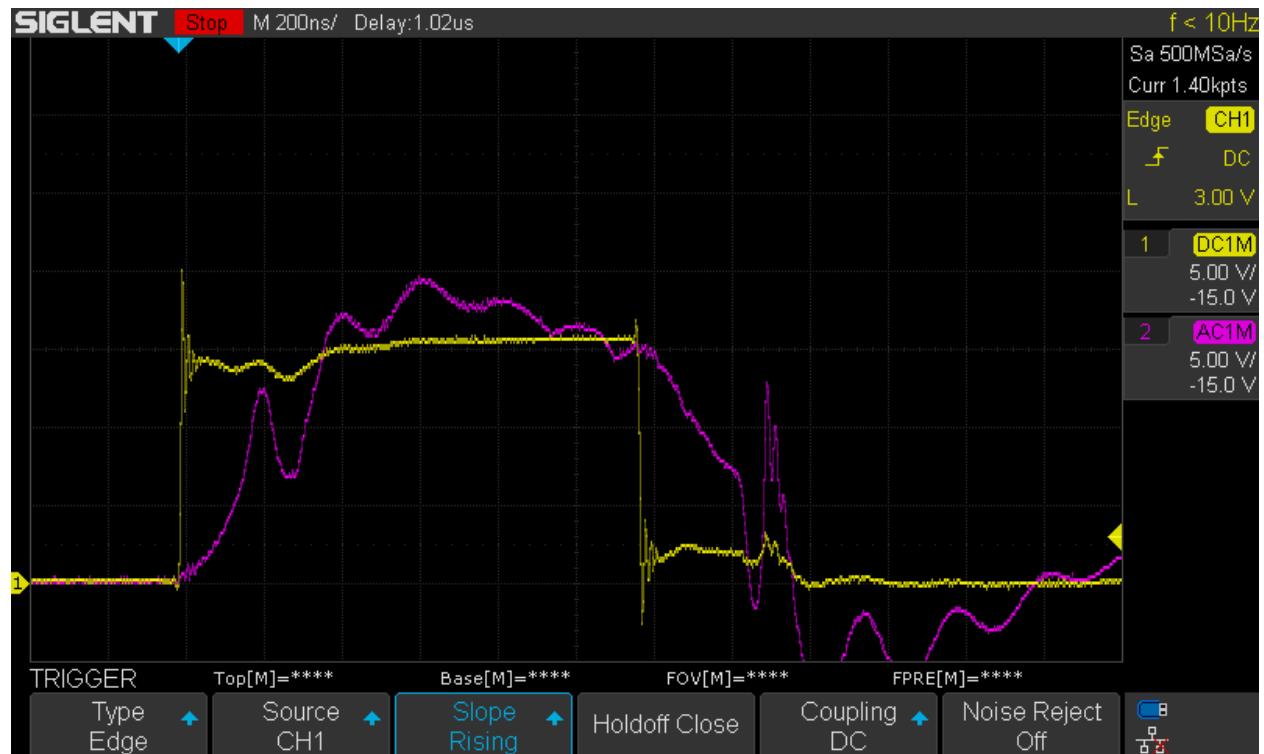
24

GATE: 12.8V

CAP ANODE: 120V

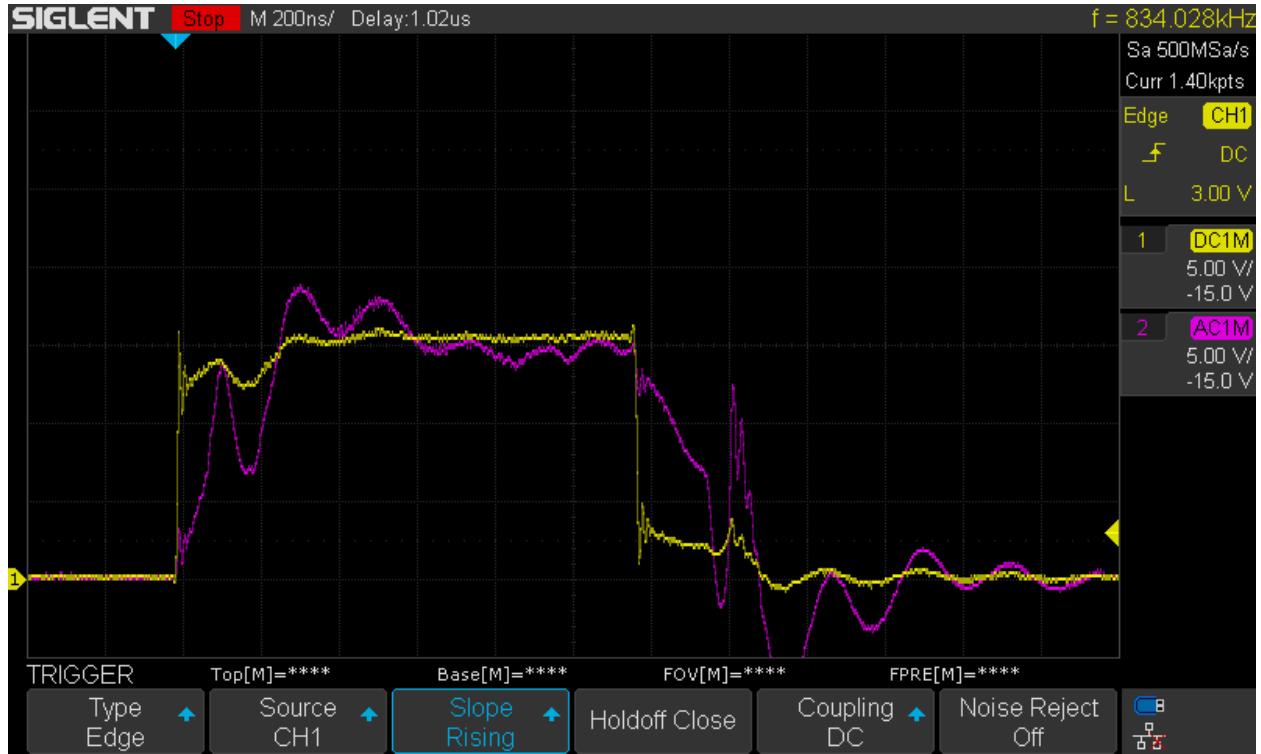
SERIES RESISTOR: R5

DURATION: 1us

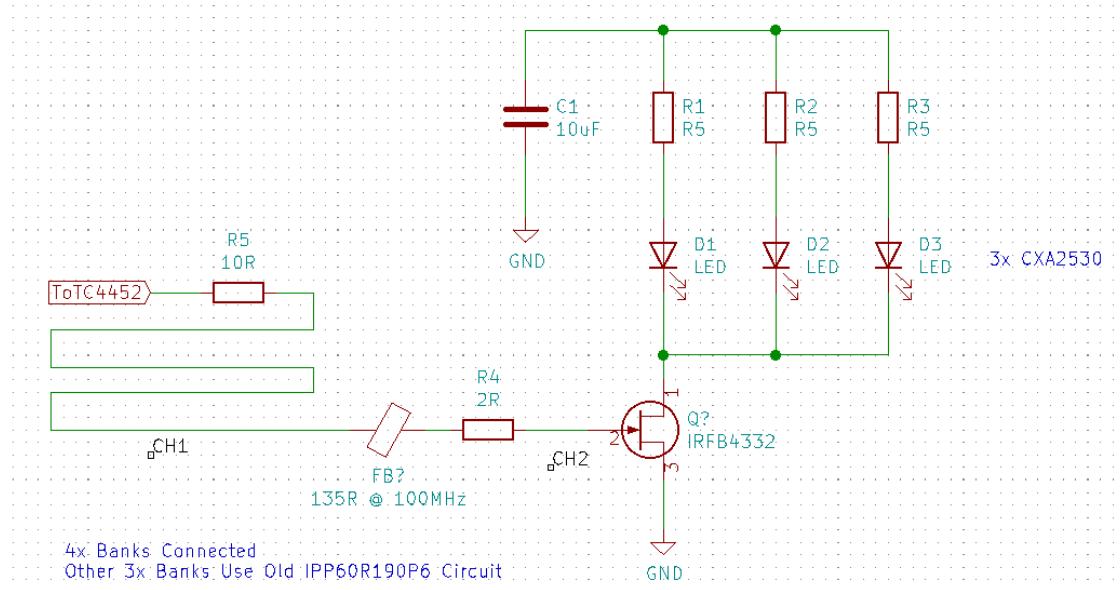


Increased Cap Anode voltage

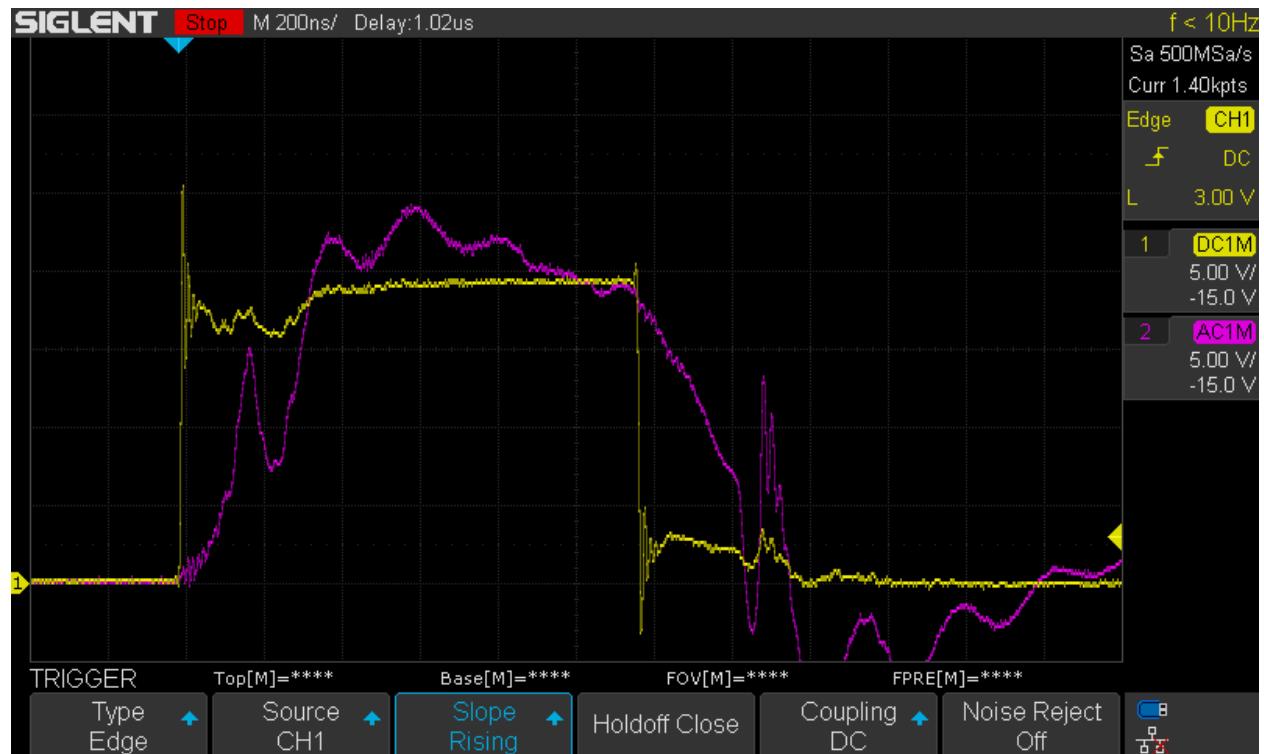
25 GATE: 12.8V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Removed 800R @ 100MHz FB

