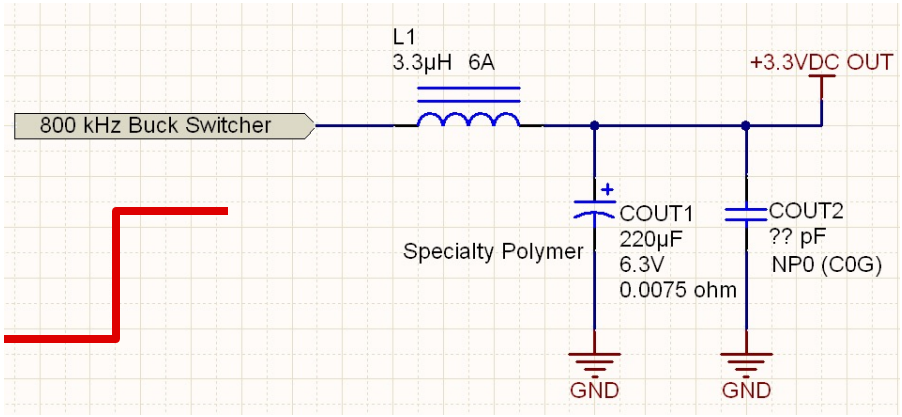
Switching Power Supply Component Selection

7.1d Capacitor Selection – High Frequency Ripple

Source of High Frequency Output Noise

- Parasitic capacitance of the inductor couples high frequency noise onto the parasitic inductance of the output capacitor.

Buck Low Pass Filter

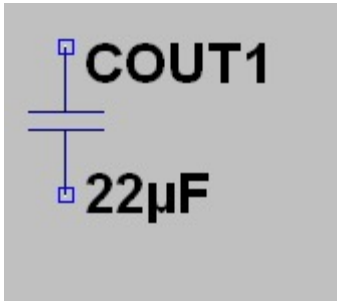


Switching

Transition

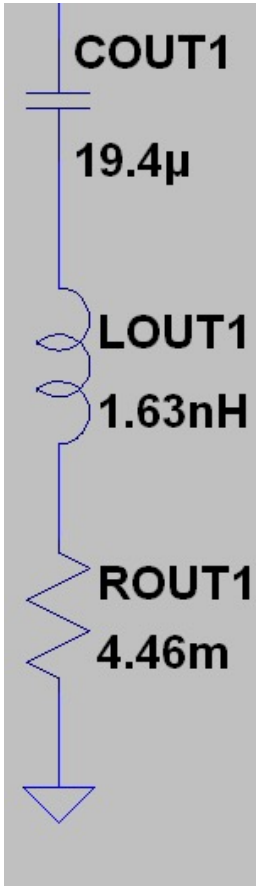
Ideal capacitor compared to actual capacitor

You buy this



22uF 4V X5R 0603 Ceramic

You get this



Voltage and Temperature De-rated Capacitance

(ESL)

Effective Series Inductance

- Parasitic inductance term -

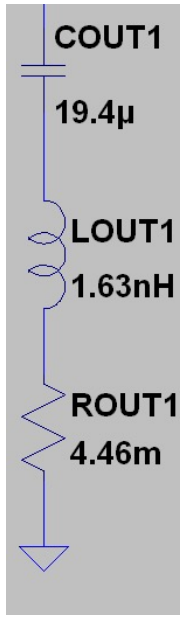
(ESR)

Effective Series Resistance

- Parasitic resistance term -

Buy one part – Get three for the price of one!

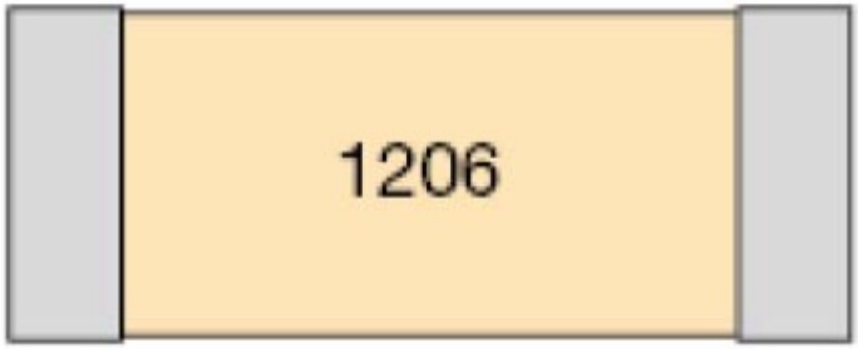
Know your parasitics! They are very important!



- Equipment to use to measure capacitor parasitic elements.
- **RLC Analyzer**
  - Some can apply DC bias
- **RF Network Analyzer**
  - DC bias can easily damage analyzer source and receiver inputs
  - AC performance measurement very accurate.
  - Agilent (aka Hewlett Packard) i.e. HP3755A goes to 200MHz
  - Many other brands
- **Frequency Response Analyzer**
  - Allows DC bias so voltage coefficient can be measured. RLC results are less accurate. Frequency range is lower than network analyzer
  - 30 MHz max; Usually just 1 or 2 MHz range. May allow plotting on reactance paper with line of constant capacitance and constant inductance. **FRA is also used for loop stability analysis**.
  - Brands – Venable Industries – Ridley (A/P) several others.
  - → Measure the parasitic terms and include them in the design ←

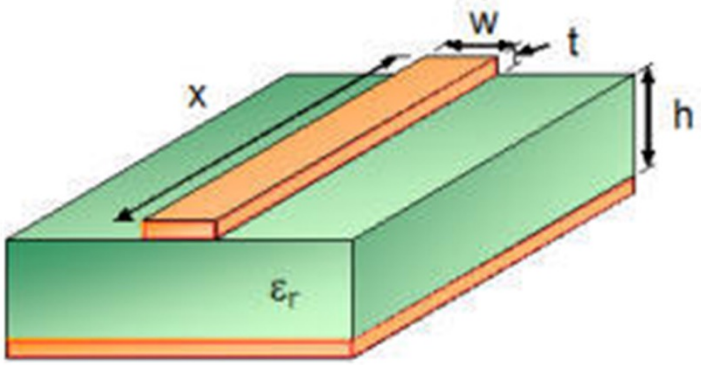
First Pass Parasitic Inductance for Ceramics

