Designing High-Voltage, Programmable Power Supply for driving High-current Pulsed loads

Part - 1

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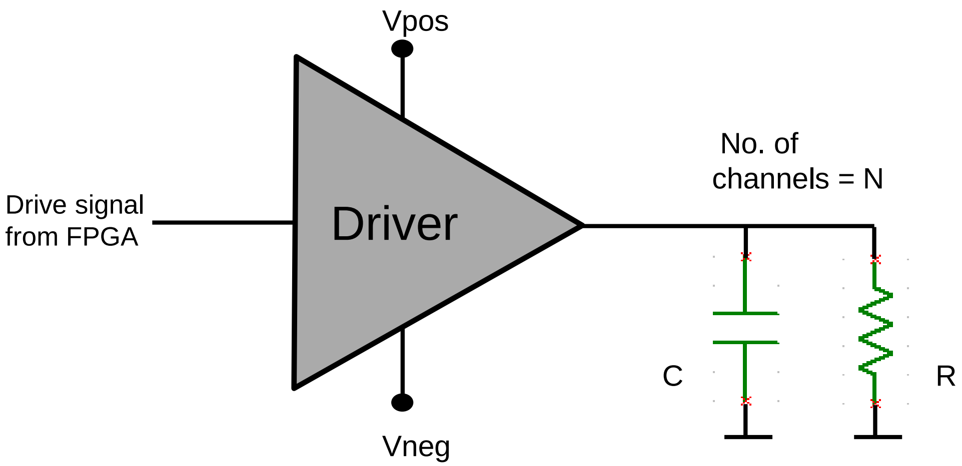
SEM – Industrial Systems, Medical Sector

Challenge to Solve

Driving High-Voltage Piezo sensors without using Big Capacitor banks

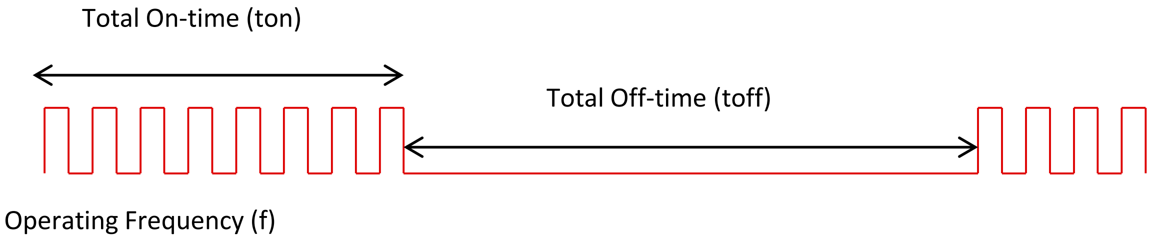
Drive Current Calculations – Piezo sensors



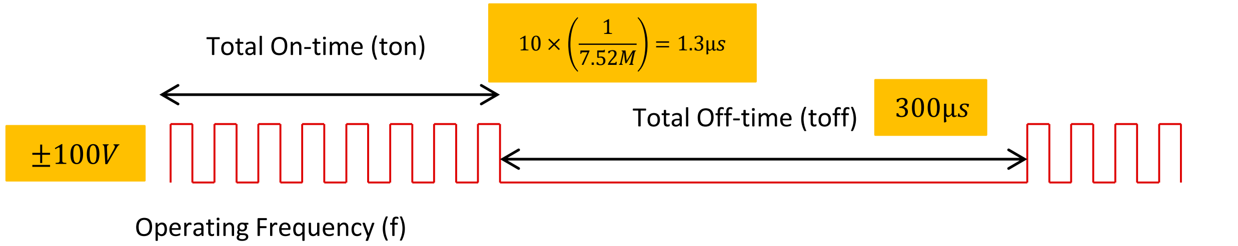
$$i_C = f \times C \times (V_{pos} - V_{neg}) \times N$$

$$i_R = \frac{V_{pos}}{2R} \times N \quad \textbf{OR} \quad \frac{V_{neg}}{2R} \times N$$

$$i_{Total} = i_C + i_R$$



Driving Piezo Load (e.g. Medical Ultrasound Probe)



$$Peak\ Power\ Consumption = N \times 2CV^2 f = 128 \times 2 \times 471p \times 100^2 \times 7.52M = 9\ kW$$

$$Peak\ Output\ Current = \frac{9\ kW}{100} = 90A$$

$$Average\ Power\ Consumption = \frac{9\ kW}{300\ \mu} \times 1.3\ \mu = 39\ W$$

For a 20V dip on the output capacitor of SMPS:

$$C_{out} > \frac{I_{out} \times ton}{V_{dip}} > \frac{90 \times 1.3\mu}{20} > 5.85\ \mu F$$