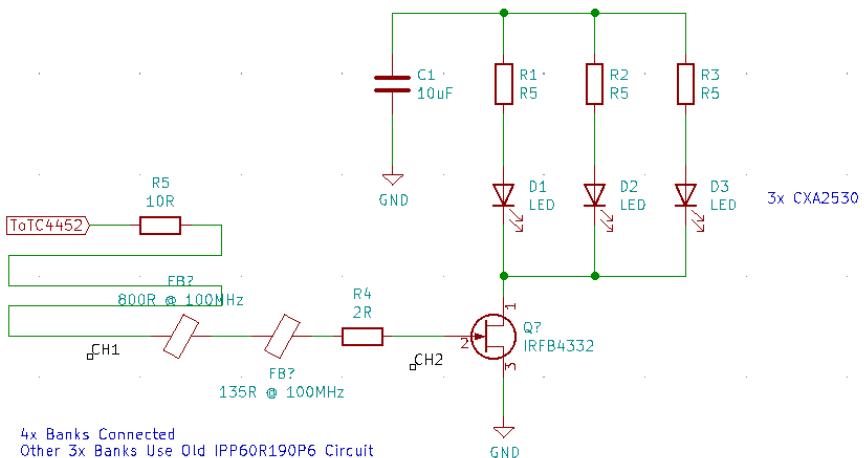


26 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

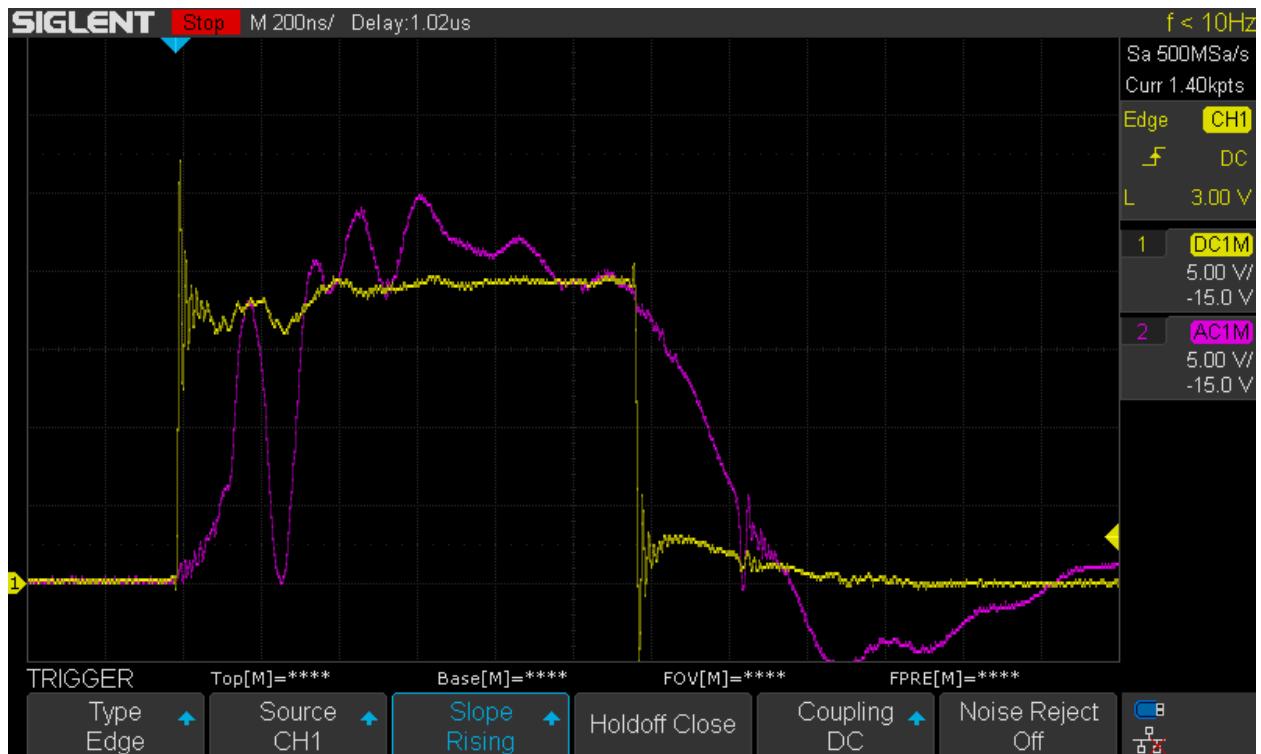


Added FB again

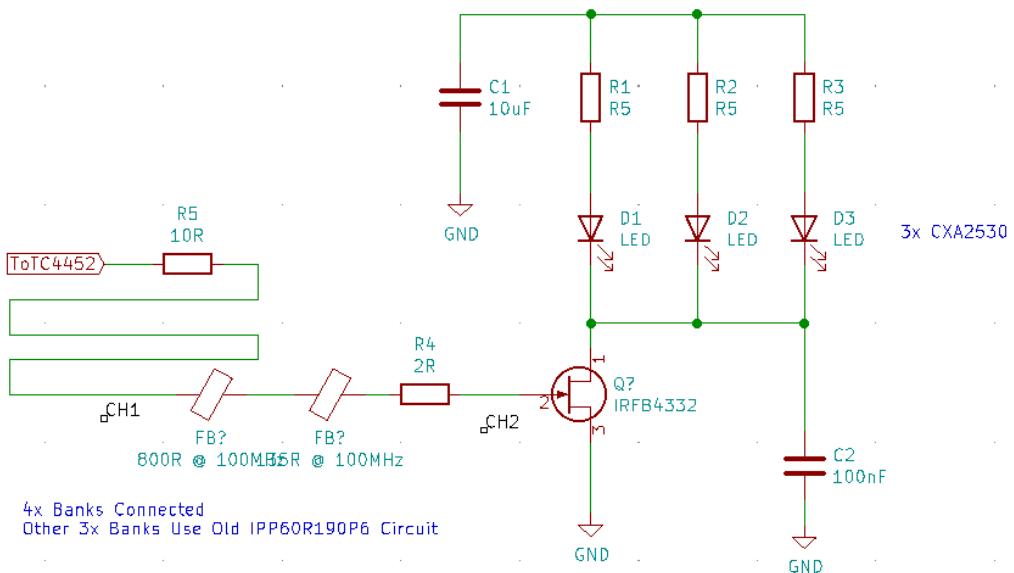
Increased TC4452 voltage to 16V



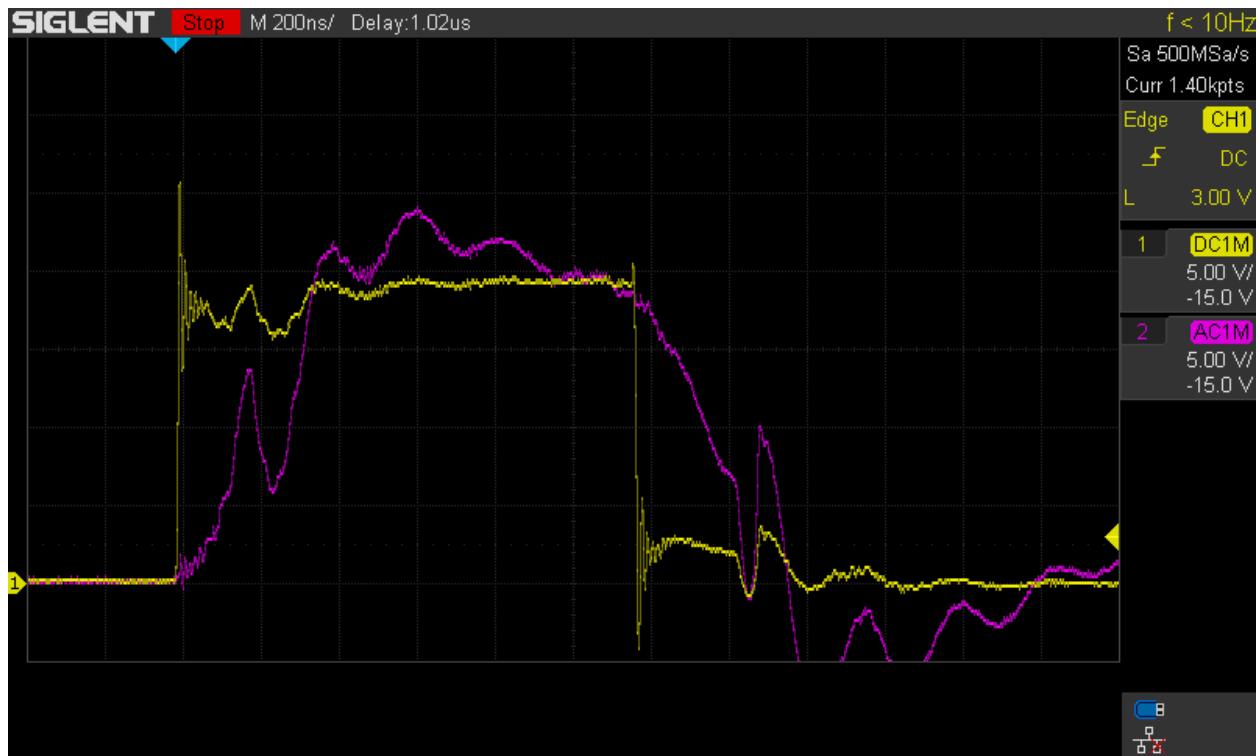
27, 28 (dup) GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