PACKAGE	ESL (pH)
0201	400
0402	550
0603	700
0805	800
1206	1250
0612	63



First Pass Trace Inductance for FR-4, microstrip

Typical Inductance for a 2500um (60mil) wide 1oz Trace
19.5 nH / inch, 19.5pH / mil , **767pH / mm**
Typical Inductance for a 250um wide (6mil) wide 1oz Trace
26.4 nH / inch, 26.4pH / mil , **1.039nH / mm**



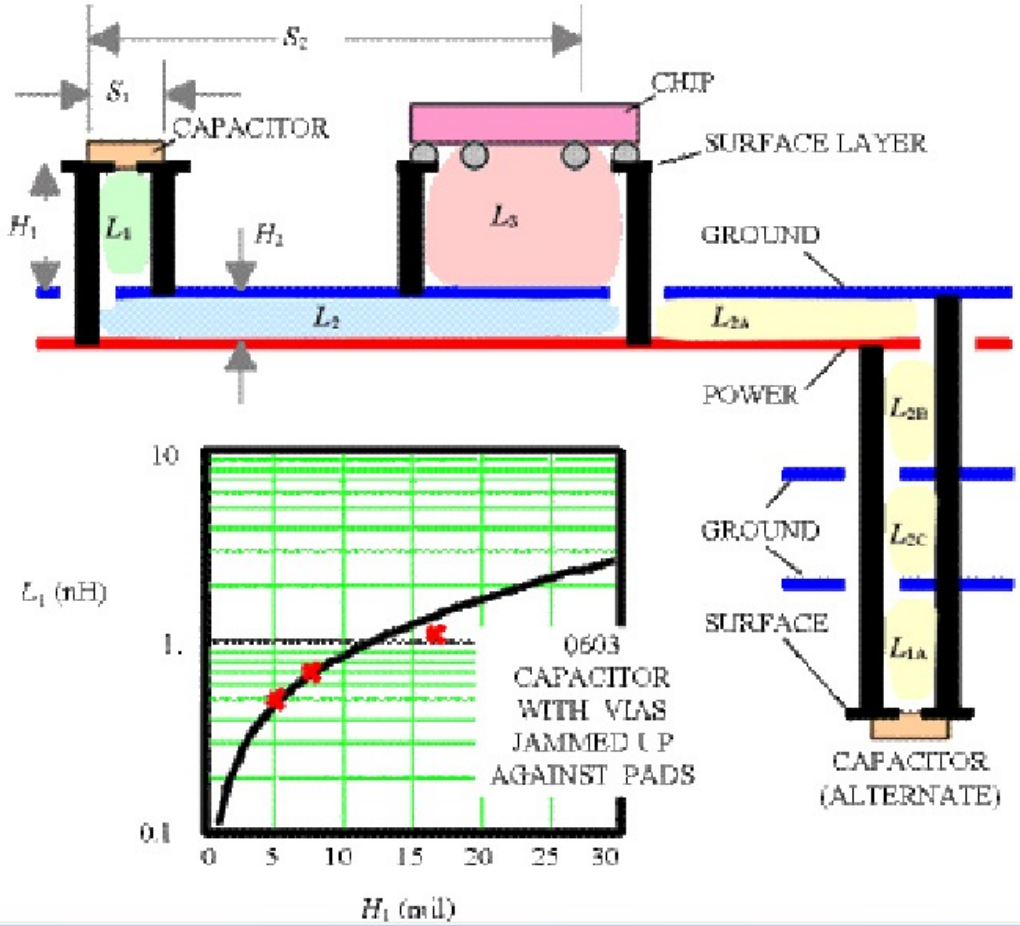
$$L = 0.00508 * b * (\ln(2*b/(w+h)) + .5 + 0.2235*(w+h)/b)$$

where:

w is width of the strip in inches,
b is the length in inches,
h is the distance between the strip and the ground plane, and
L is inductance in uH.

