

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

Part - 1

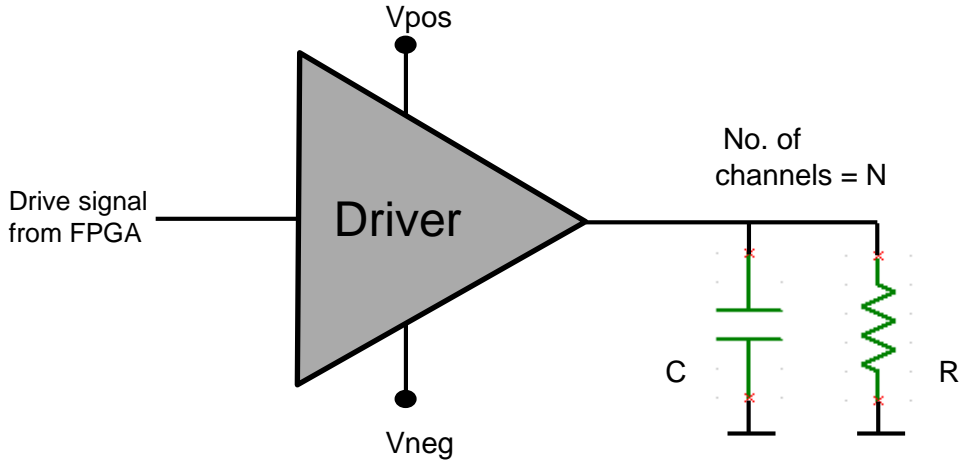
Presented by: Sanjay Pithadia

SEM – Industrial Systems, Medical Sector

Challenge to Solve

**Driving High-Voltage Piezo sensors without using Big
Capacitor banks**

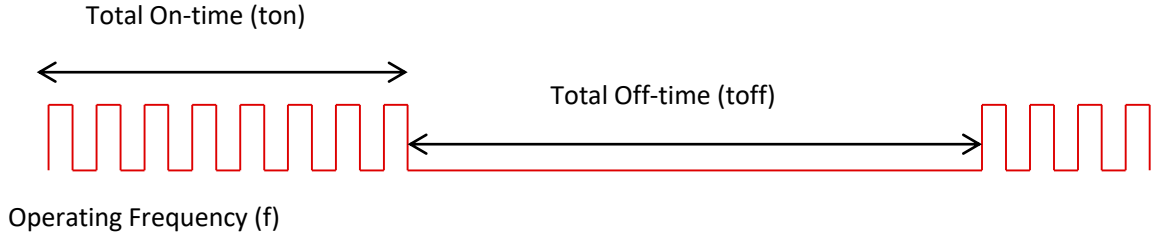
Drive Current Calculations – Piezo sensors



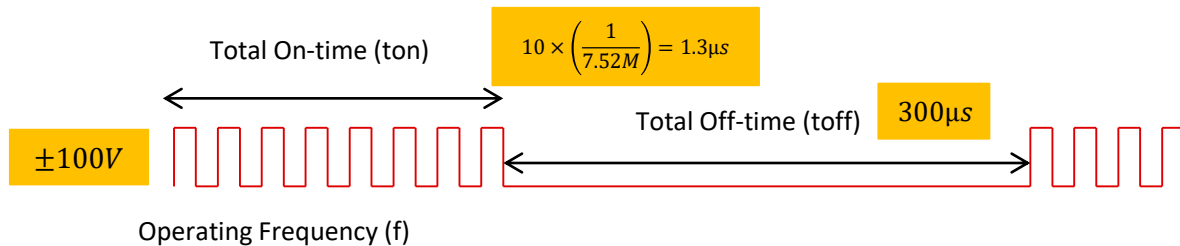
$$i_C = f \times C \times (V_{pos} - V_{neg}) \times N$$

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

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



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



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

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

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

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

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

N

7.5MHz 128ch Linear Probe



RoHS compliant.

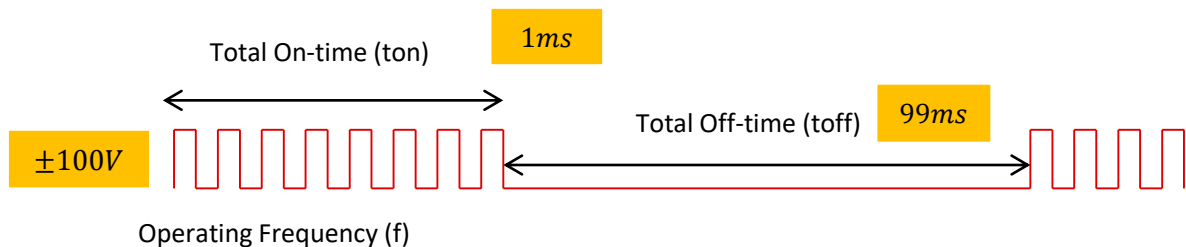
RoHS Compliant
Directive 2011/65/EU

Element Pitch	0.315 mm
Transverse Aperture	4 mm
Curvature	---
Geometrical Focus	20 mm
Center Frequency(-6dB)	7.52 MHz
Fractional Bandwidth(-6dB)	81.7 %
Pulse Length(-20dB)	0.41 μs
Sensitivity	-52.5 dB
Capacitance	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