N — 7.5MHz 128ch Linear Probe

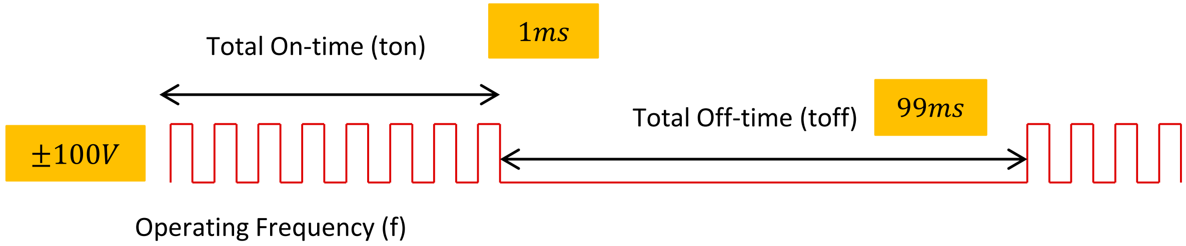
RoHS compliant.

Element Pitch	0.315 mm
Transverse Aperture	4 mm
Curvature	---
Geometrical Focus	20 mm
Center Frequency(-6dB) (f)	7.52 MHz
Fractional Bandwidth(-6dB)	81.7 %
Pulse Length(-20dB)	0.41 μs
Sensitivity	-52.5 dB
Capacitance (C)	471 pF
Pulser	5800
Damping	50 Ω
Energy	12.5 μJ

1559

Source:http://www.ndk.com/en/products/search/ultrasonic/linear_probe.html

Driving Medical Ultrasound Probe – Elastography



Elastography is a medical imaging modality that maps the elastic properties and stiffness of soft tissue.

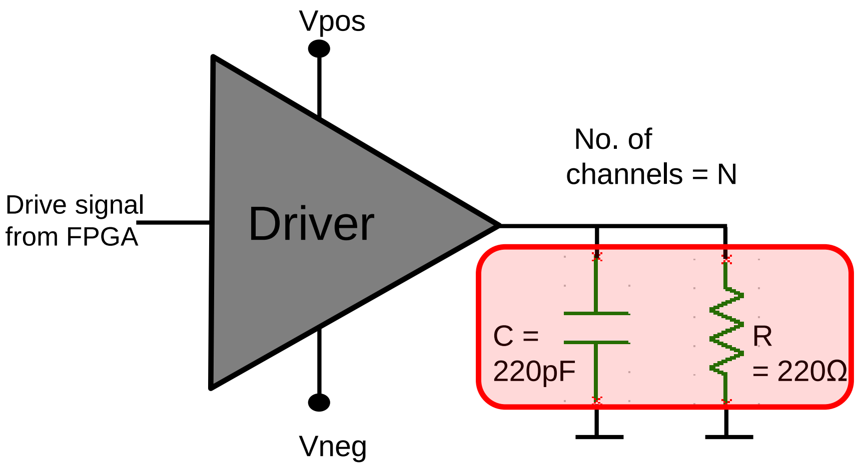
$$Peak\ Power\ Consumption = N \times 2CV^2 f = 128 \times 2 \times 471p \times 100^2 \times 7.5M = 9\ kW$$

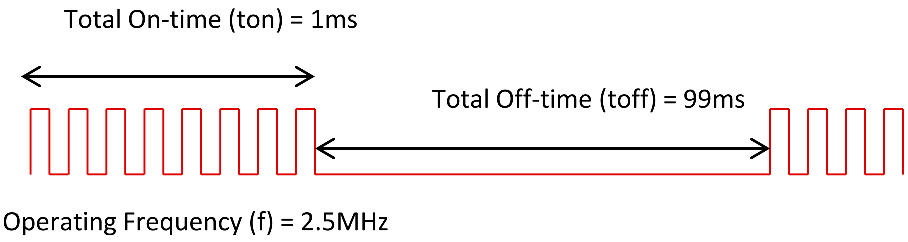
$$Peak\ Output\ Current = \frac{9\ kW}{100} = 90A$$