From ARRL Handbook

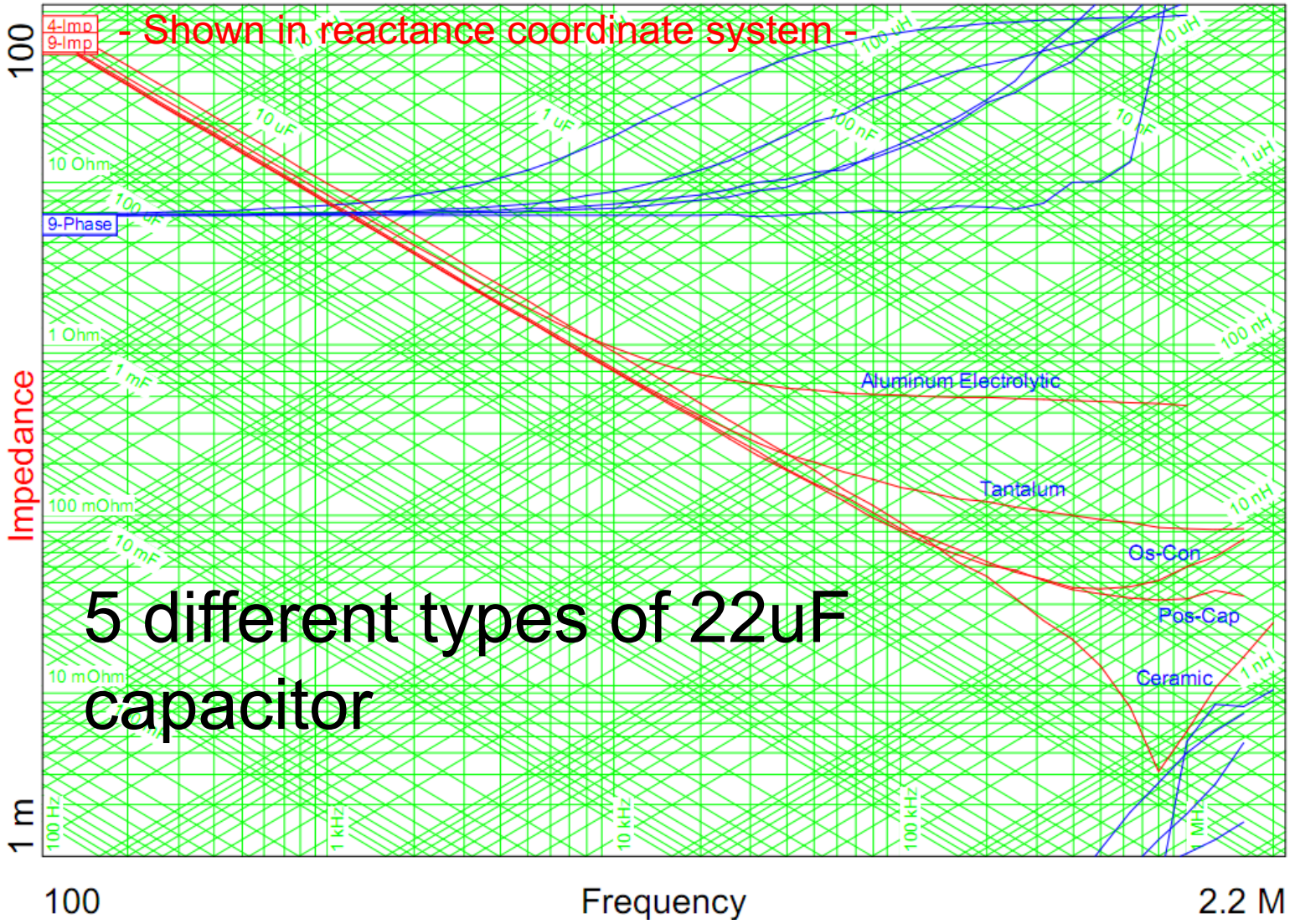
First Pass Trace Inductance for Via



http://www.signalintegrity.com/Pubs/edn/ParasiticInductance.htm

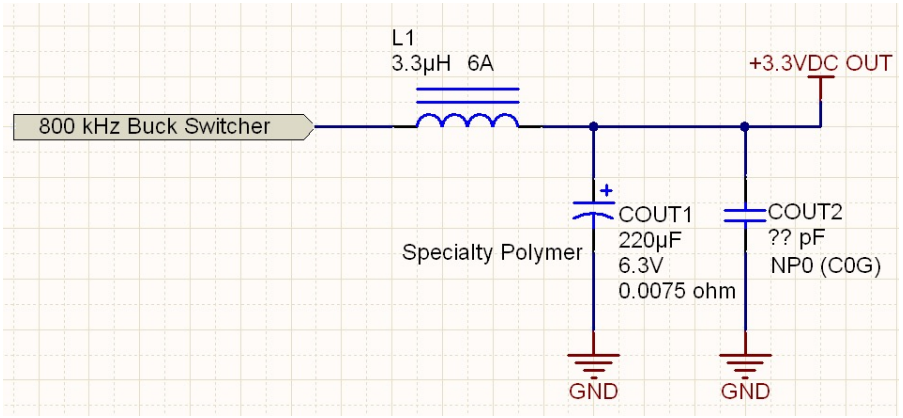
From Dr.Howard Johnson

Comparison of capacitor types using Frequency Response Analyzer



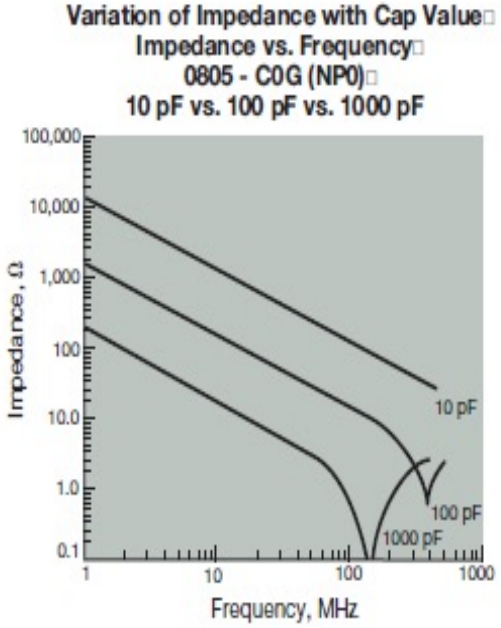
Techniques to Reduce High Frequency Output Noise

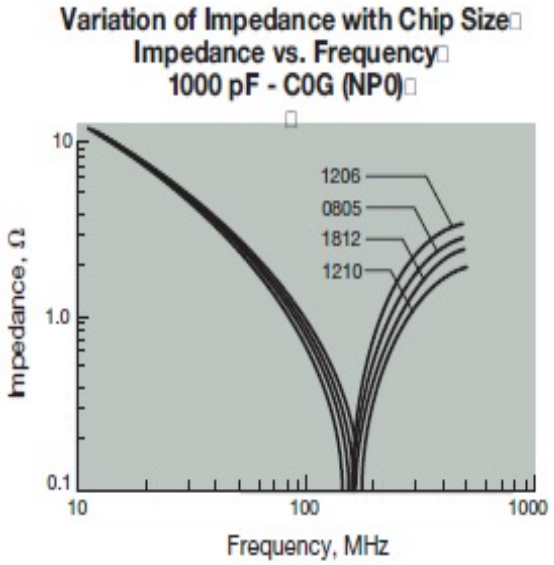
- If the output capacitor(s) is not ceramic; then adding a small ceramic(s) in parallel with the output will reduce high frequency ripple
- Choose a ceramic capacitor that has an impedance null (self resonance) that is the same as the frequency to be attenuated
- One, two or three small ceramics can give 10X improvement (-20 dB)