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

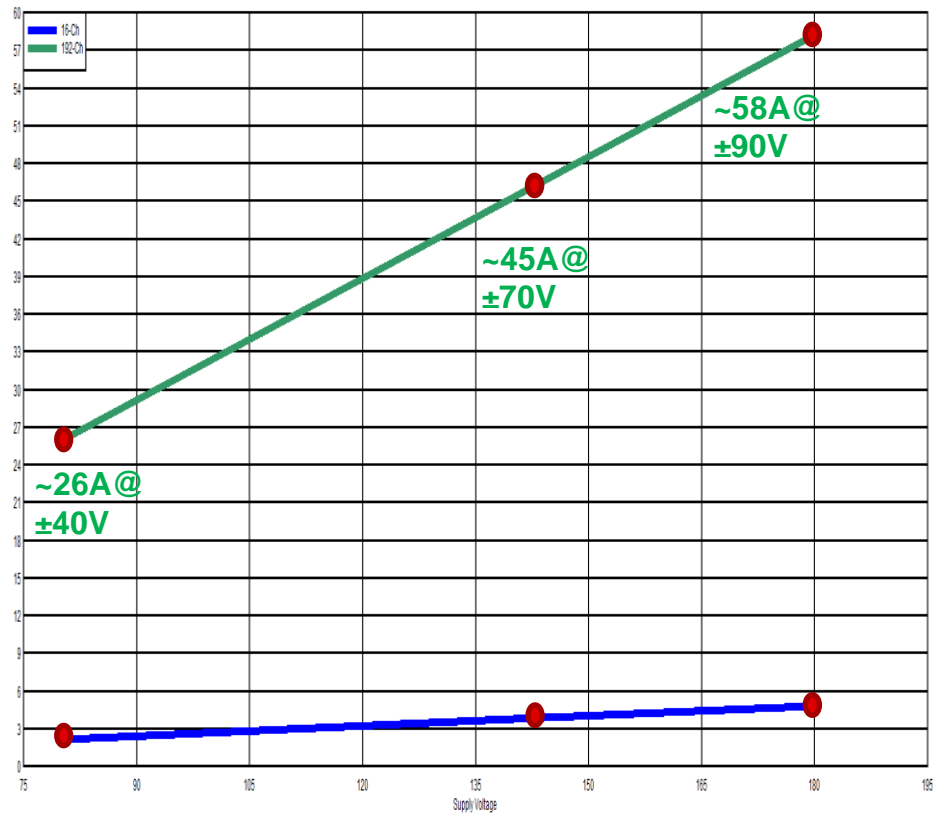
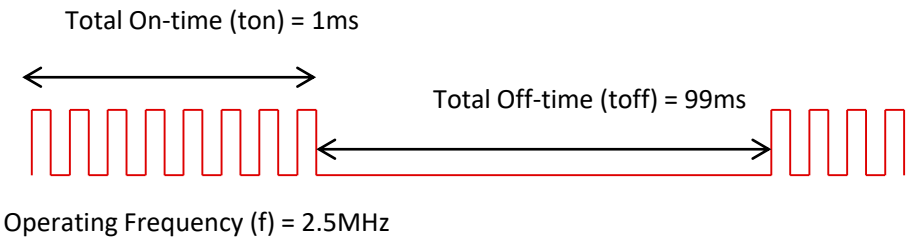
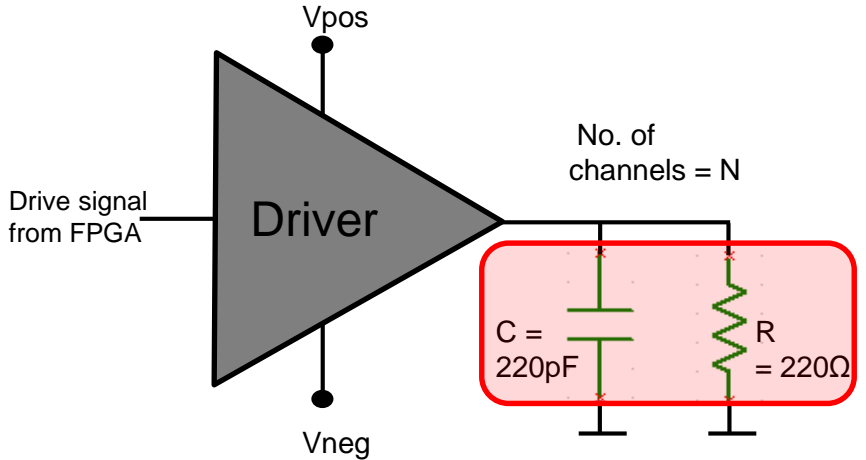
$$\text{Peak Output Current} = \frac{9 \text{ kW}}{100} = 90A$$