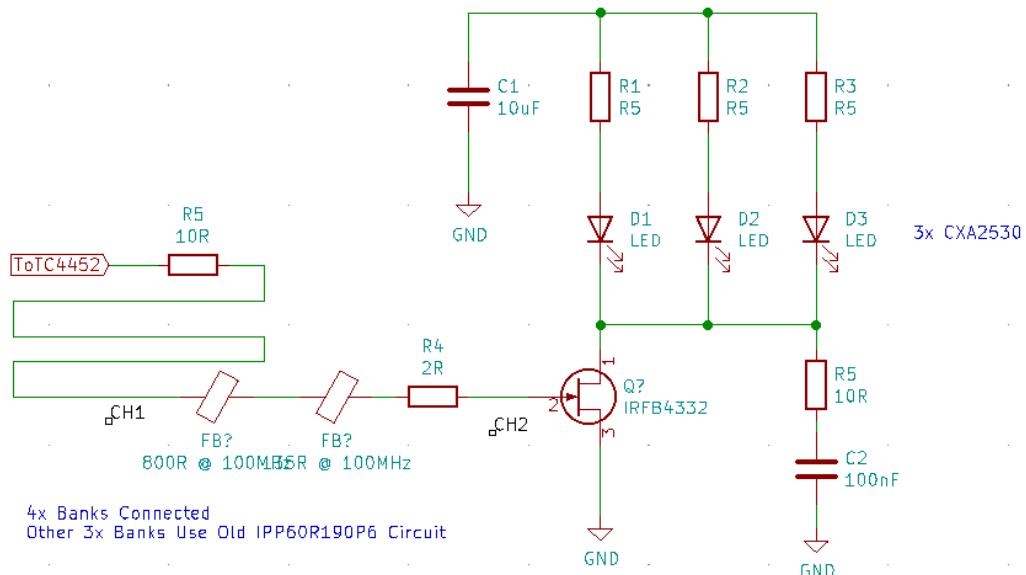
Added 100nF Ceramic Cap to Drain



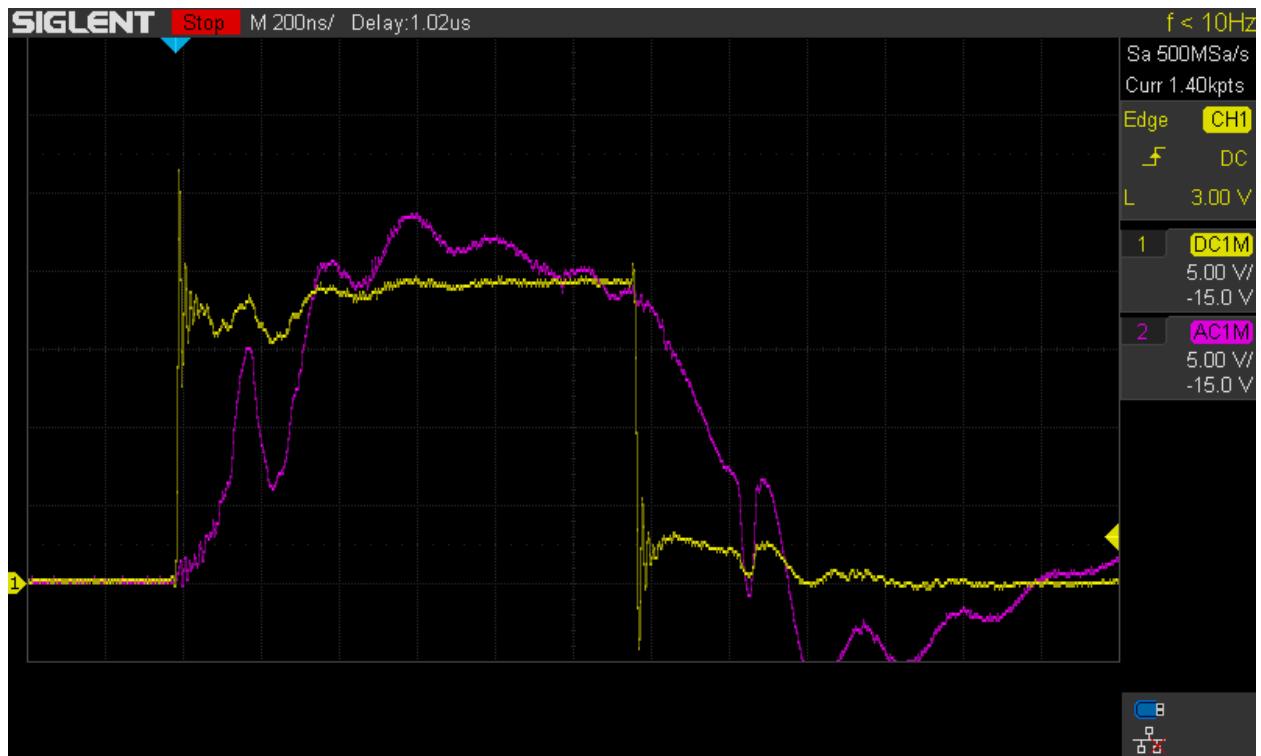
29, 30 (dup) GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