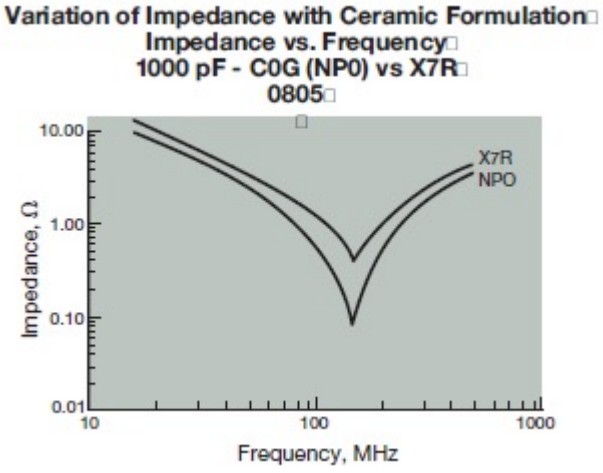


Use C0G (NP0) Dielectric for High Frequency Shunt Filter Capacitors

Lower ESR – more stable over temp







Start with manufacturer data sheets, then measure SRF on bench to confirm

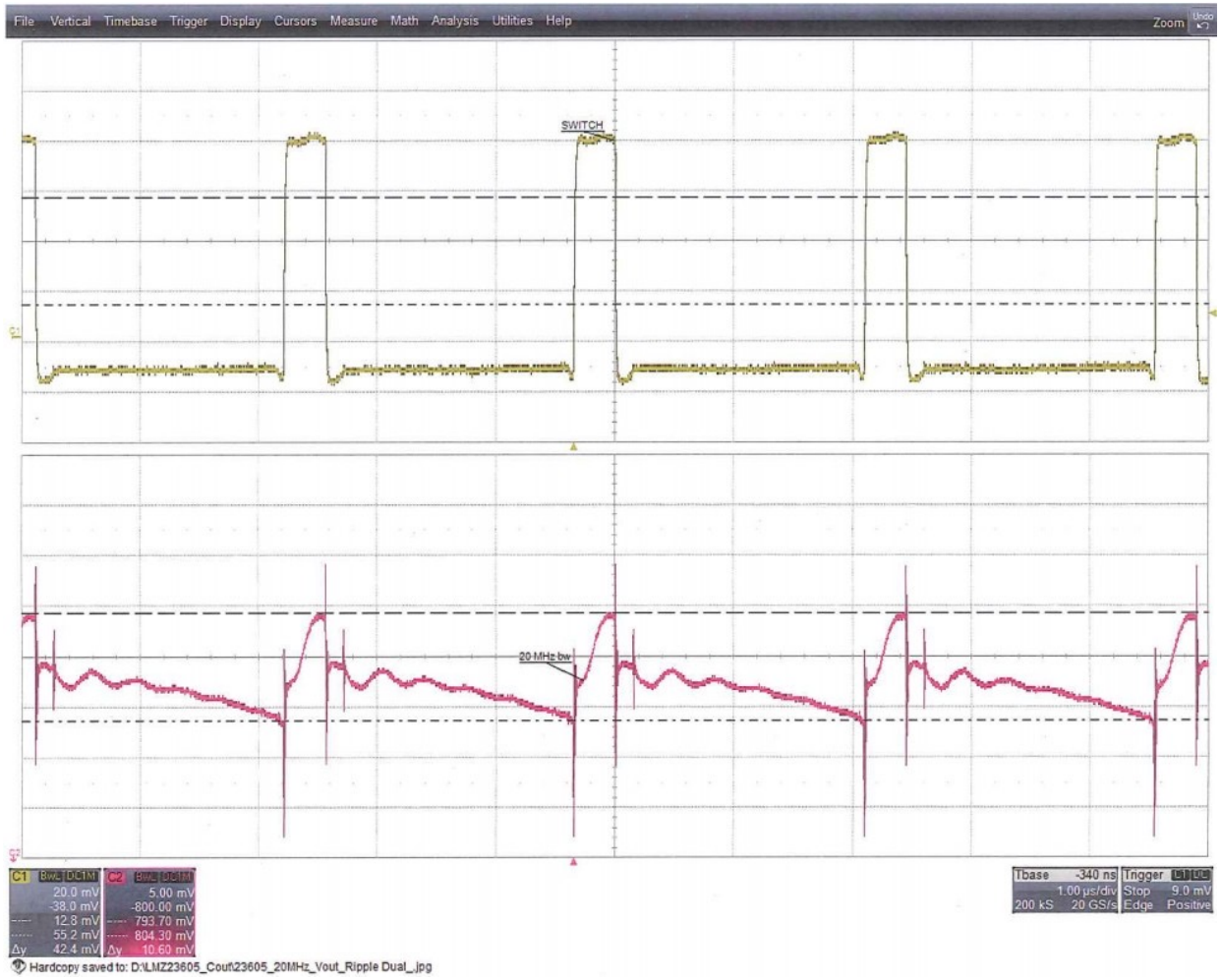
High Frequency Ripple

Switch waveform (scope trigger)

V_{out} ripple w/ 20 MHz bandwidth (bw)