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

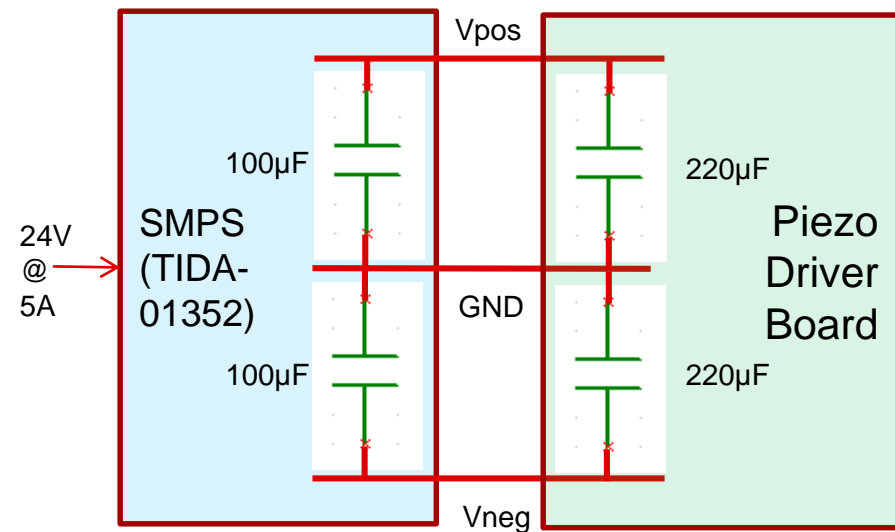
$$C_{out} > \frac{I_{out} \times t_{on}}{V_{dip}} > \frac{90 \times 1 \text{ m}}{20} > 4500 \mu F$$

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

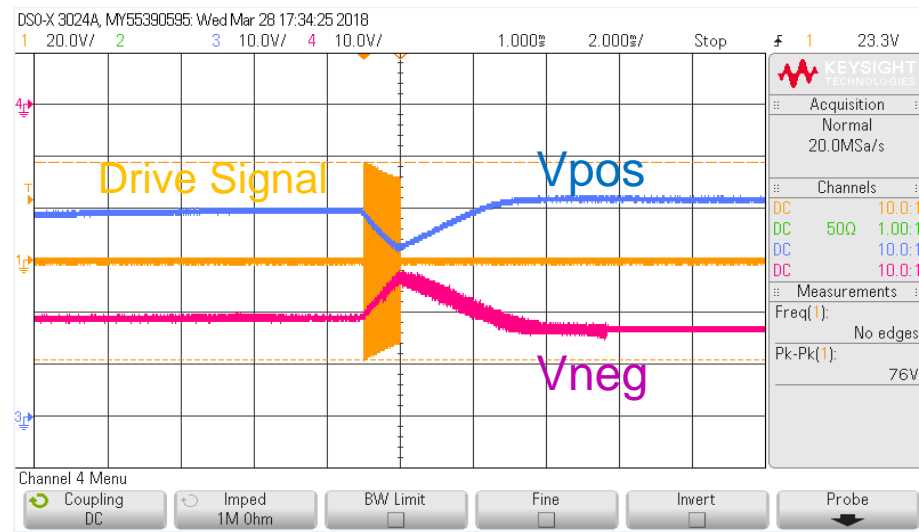
Calculated Drive Current (Varied supply Voltage)



Test Set-up & Waveforms for 16-Ch System



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

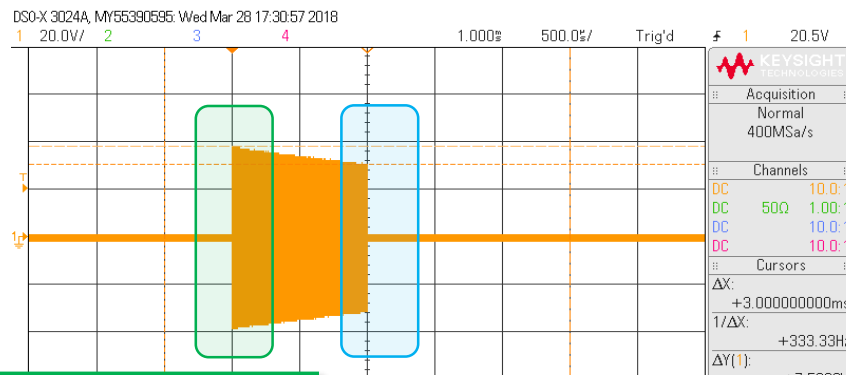


The Supply voltage dips on each rail when 1ms Elastography waveform is enabled.
(Waveforms shown for $V = \pm 40V$)