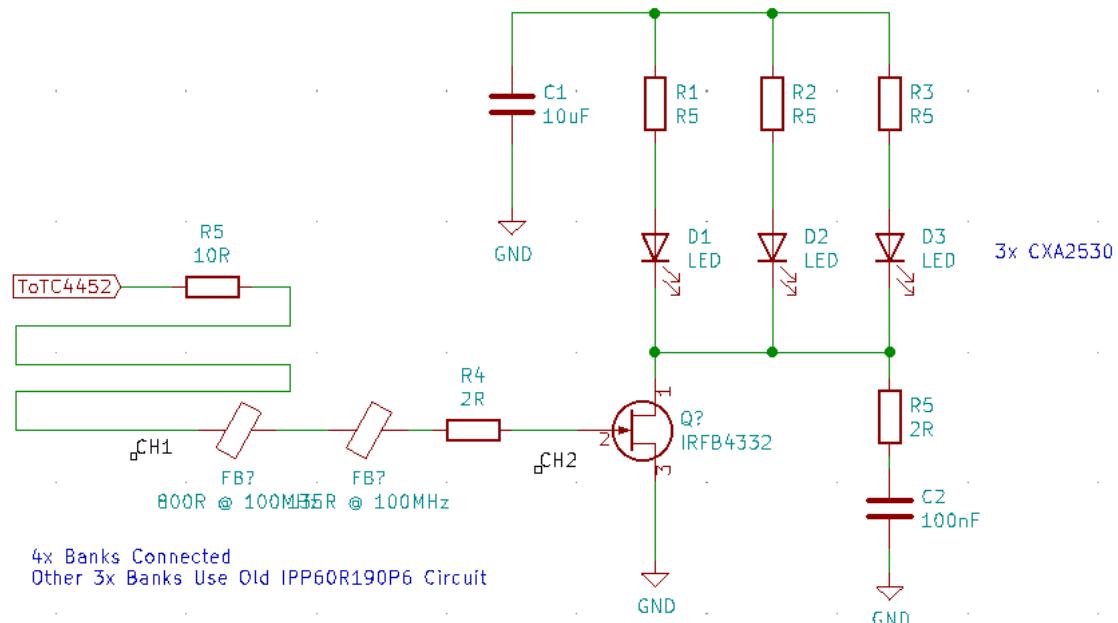
Added 10R resistor in series with cap



31 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Changed R5 to 2R



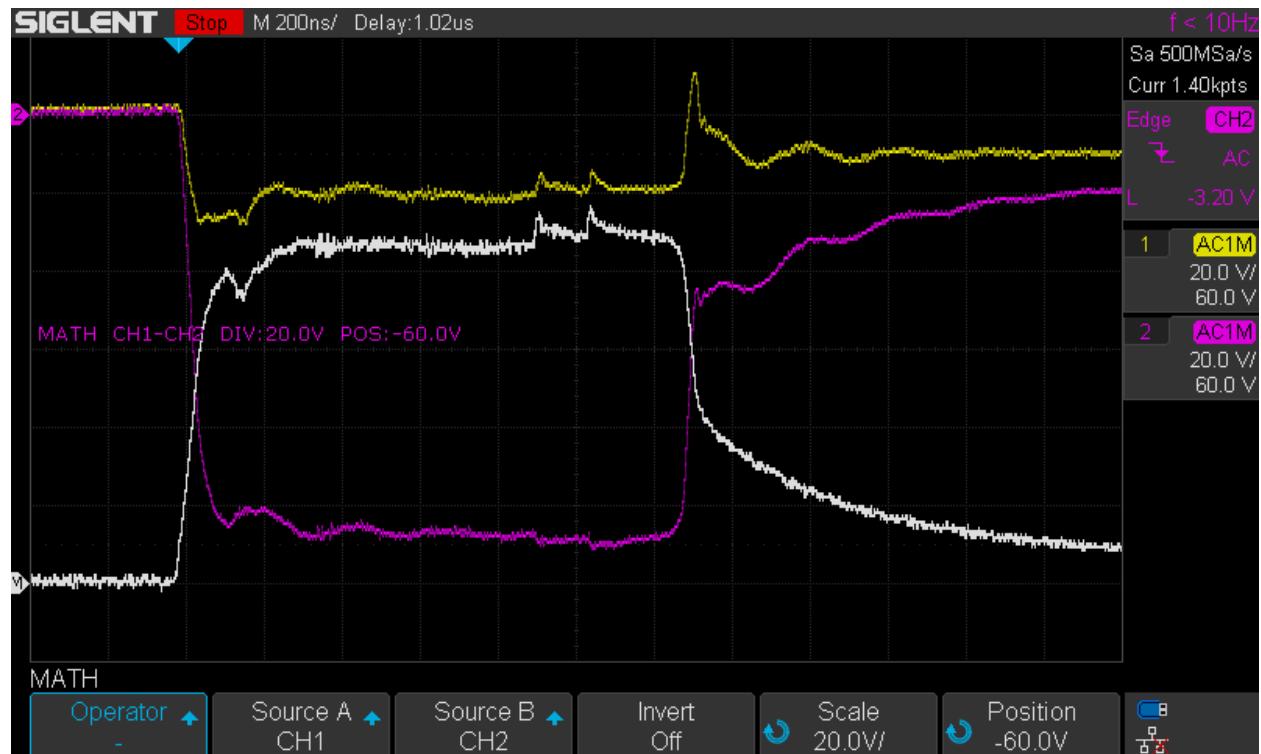
32

GATE: 16.0V

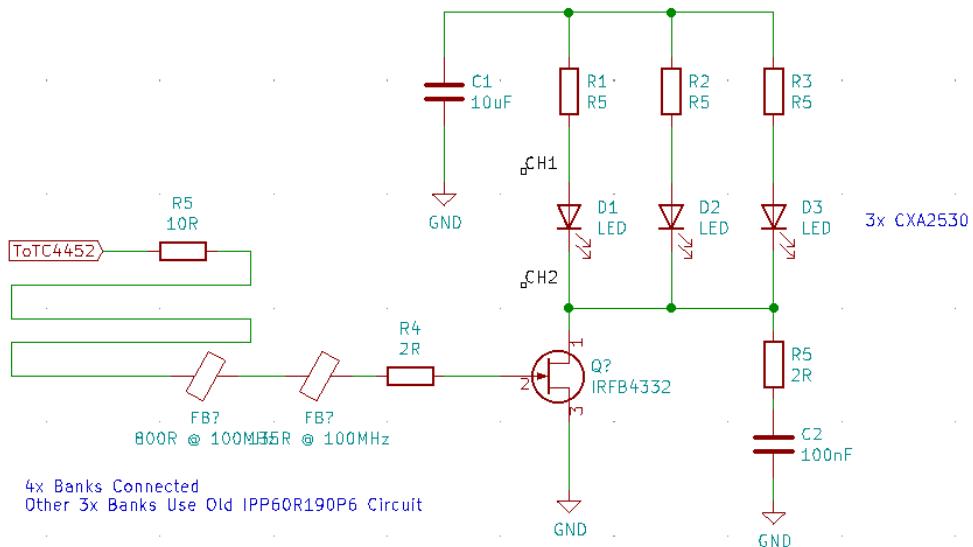