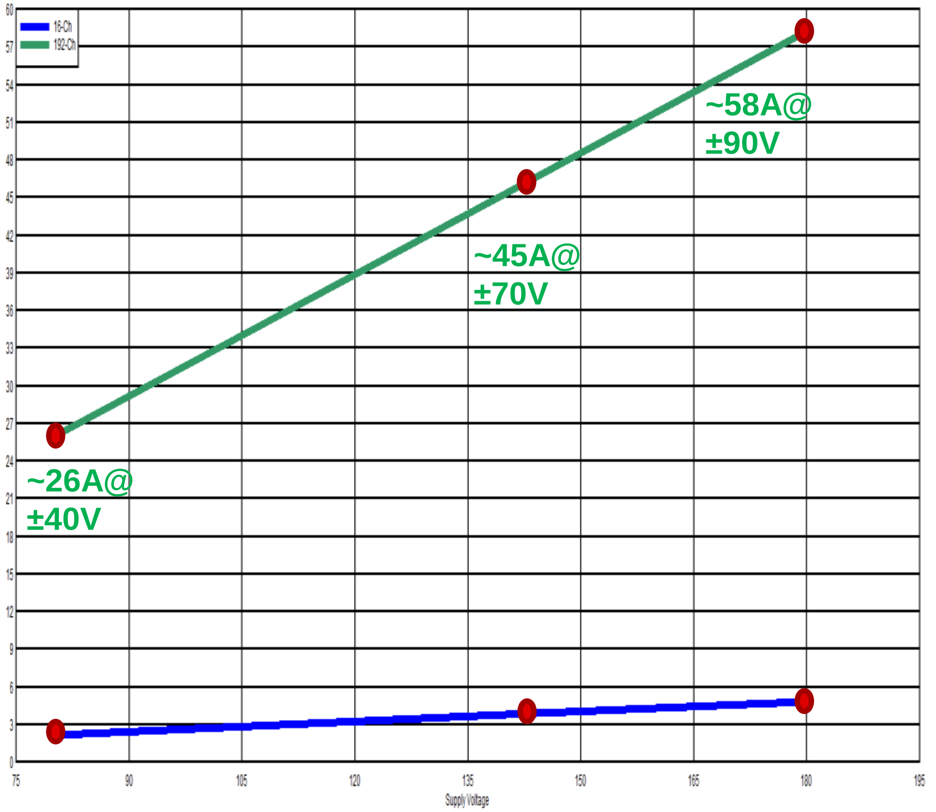
For a 20V dip on the output capacitor of SMPS:

$$C_{out} > \frac{I_{out} \times ton}{V_{dip}} > \frac{90 \times 1\ m}{20} > 4500\ \mu F$$

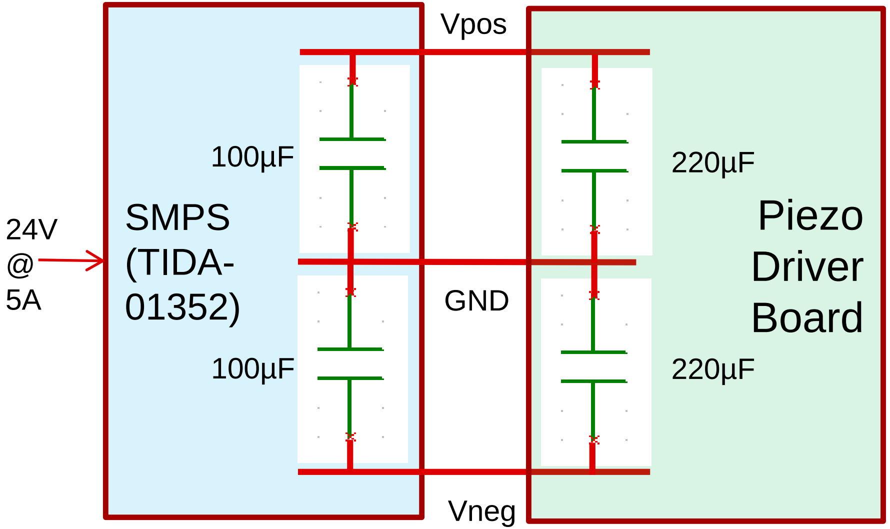
Calculated Drive Current (Varied supply Voltage)