Zoomed Waveforms for the Drive Signal

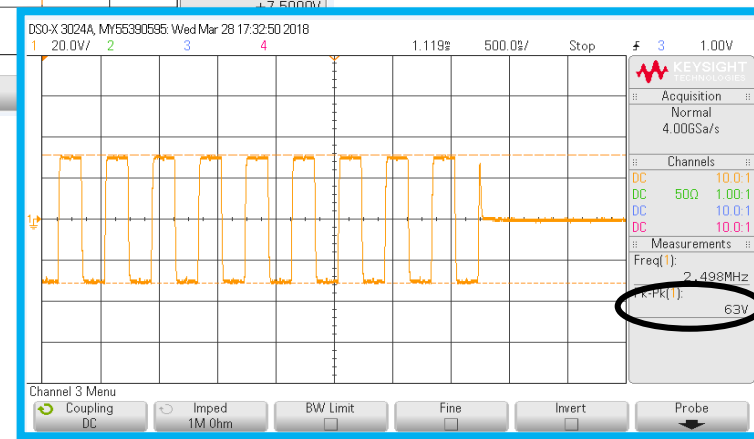
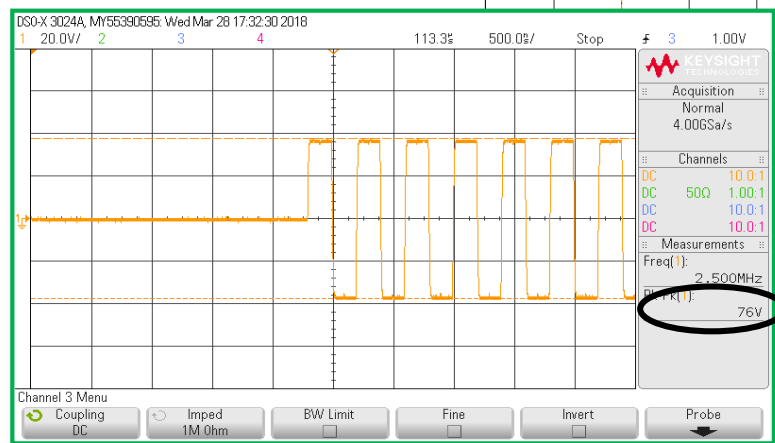
Calculated dip
= 6.7V