CAP ANODE: 120V

SERIES RESISTOR: R5

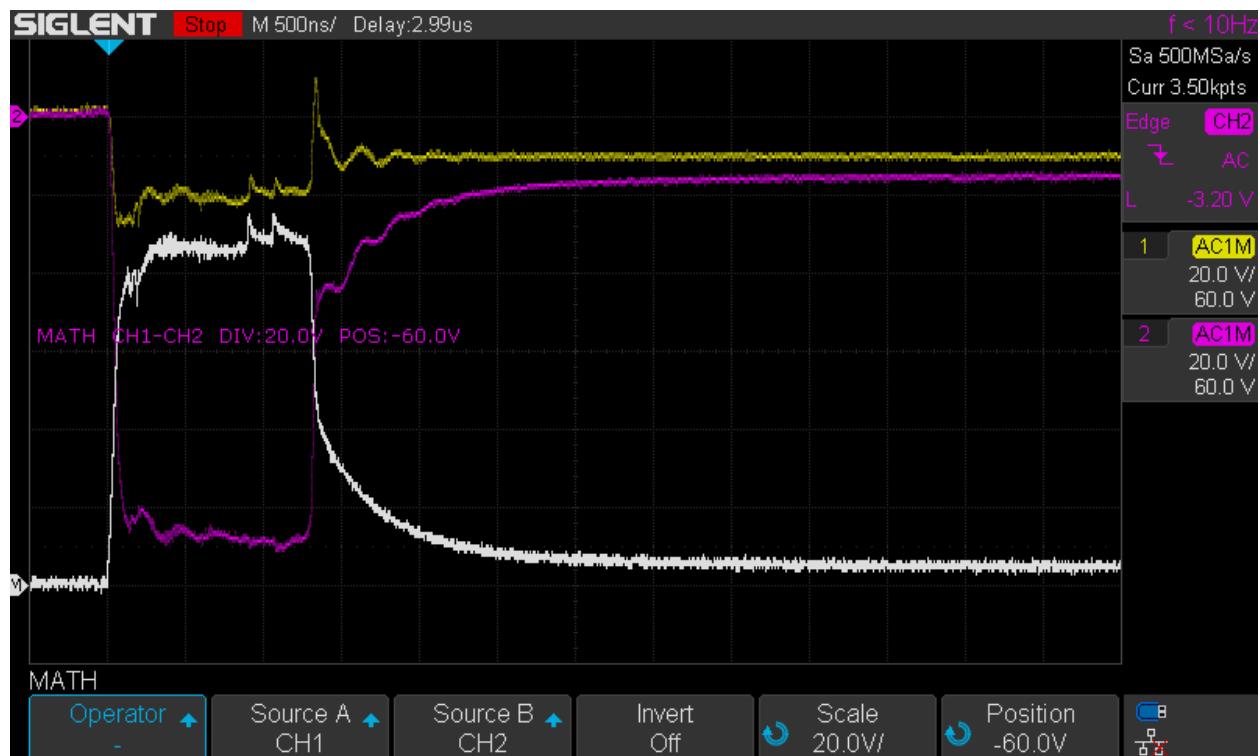
DURATION: 1us



Measuring across LED #1



33 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



No Change – Timebase changed