5 mV /div →
10 mv p-p

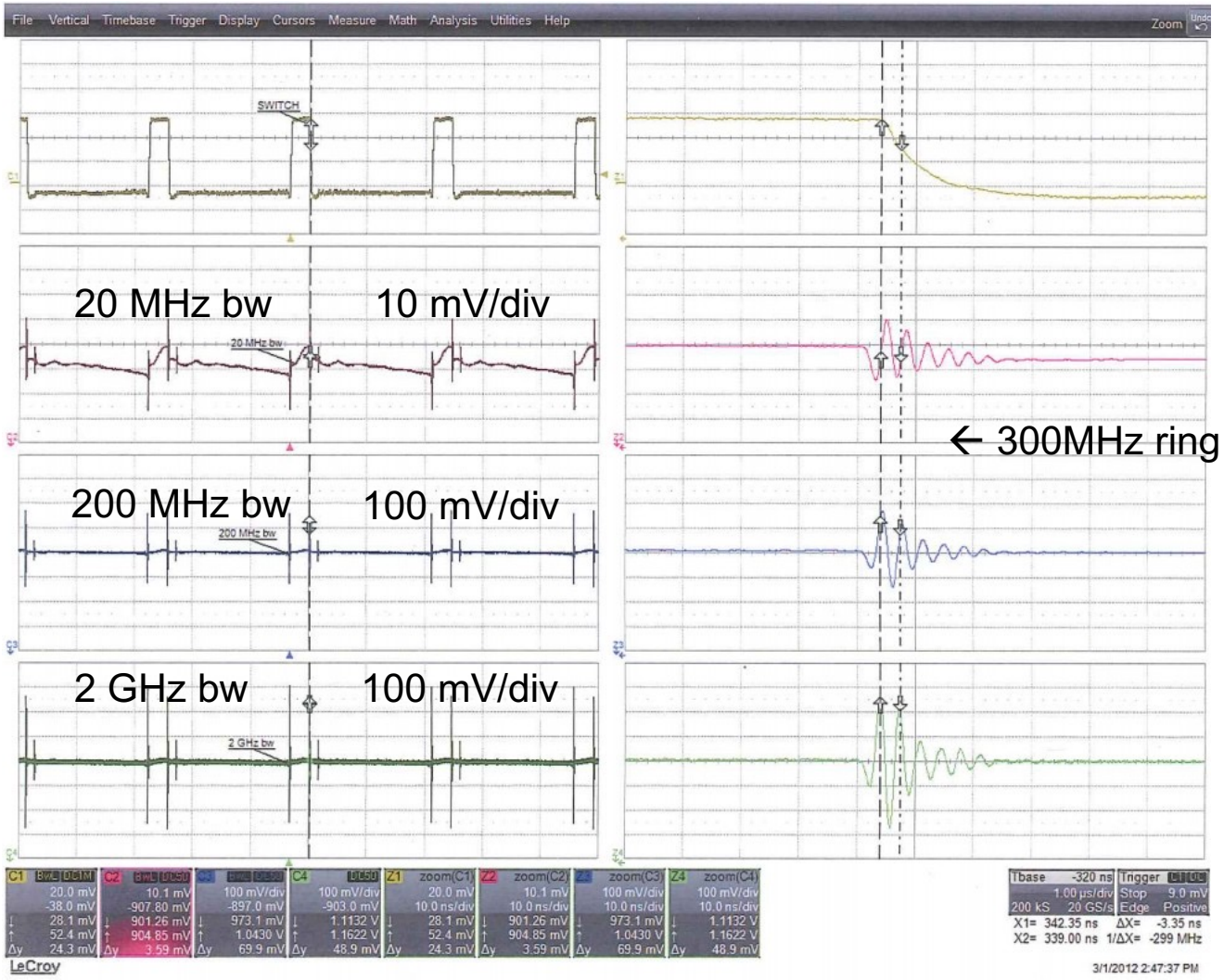
HF spikes ignored !