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

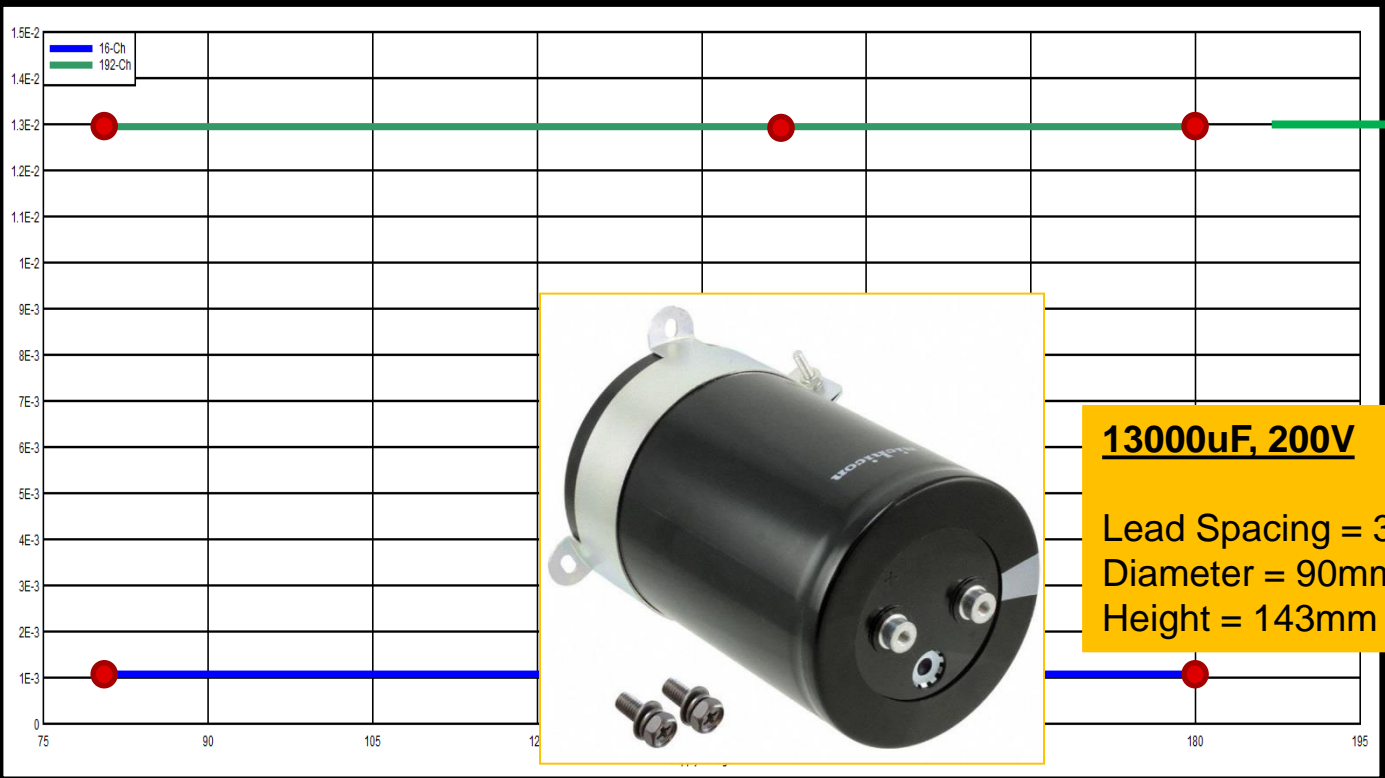


Measured dip
= 6.5V

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



Required Capacitance at the output of SMPS



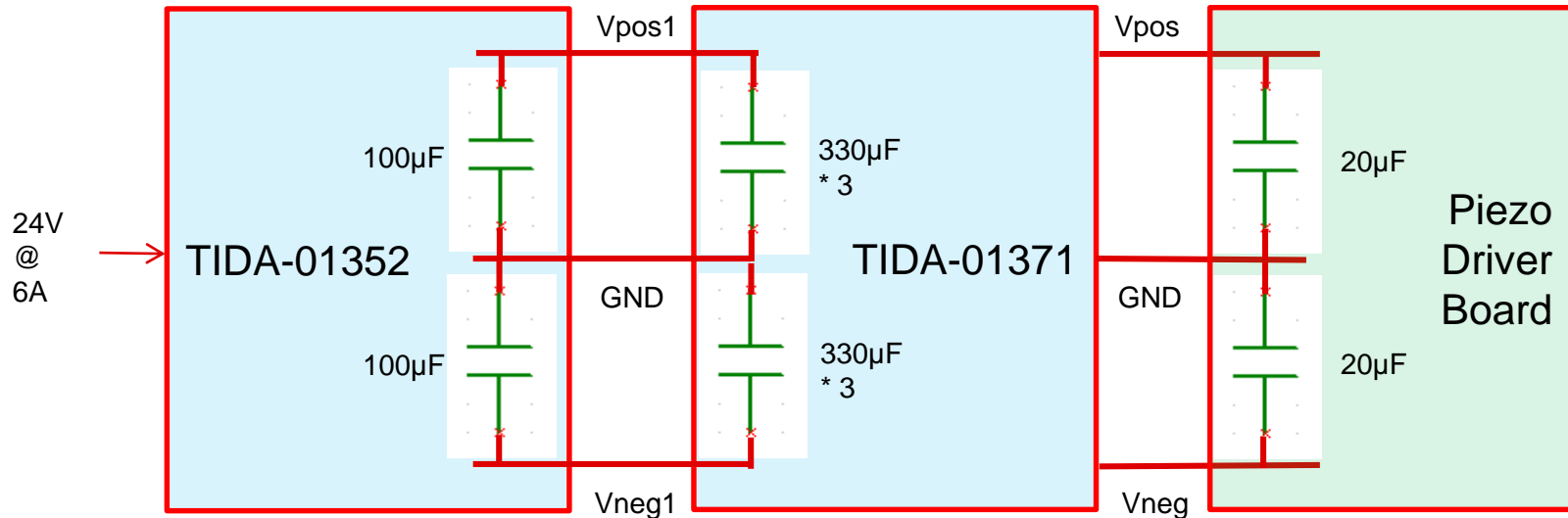
~13000 μ F for 5% dip in the supply voltage



13000 μ F, 200V
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 $20\mu\text{F}$