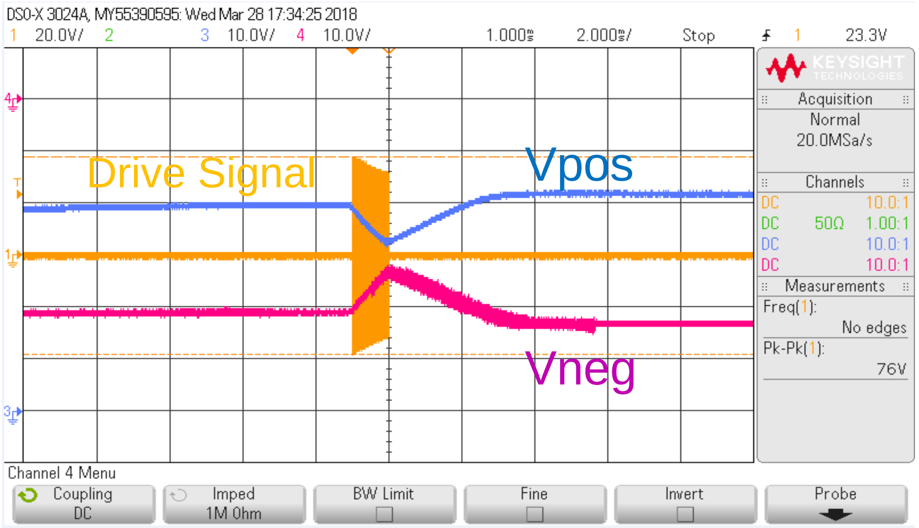






Test Set-up & Waveforms for 16-Ch System





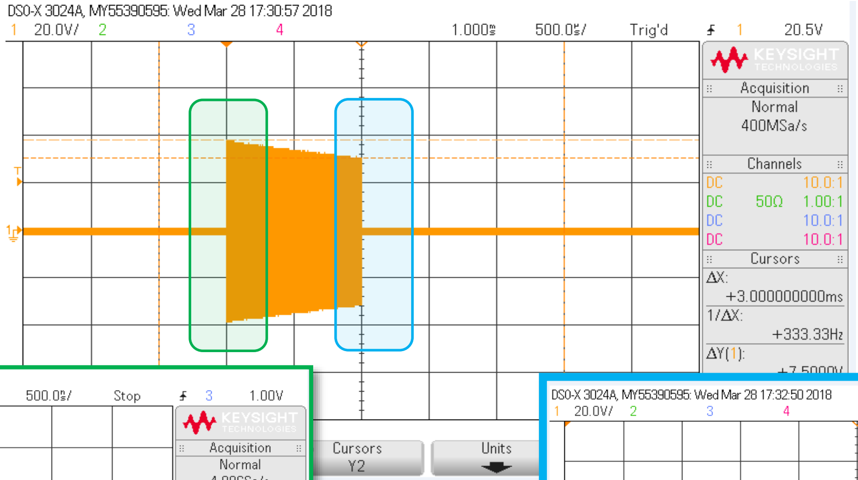
- Single SMPS powering Piezo Driver Board.
- The total capacitance on each rail is 320µF

The Supply voltage dips on each rail when 1ms Elastography waveform is enabled.
(Waveforms shown for V = ±40V)

Zoomed Waveforms for the Drive Signal

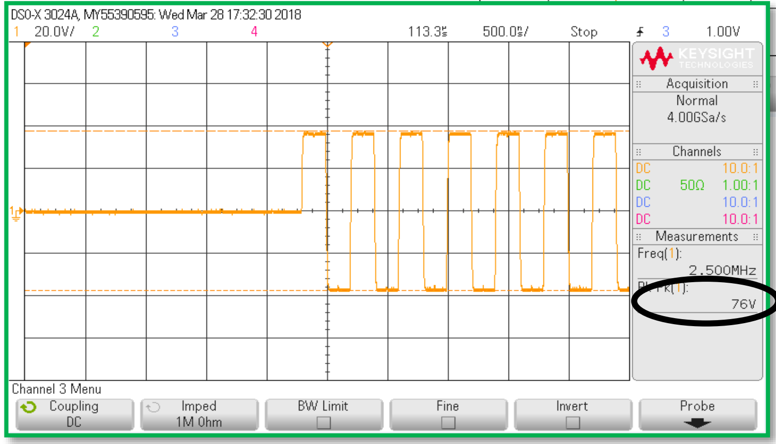
Calculated dip
= 6.7V

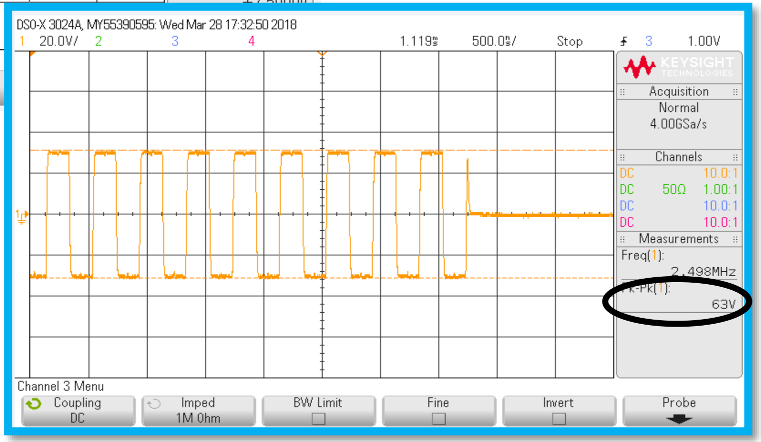
$$dv = i \times \frac{dt}{C} = 2.1585 \times \frac{1m}{320\mu} = 6.7V$$