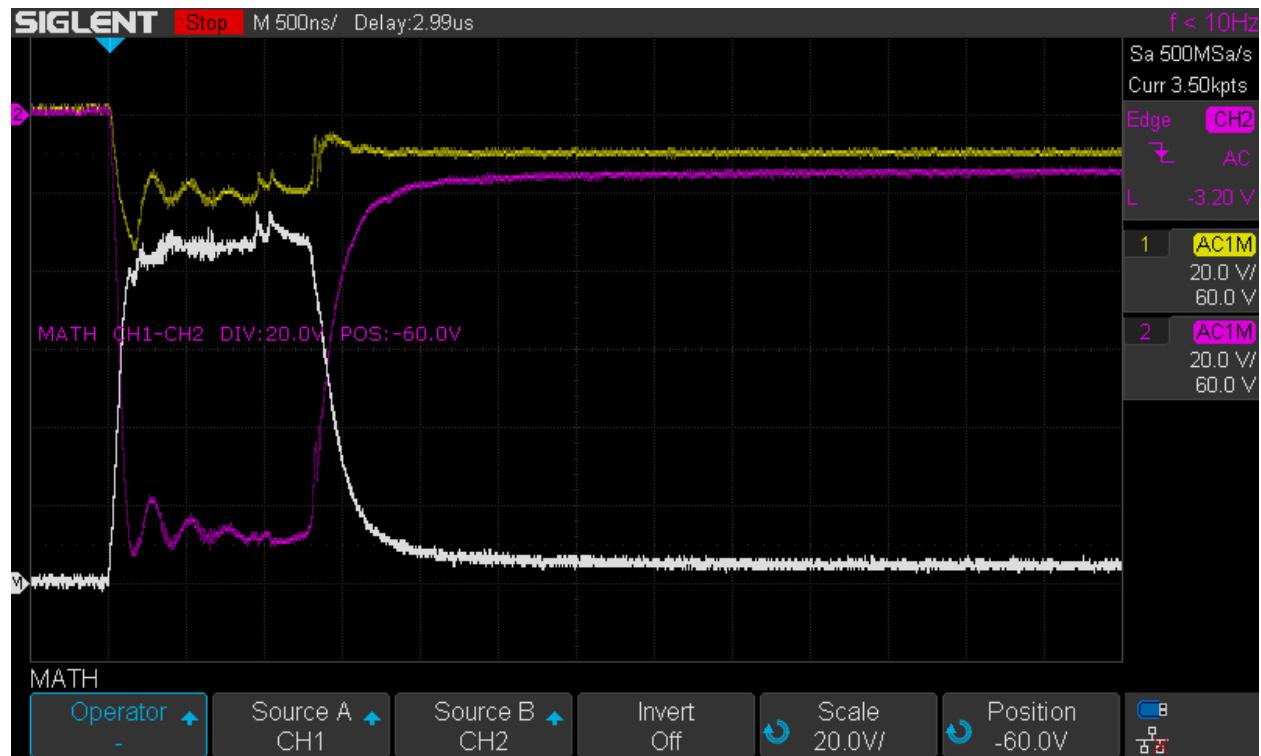
34

GATE: 16.0V

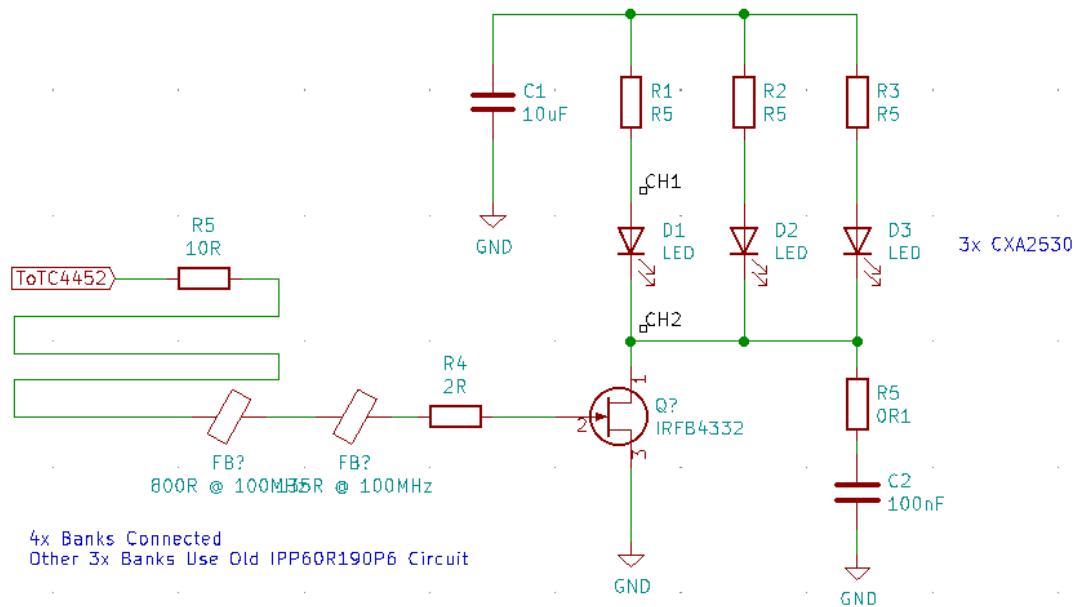
CAP ANODE: 120V

SERIES RESISTOR: R5

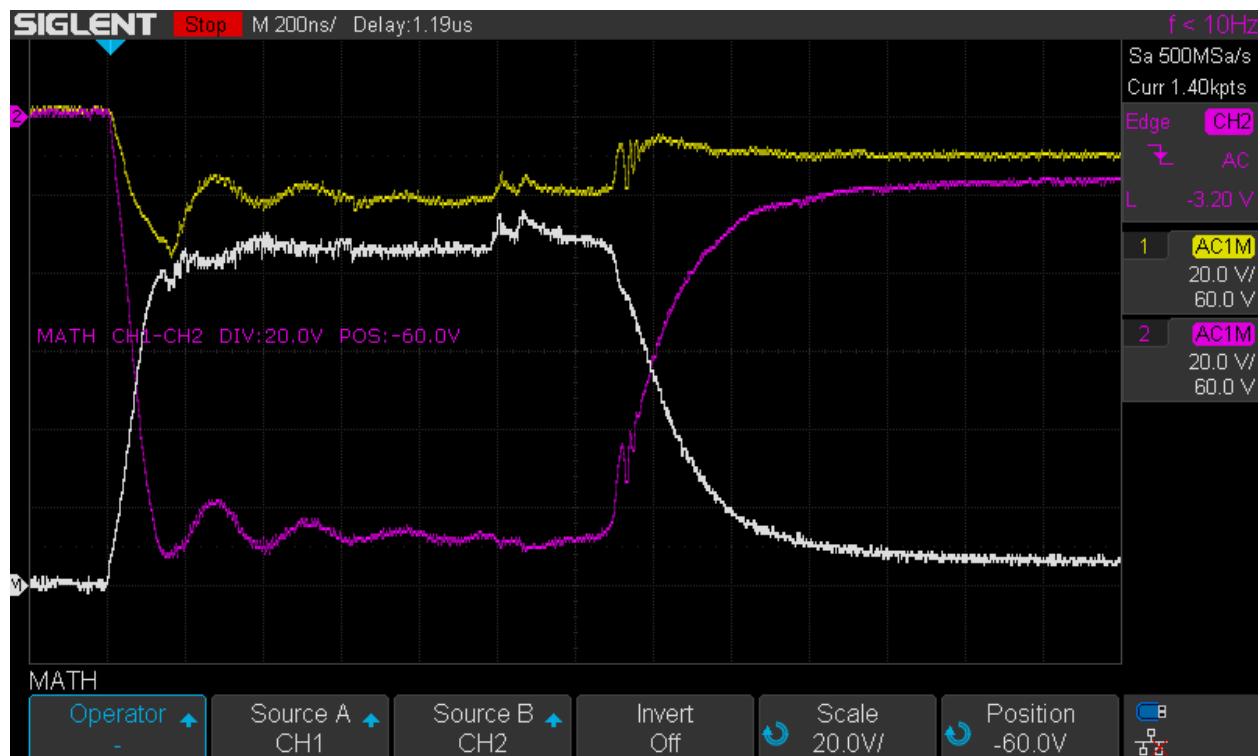
DURATION: 1us



Changed R5 to 0.1R

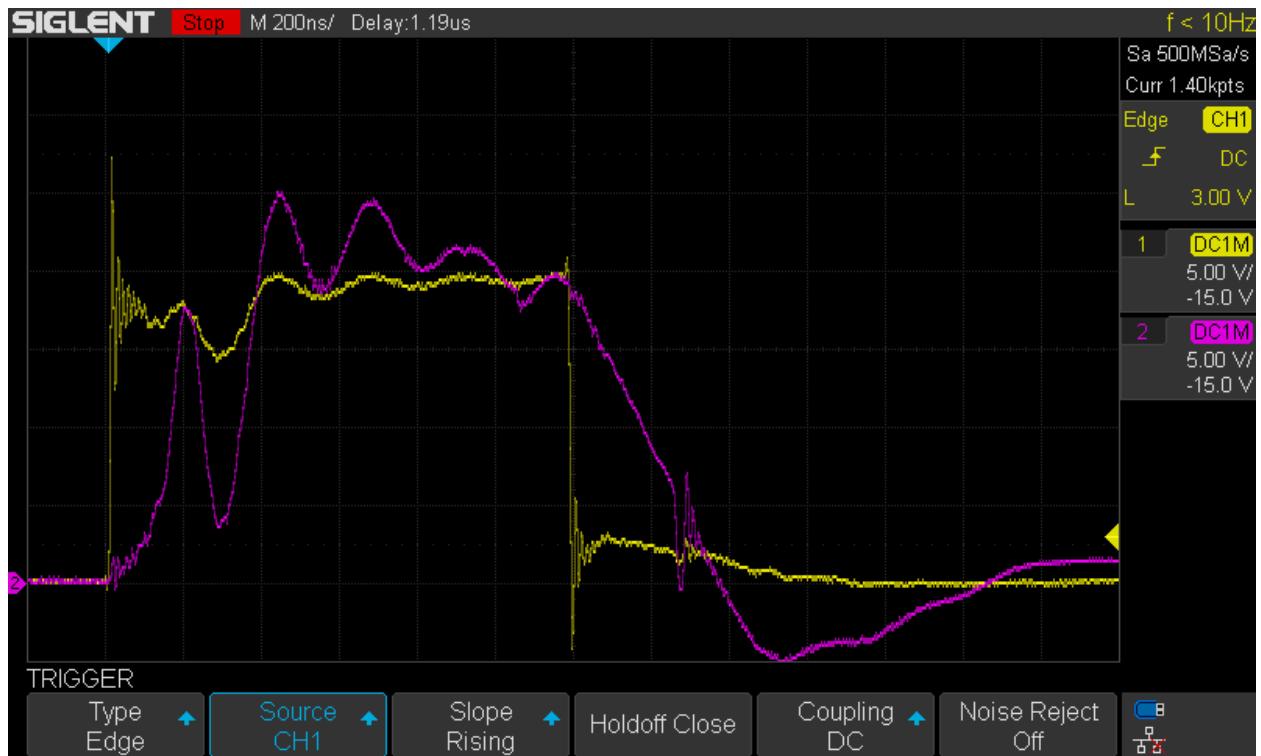