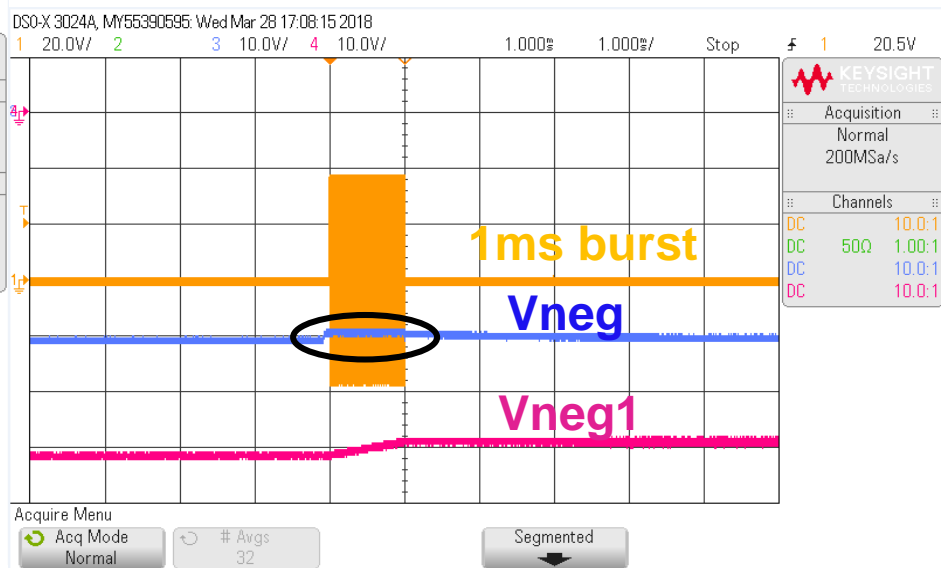
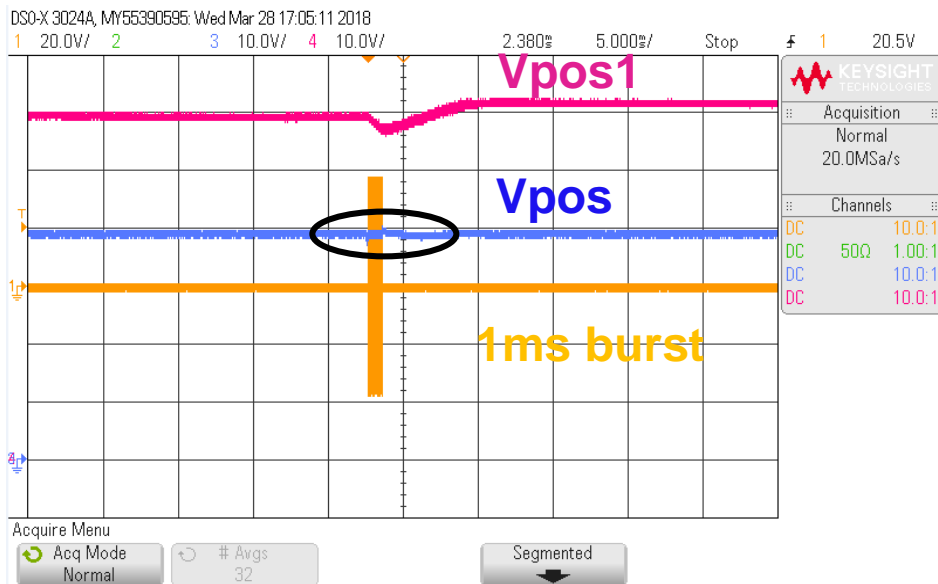


$$V_{pos1} = V_{pos} + 10\text{V}$$

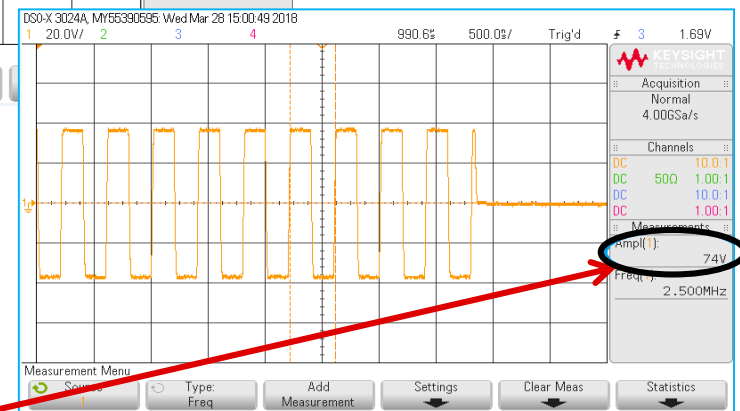
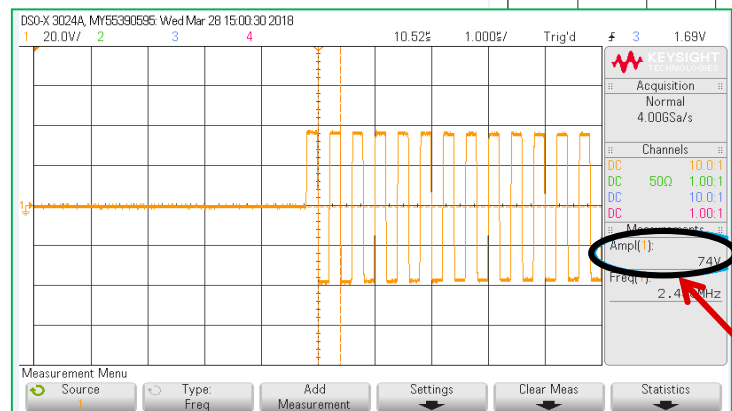
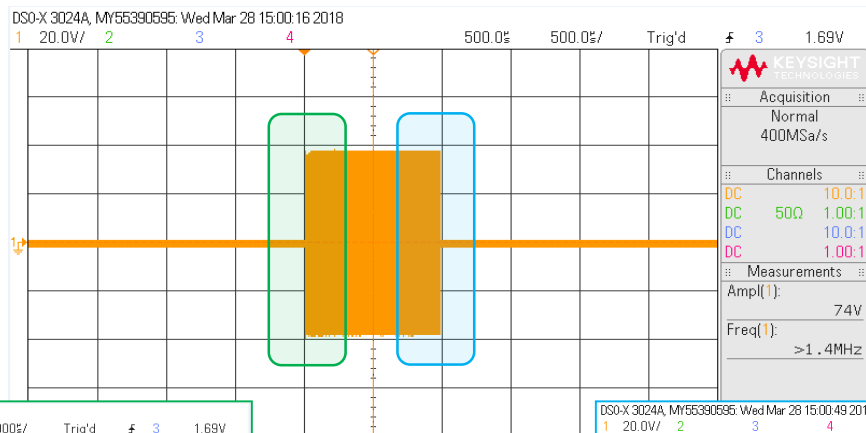
$$V_{neg1} = V_{neg} + 10\text{V}$$

Pulling 1ms burst current from output

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



No Voltage dip is observed!!