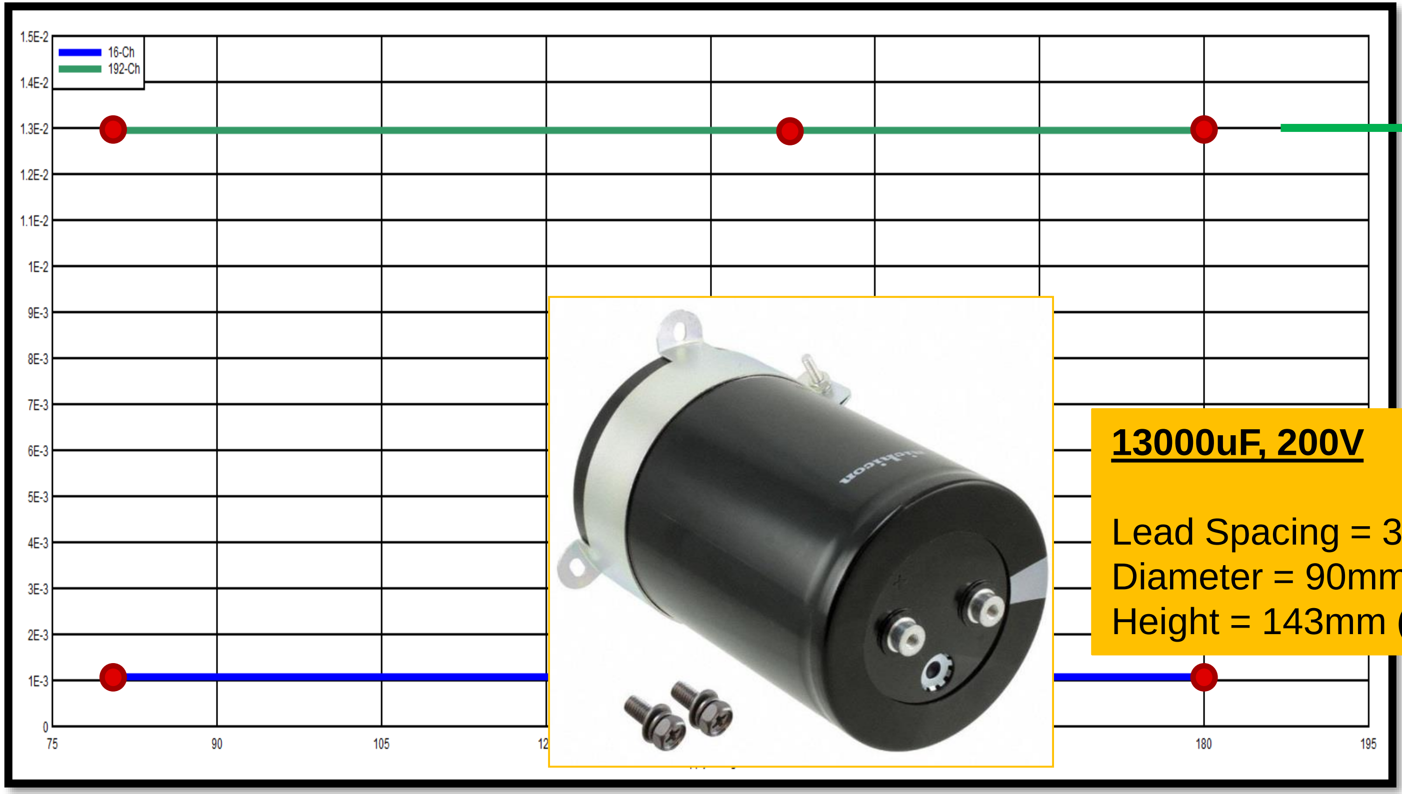
Measured dip
= 6.5V

$$dv = \frac{76 - 63}{2} = 6.5V$$





Required Capacitance at the output of SMPS



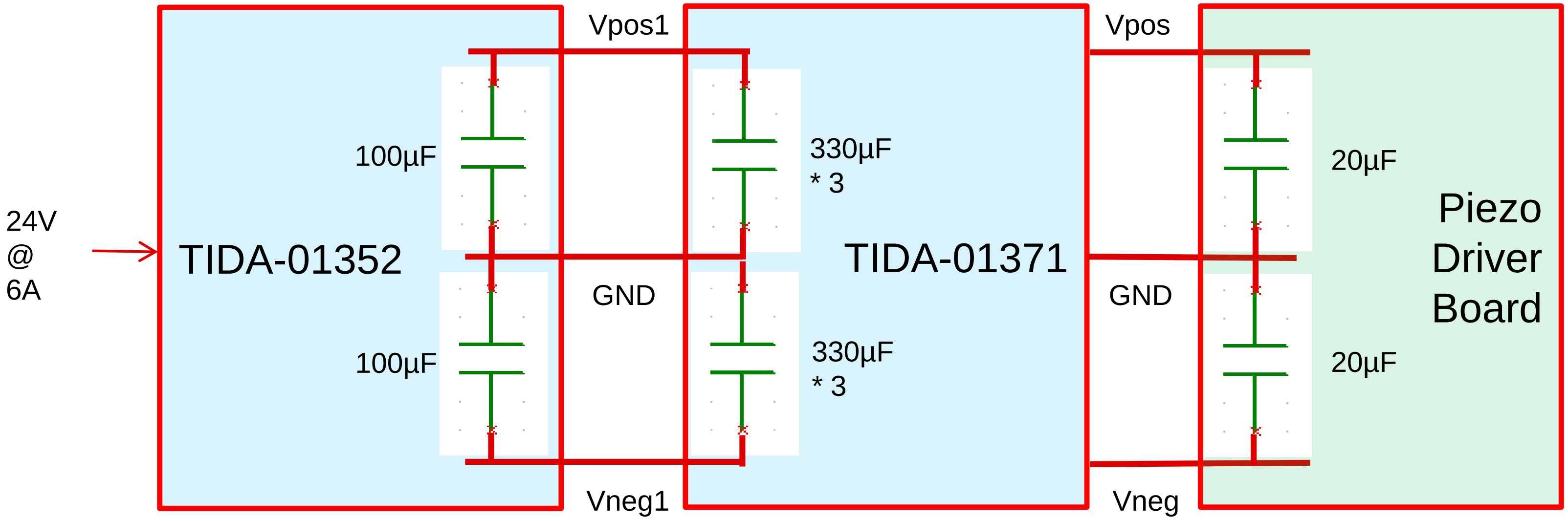
~13000µF for 5% dip in the supply voltage