35 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us

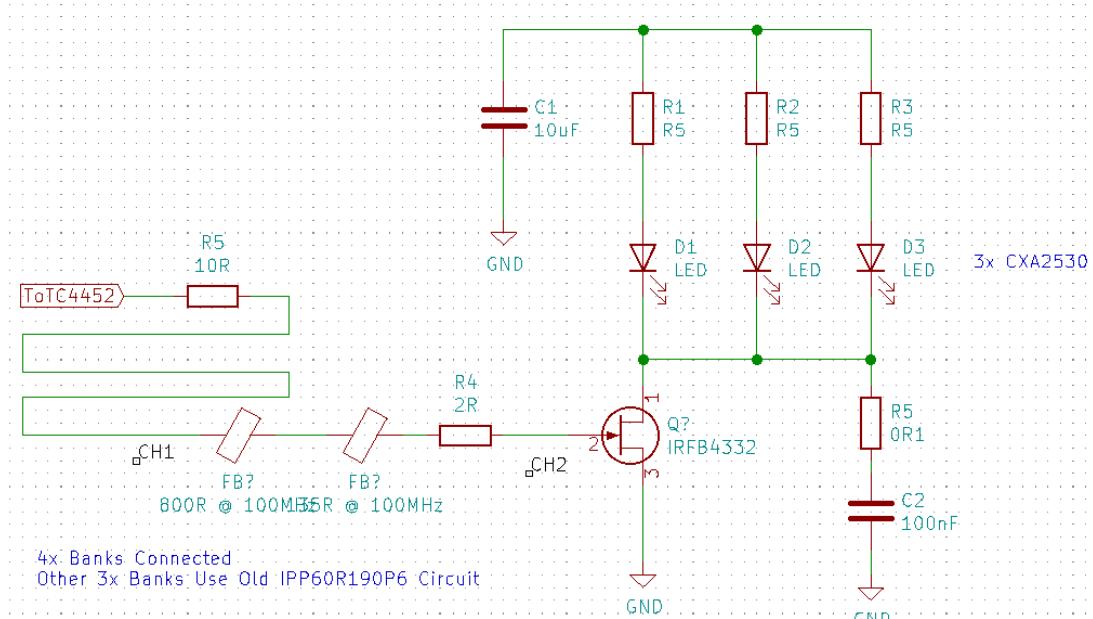


No Change – Timebase changed

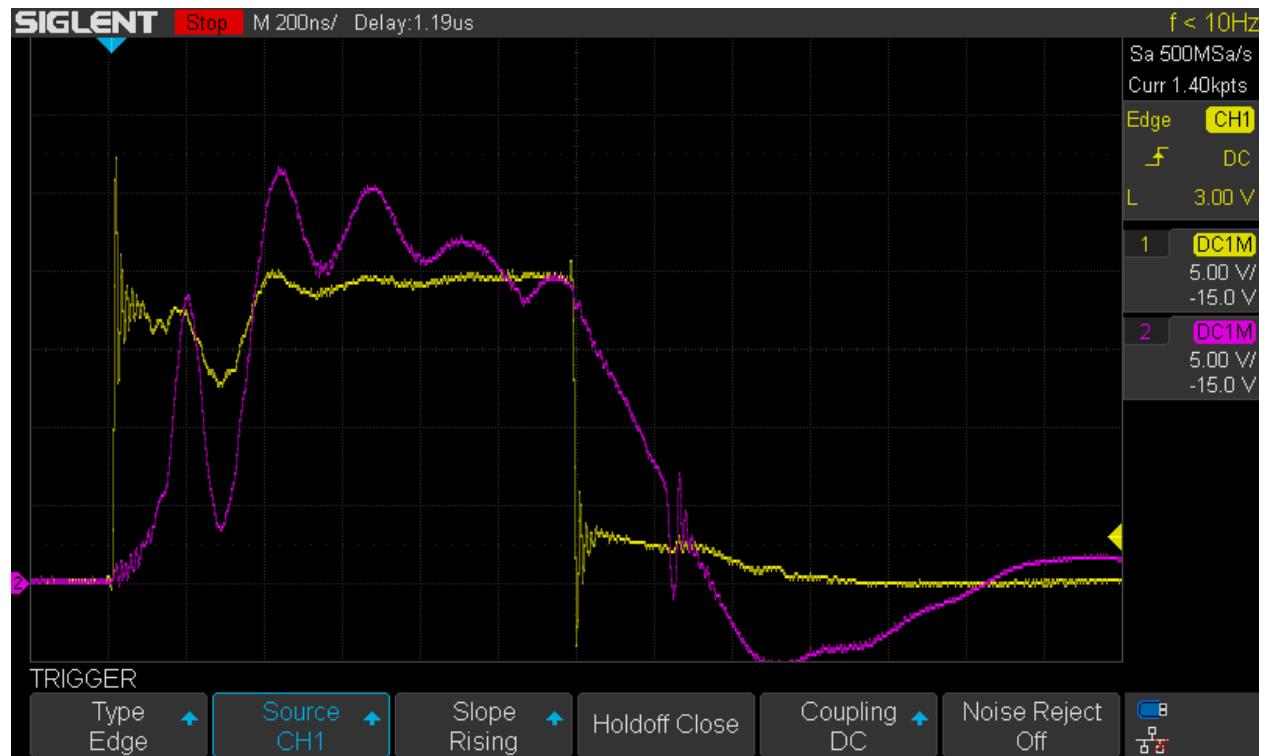
36, 37 (dup) GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