No dip in the supply voltage

Capacitor Size Comparison



13000uF, 200V

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



~70% Board
Space
Saving



1000uF, 200V

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

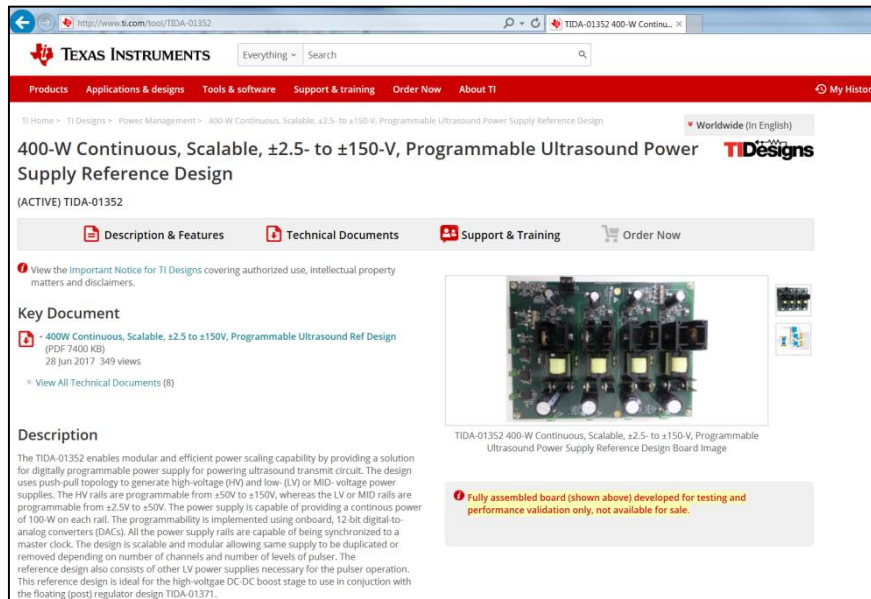
Comparison

	Using only SMPS	Using SMPS + Floating LDO
SMPS Output Capacitor	Huge (~13000 μ F) for 192-Ch system	1000uF (for 192 Ch system) – This is input capacitance of Floating LDO circuit.
Power Supply Output Capacitors	Huge (~13000 μ F) for 192-Ch system	Low (~100 μ F) as required by the TX chip
Size of output caps	77mm dia & 107mm height (x2) = 9313mm ² area	20mm dia & 30mm height (x2) = 314mm ² area + 3600mm ² 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.

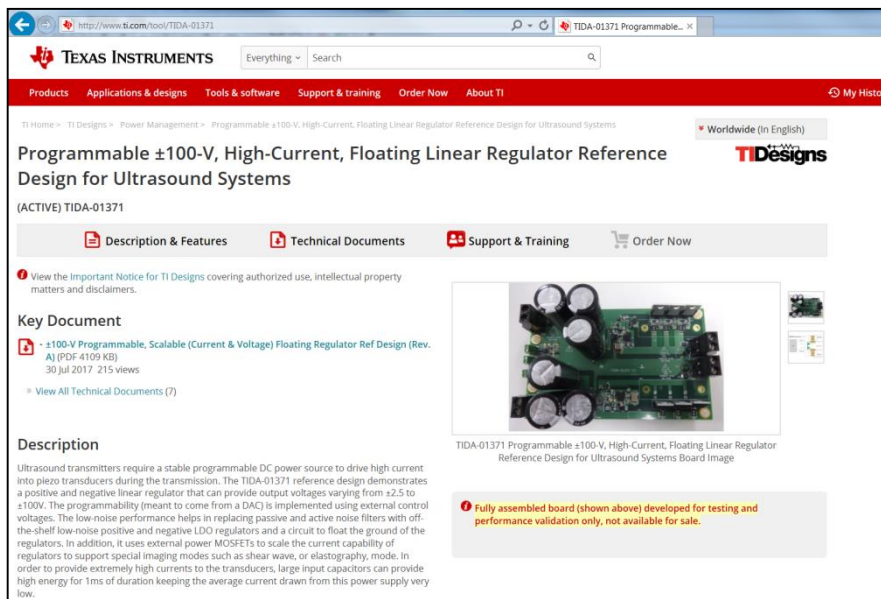
TIDA-01352 & TIDA-01371 are available on TI.com