<u>13000uF, 200V</u>

Lead Spacing = 31.80mm (1.252 inches)
Diameter = 90mm (3.543 inches)
Height = 143mm (5.630 inches)

Driving Piezo load with floating regulators

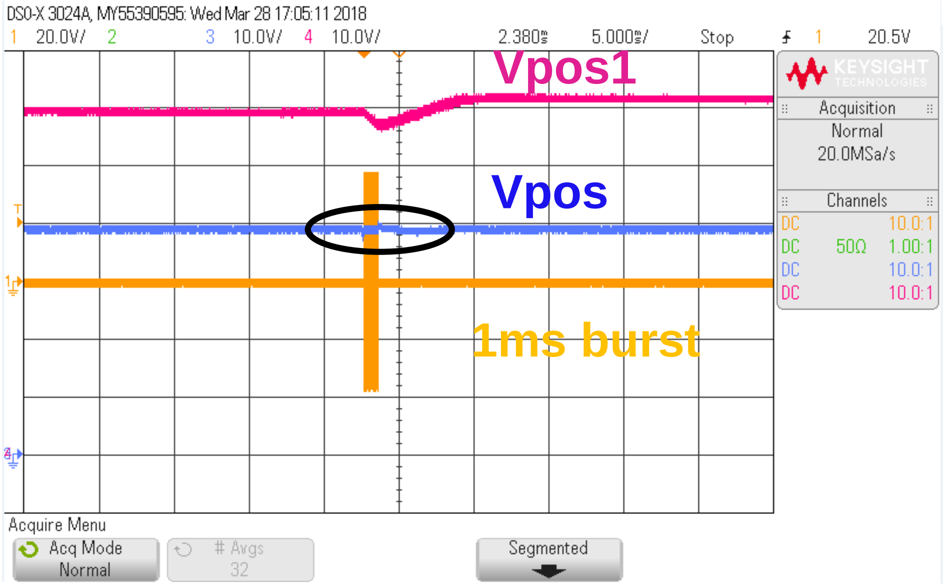
- SMPS (TIDA-01352) followed by Floating Regulator (TIDA-01371) is powering Piezo Driver Board.
- The total capacitance on supply is 20µF