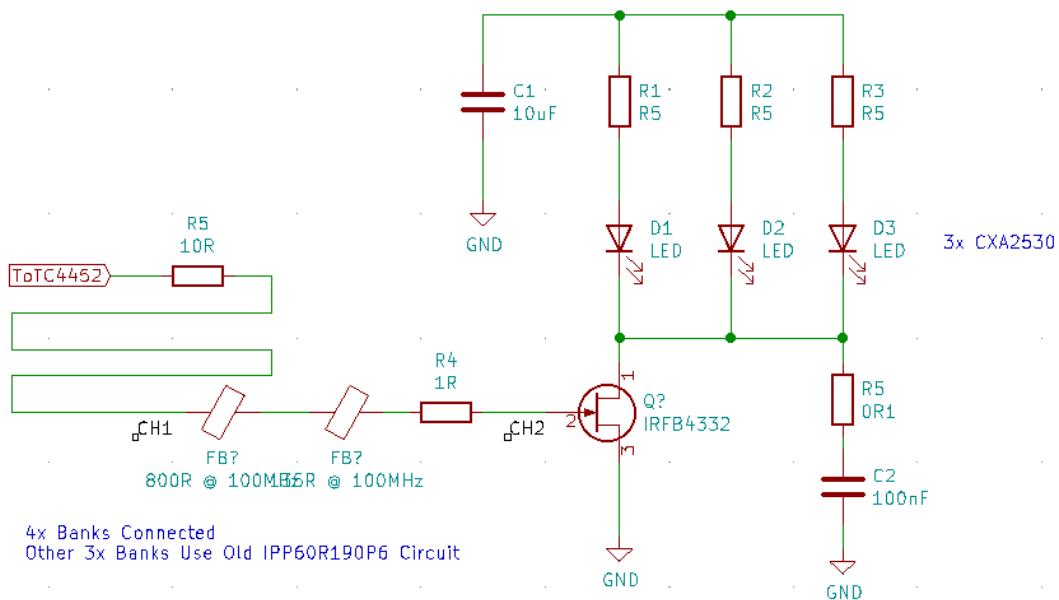
Measuring gate voltage



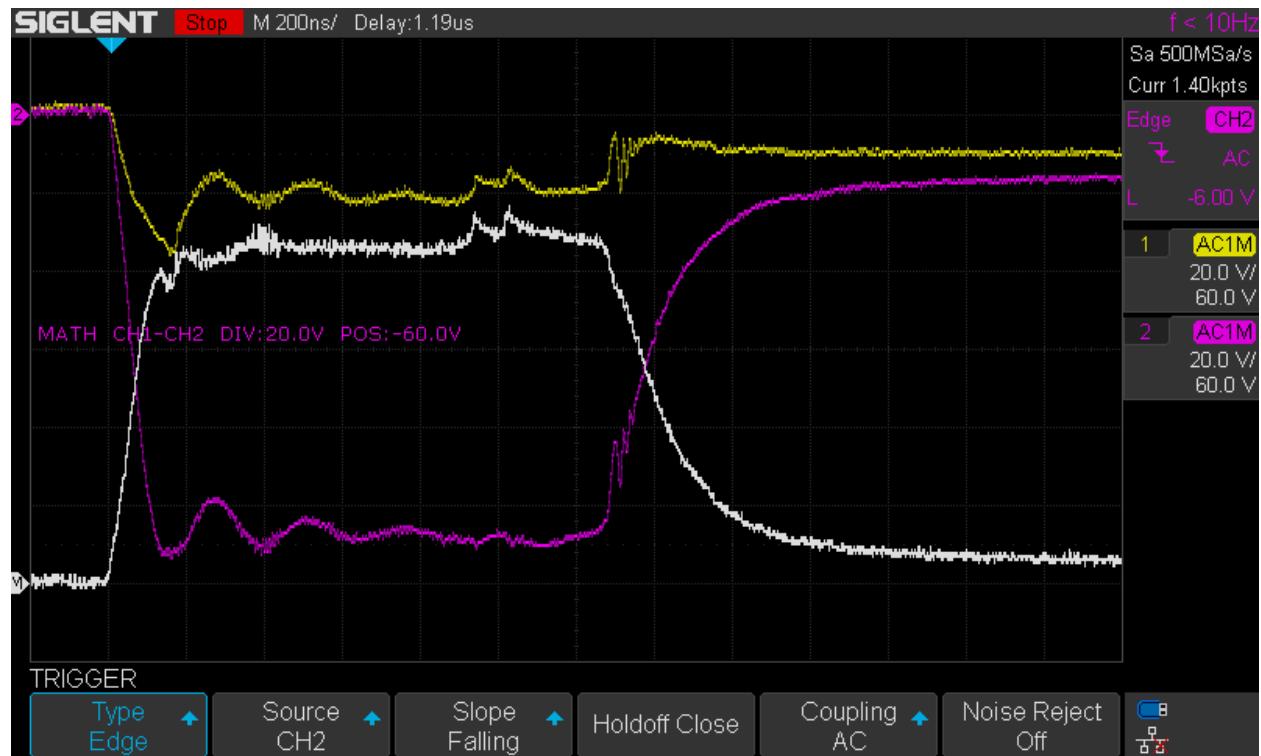
38 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



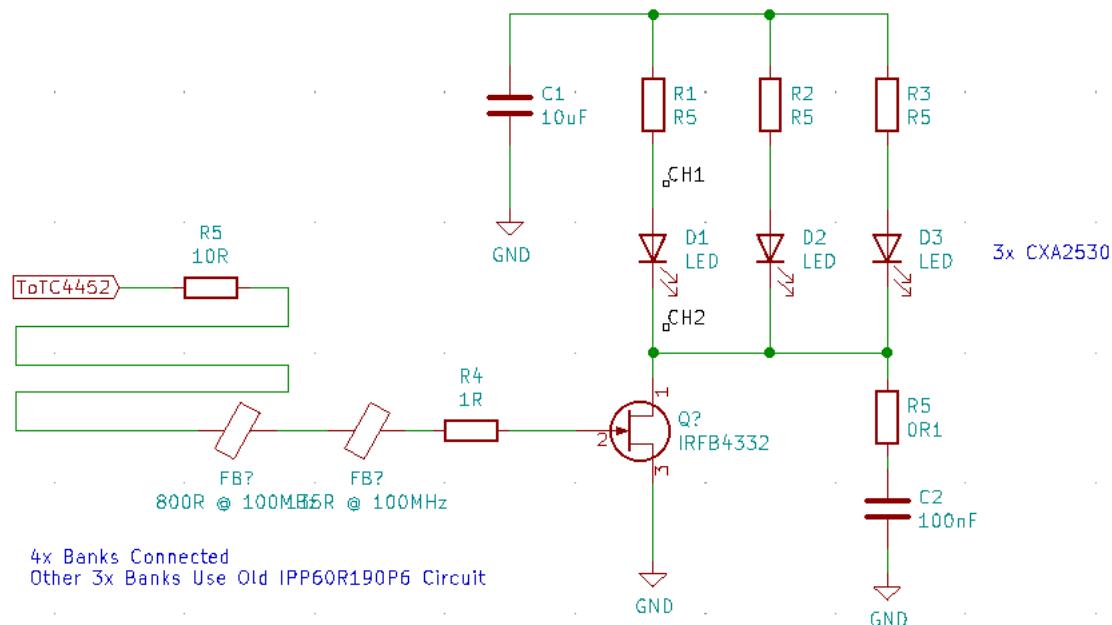
Changed gate resistor to 1R



39 GATE: 16.0V CAP ANODE: 120V SERIES RESISTOR: R5 DURATION: 1us



Measuring LED #1



DRAFT 2020-08-23

E2 Flash Development Testing.odt