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

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The screenshot shows the TI.com website for the TIDA-01352 product. The page title is "400-W Continuous, Scalable, ± 2.5 - to ± 150 -V, Programmable Ultrasound Power Supply Reference Design". The page includes a navigation bar with "Products", "Applications & designs", "Tools & software", "Support & training", "Order Now", and "About TI". Below the navigation bar, there is a breadcrumb trail: "TI Home > TI Designs > Power Management > 400-W Continuous, Scalable, ± 2.5 - to ± 150 -V, Programmable Ultrasound Power Supply Reference Design". The main content area features a "Key Document" section with a PDF icon and the text: "400-W Continuous, Scalable, ± 2.5 to ± 150 V, Programmable Ultrasound Ref Design (PDF 7400 KB) 28 Jun 2017 349 views". Below this is a "Description" section with a paragraph of text: "The TIDA-01352 enables modular and efficient power scaling capability by providing a solution for digitally programmable power supply for powering ultrasound transmit circuit. The design uses push-pull topology to generate high-voltage (HV) and low- (LV) or MID- voltage power supplies. The HV rails are programmable from ± 50 V to ± 150 V, whereas the LV or MID rails are programmable from ± 2.5 V to ± 50 V. The power supply is capable of providing a continuous power of 100-W on each rail. The programmability is implemented using onboard, 12-bit digital-to-analog converters (DACs). All the power supply rails are capable of being synchronized to a master clock. The design is scalable and modular allowing same supply to be duplicated or removed depending on number of channels and number of levels of pulser. The reference design also consists of other LV power supplies necessary for the pulser operation. This reference design is ideal for the high-voltage DC-DC boost stage to use in conjunction with the floating (post) regulator design TIDA-01371." A central image shows the TIDA-01352 board, with a caption: "TIDA-01352 400-W Continuous, Scalable, ± 2.5 - to ± 150 -V, Programmable Ultrasound Power Supply Reference Design Board Image". Below the image is a red callout box: "Fully assembled board (shown above) developed for testing and performance validation only, not available for sale."



The screenshot shows the TI.com website for the TIDA-01371 product. The page title is "Programmable ± 100 -V, High-Current, Floating Linear Regulator Reference Design for Ultrasound Systems". The page includes a navigation bar with "Products", "Applications & designs", "Tools & software", "Support & training", "Order Now", and "About TI". Below the navigation bar, there is a breadcrumb trail: "TI Home > TI Designs > Power Management > Programmable ± 100 -V, High-Current, Floating Linear Regulator Reference Design for Ultrasound Systems". The main content area features a "Key Document" section with a PDF icon and the text: " ± 100 -V Programmable, Scalable (Current & Voltage) Floating Regulator Ref Design (Rev. A) (PDF 4109 KB) 30 Jul 2017 215 views". Below this is a "Description" section with a paragraph of text: "Ultrasound transmitters require a stable programmable DC power source to drive high current into piezo transducers during the transmission. The TIDA-01371 reference design demonstrates a positive and negative linear regulator that can provide output voltages varying from ± 2.5 to ± 100 V. The programmability (meant to come from a DAC) is implemented using external control voltages. The low noise performance helps in replacing passive and active noise filters with off-the-shelf low-noise positive and negative LDO regulators and a circuit to float the ground of the regulators. In addition, it uses external power MOSFETs to scale the current capability of regulators to support special imaging modes such as shear wave, or elastography, mode. In order to provide extremely high currents to the transducers, large input capacitors can provide high energy for 1ms of duration keeping the average current drawn from this power supply very low." A central image shows the TIDA-01371 board, with a caption: "TIDA-01371 Programmable ± 100 -V, High-Current, Floating Linear Regulator Reference Design for Ultrasound Systems Board Image". Below the image is a red callout box: "Fully assembled board (shown above) developed for testing and performance validation only, not available for sale."

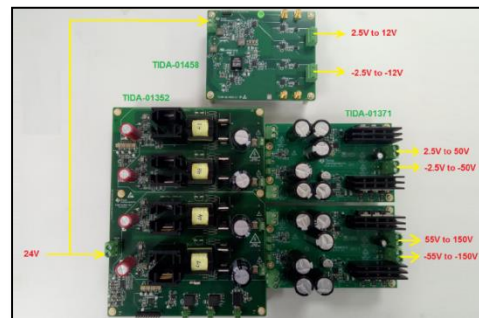
Other Resources



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

Application Report
SLOA262–February 2018

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



TIDA-01352 and TIDA-01371 Demo for Ultrasound Transmit Power Supply

This video demonstration discusses two of TI's latest reference designs targeted for Transmit power supply of Ultrasound Scanners. One is TIDA-01352, which is programmable push-pull power supply and other is TIDA-

Posted: 07-Jan-2017

Duration: 03:25

Related Videos



TIDA-01352 and TIDA-01371...

TX810
1st integrated T/R
switch ease



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