Use Zoom Function to Measure Ring Frequency

Need to add 470 pF 0603 bypass SRF ~ 300 MHz

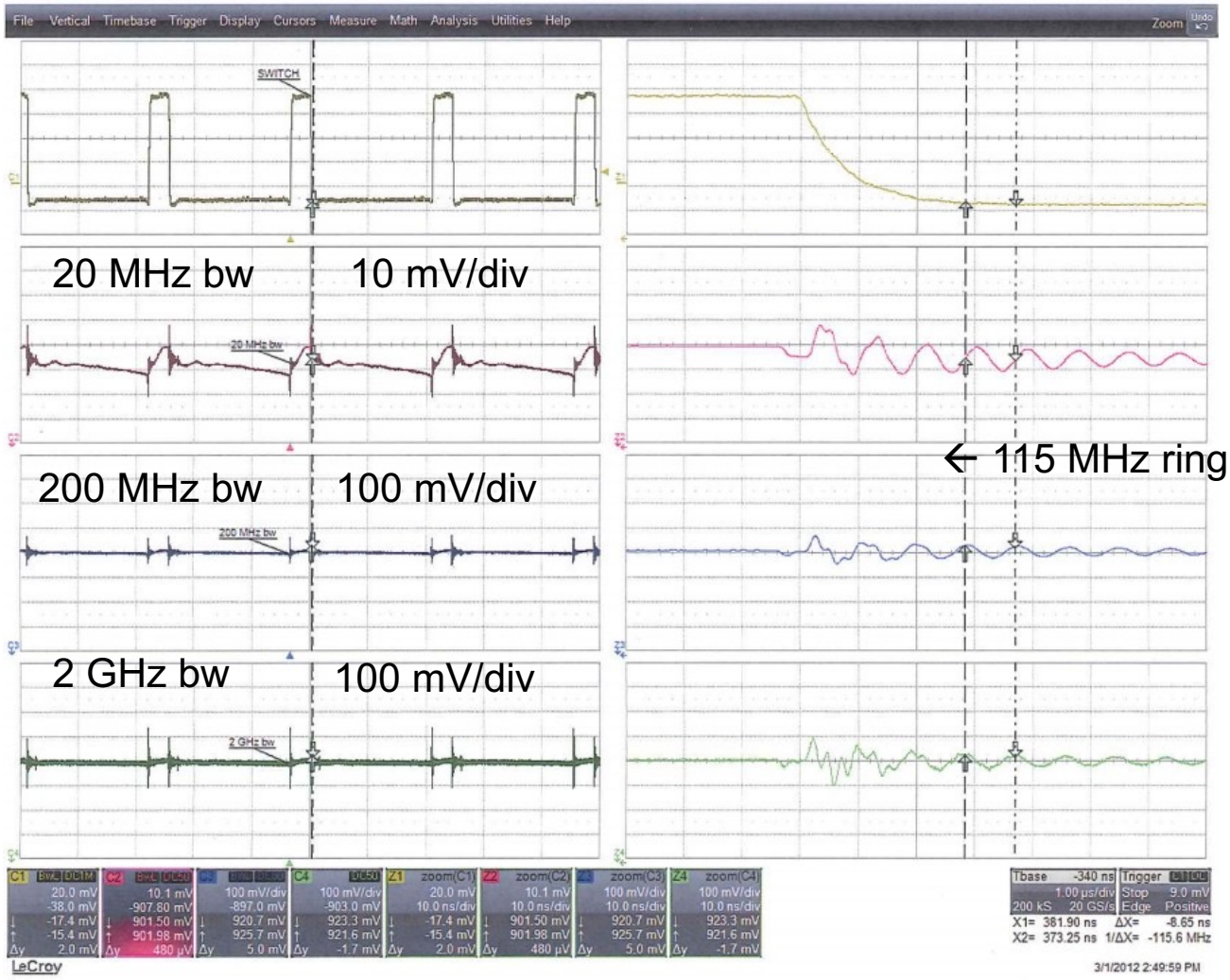
Timebase Zoomed traces



Continue the Method

Measured after adding a 470 pF 0603 but before adding 2200pF 0603