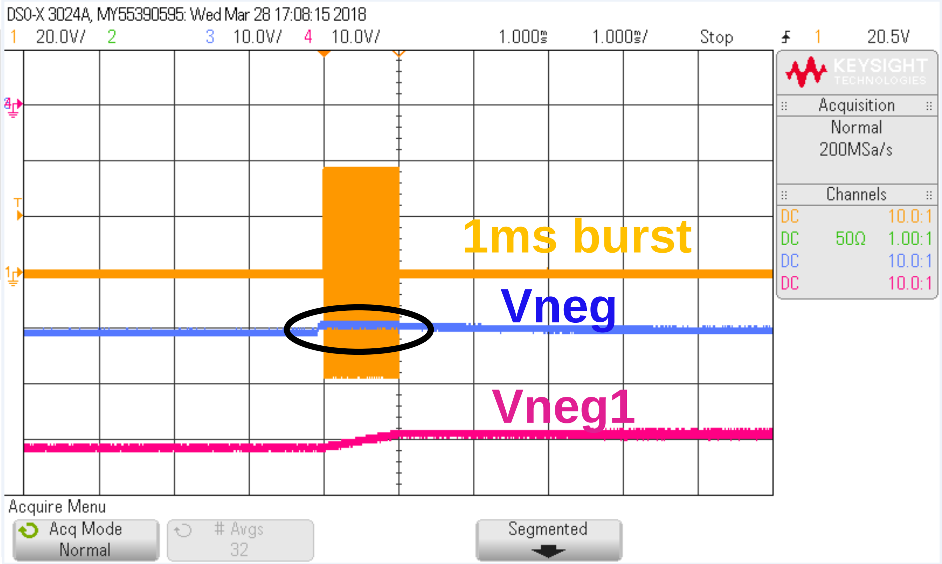


Vpos1 = Vpos + 10V
Vneg1 = Vneg + 10V

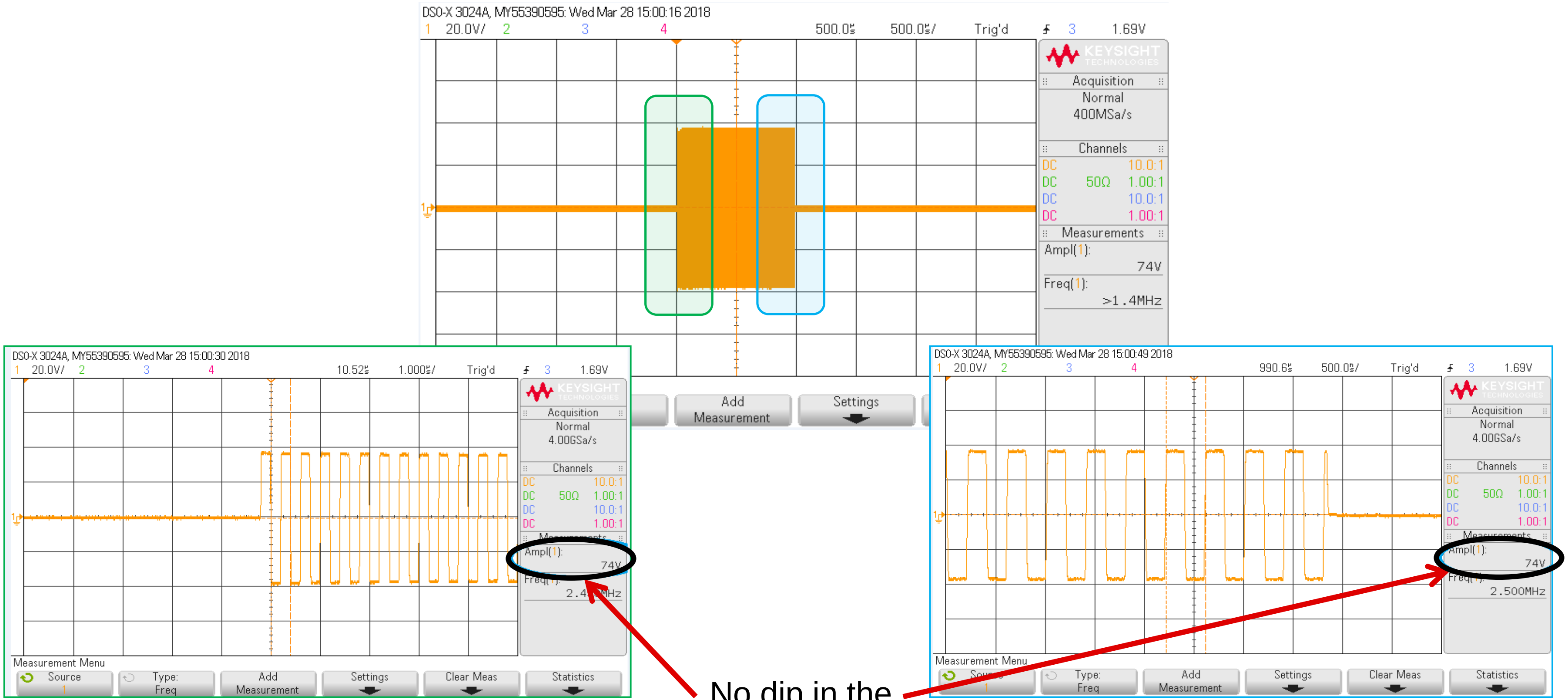
Pulling 1ms burst current from output

- The Supply voltage does not dip when 1ms Elastography waveform is enabled. (Waveforms shown for V = ±40V)





No Voltage dip is observed!!



No dip in the supply voltage

Capacitor Size Comparison

~70% Board Space Saving

<u>13000uF, 200V</u>

Lead Spacing = 31.80mm (1.252 inches)
Diameter = 90mm (3.543 inches)
Height = 143mm (5.630 inches)

<u>1000uF, 200V</u>

Lead Spacing = 10mm (0.394 inches)
Diameter = 22mm (0.866 inches)
Height = 50mm (1.969 inches)

Comparison

	Using only SMPS	Using SMPS + Floating LDO
SMPS Output Capacitor	Huge (~13000µF) for 192-Ch system	1000uF (for 192 Ch system) – This is input capacitance of Floating LDO circuit.
Power Supply Output Capacitors	Huge (~13000µF) for 192-Ch system	Low (~100µF) as required by the TX chip
Size of output caps	77mm dia & 107mm height (x2) = 9313mm2 area	20mm dia & 30mm height (x2) = 314mm2 area + 3600mm2 for floating regulator
Additional Circuitry	No	Yes, floating regulator circuit with MOSFETs are required
Power Dissipation	Minimum	There has to be enough drop-out voltage for floating LDO circuit to operate. This will increase overall power dissipation of the circuit.