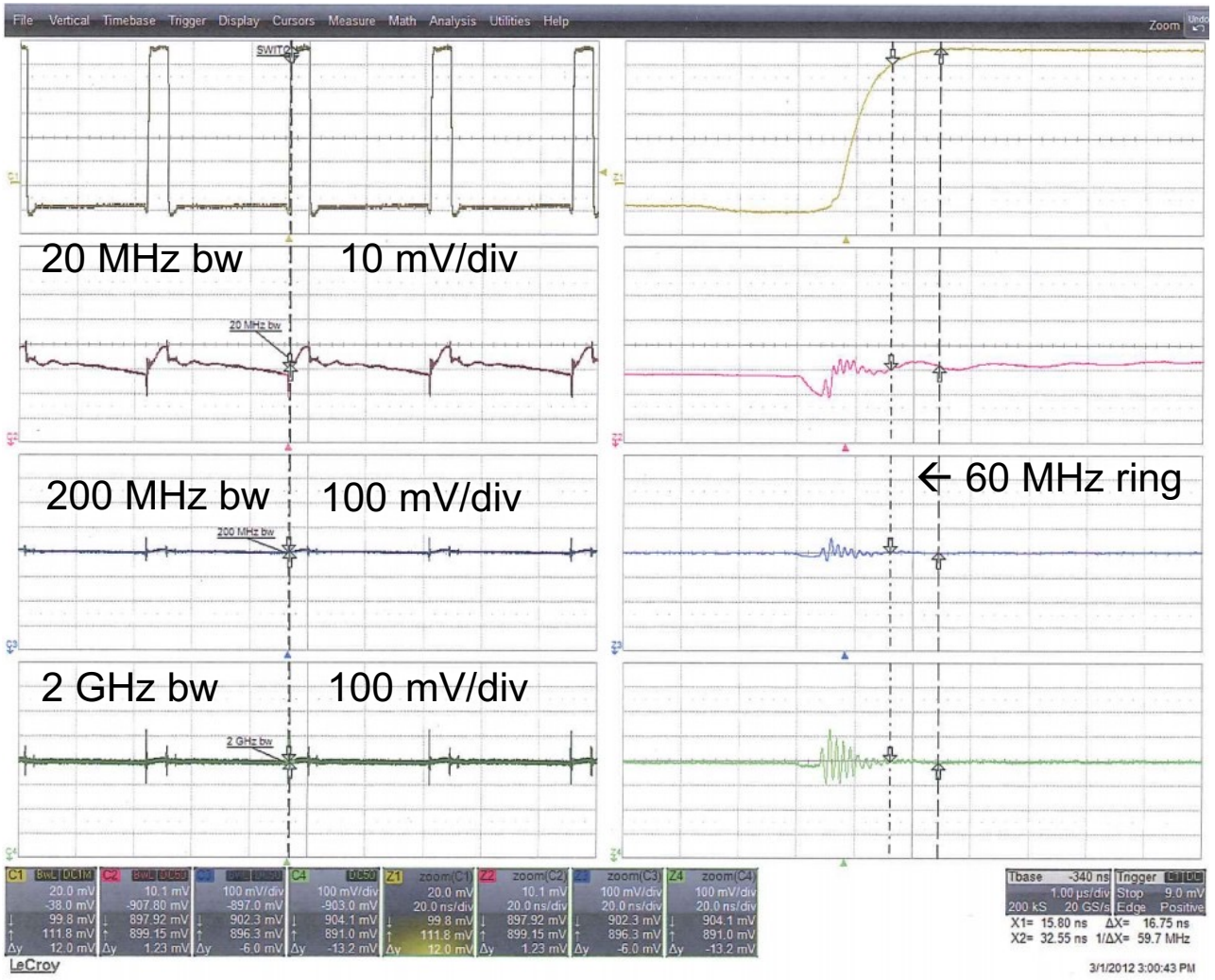
Timebase Zoomed traces



Continue the Method

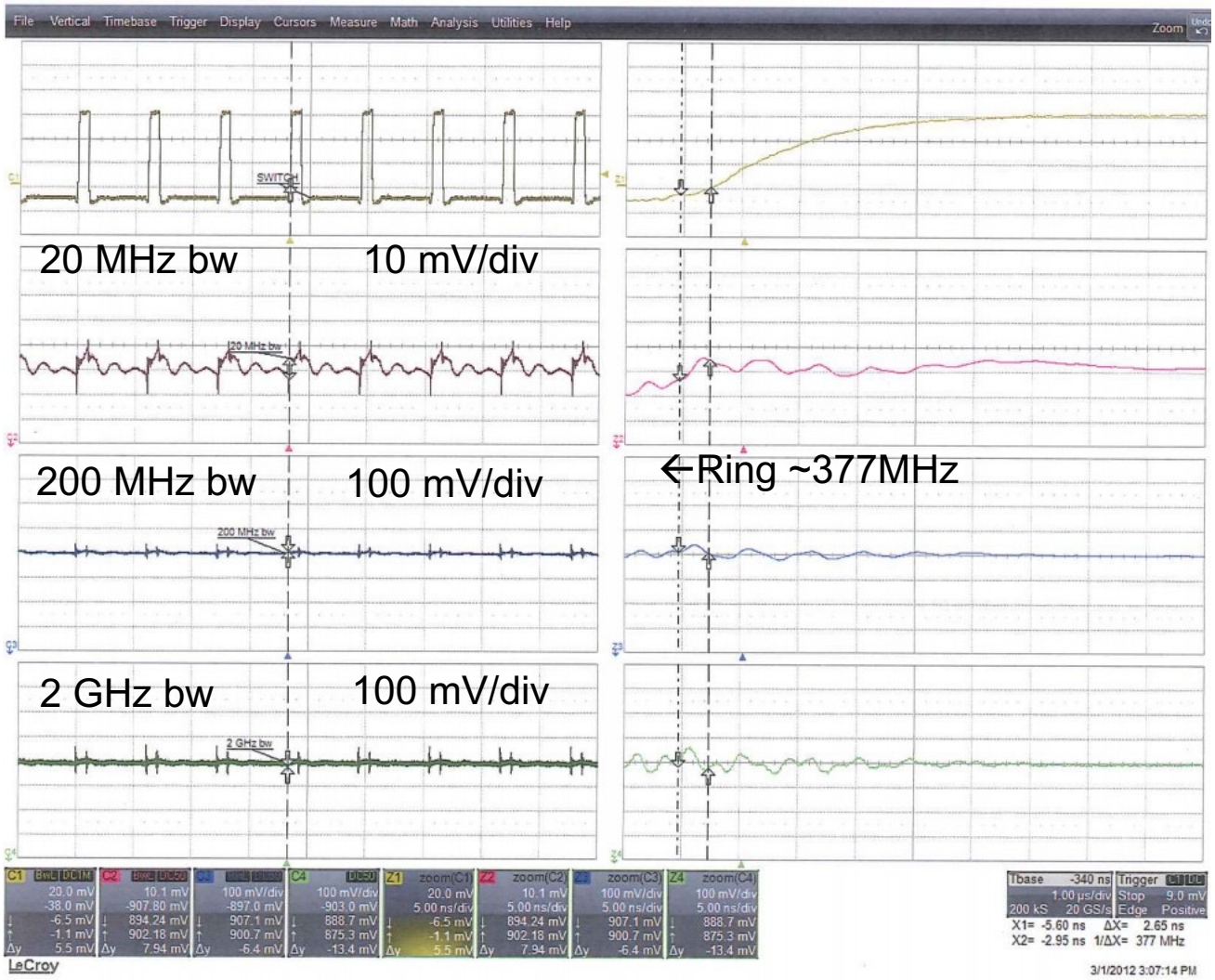
Measured after adding a 470pF 0603 and a 2200pF 0603 but before 4700pF 0805