TIDA-01352 & TIDA-01371 are available on TI.com

Visit www.ti.com/tool/TIDA-01352 to find design resources (Gerbers, Schematics and more).

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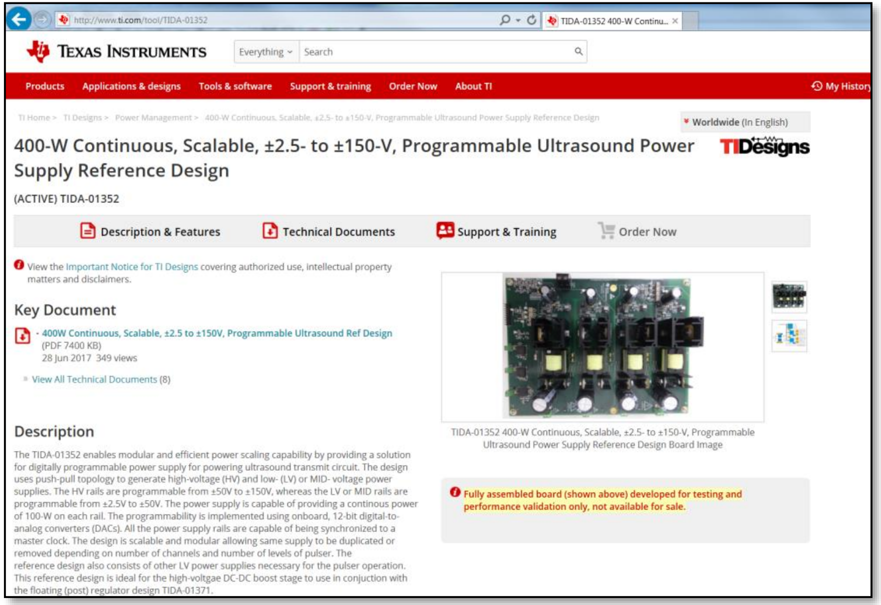
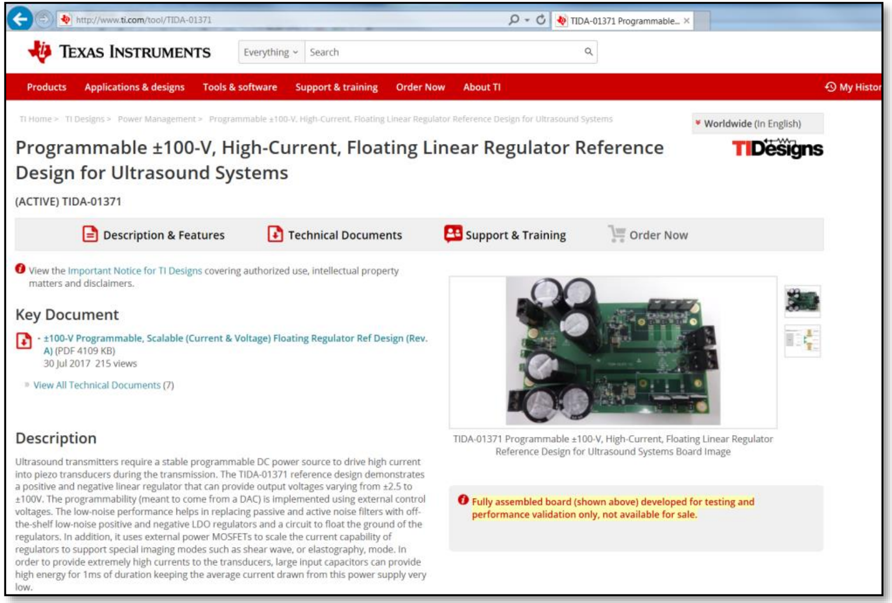




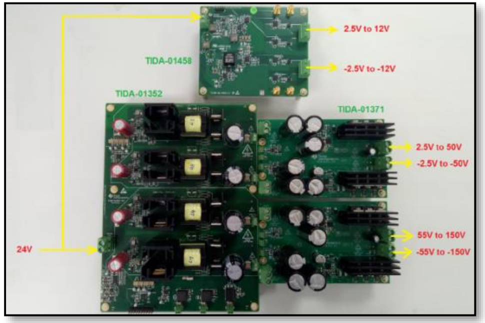
TEXAS INSTRUMENTS

Other Resources

TEXAS INSTRUMENTS

Application Report
SLOA262–February 2018

Supporting Elastography (Shear Wave) and CW Doppler Modes in Ultrasound Using Power Reference TI Designs



http://www.ti.com/lit/an/sloa262/sloa262.pdf