Timebase Zoomed traces



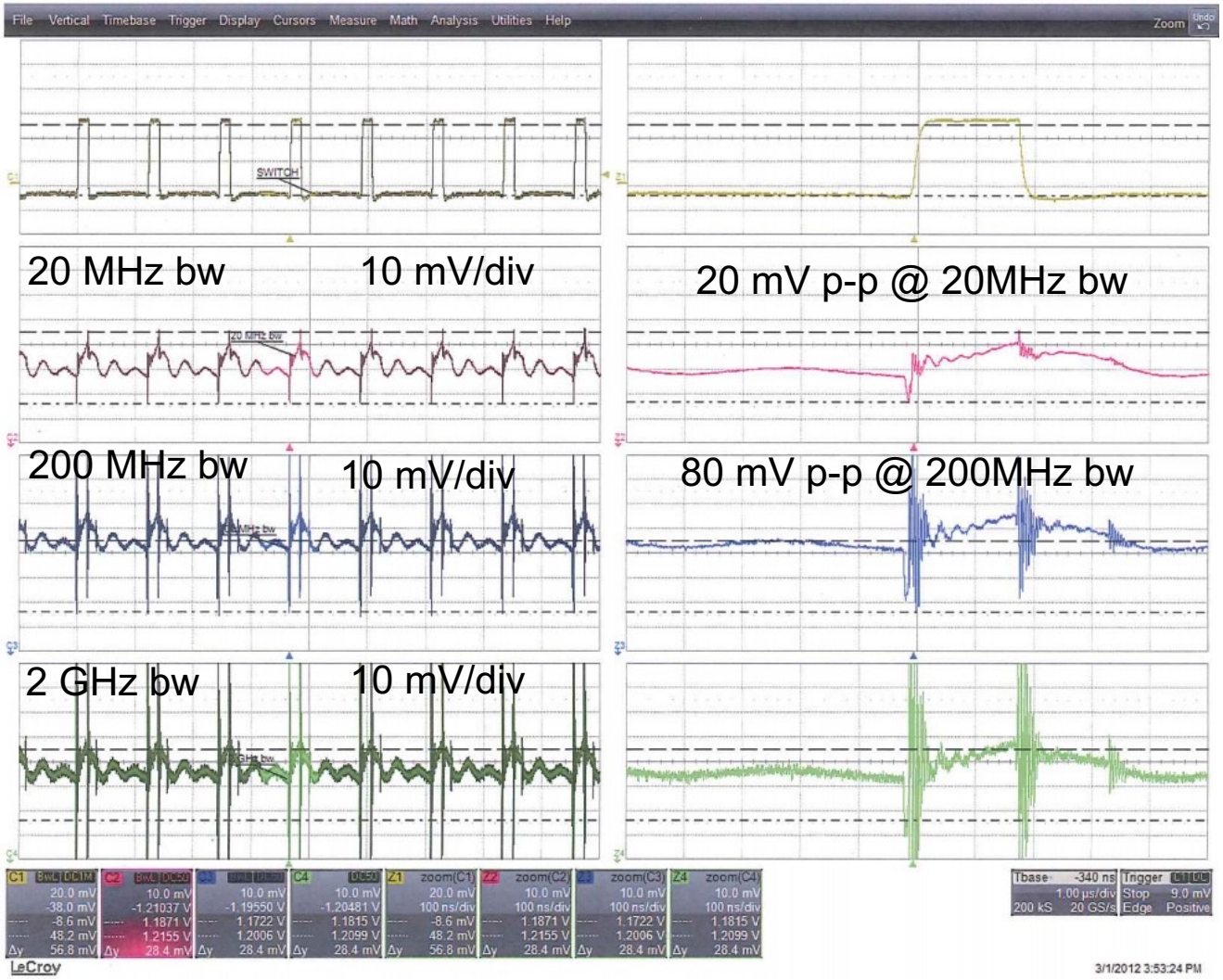
Results After 3rd Added Small Capacitor

Measured after adding a 470pF 0603, 2200pF 0603, and 4700pF 0805

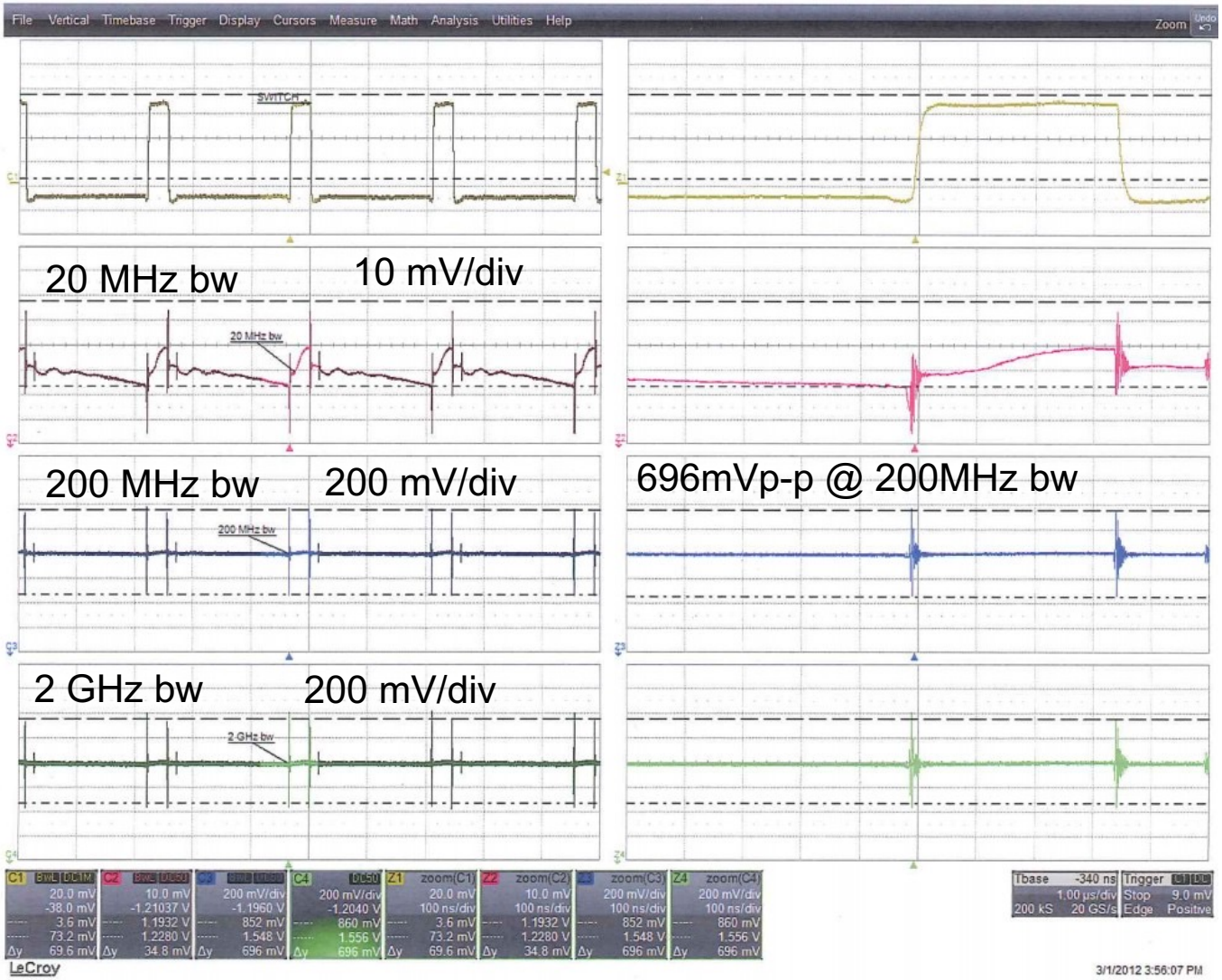


Final Amplitude Improvement Results

After 470pF
2200pF 4700pF

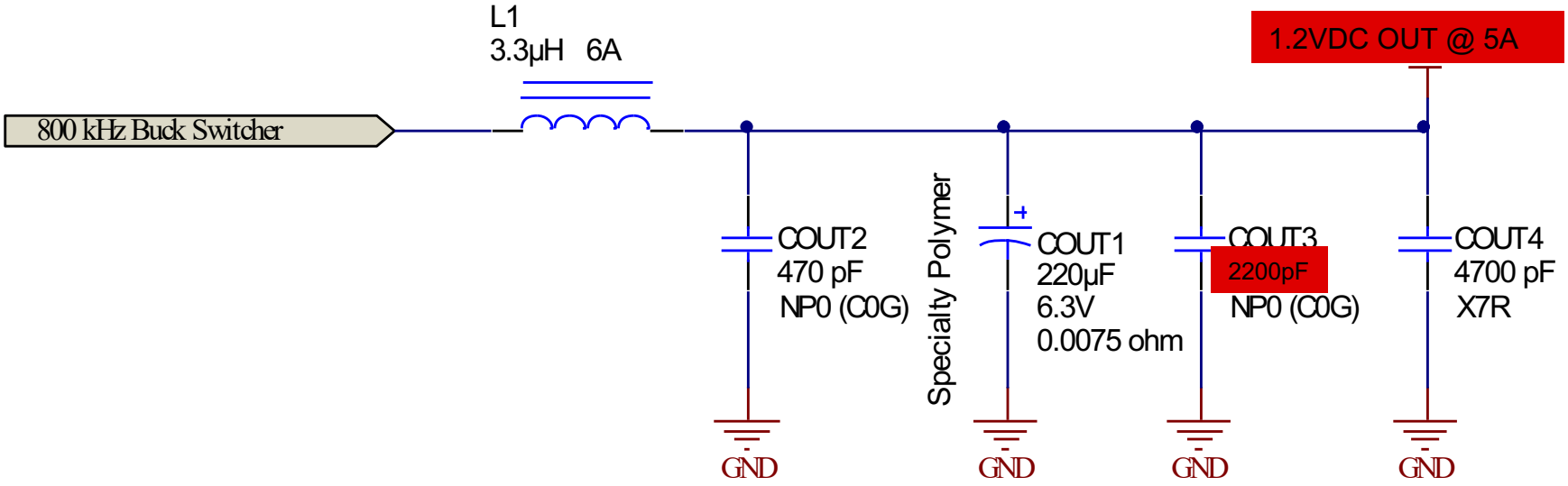


Starting Point for Comparison – 3 Caps Removed



Final Schematic & Bill of Materials

15 minutes later
Cost Approximately < $0.03 USD



- Remember to reserve locations on the schematic and PCB for these parts
- You will not know the capacitor values until **after** you test the running power supply for ringing noise
- → Plan ahead ←

Thank you!