Extending output performance of ST ultrasound pulsers

Introduction

STHV TX pulsers are multi-channel, high-voltage, high-speed, pulse waveform generators with respectively 4, 8, 16 channels, primarily intended to drive piezoelectric transducer arrays in ultrasound applications.

ST ultrasound pulser ICs are designed to meet the high integration level needed in high-end medical ultrasound systems with up to thousands of channels.

Each ST pulser channel features up to 200 V_{PP} output voltage and 4 A output current allowing to drive a wide range of loads and transducers with low distortion.

However, some ultrasound transducers may require a higher excitation voltage, a higher current or a lower distortion depending on the imaging system requirements and on the transducer principle of operation.

This application note provides some methods to extend the ST pulser output equivalent performance above the datasheet absolute maximum ratings or AC characteristics, but with a lower level of integration.

Starting from the ST pulser HV output pins available, you can combine outputs or connect an RLC network to extend the piezo-driver capability to perform:

- Differential drive - to extend the maximum driving excitation voltage and reduce distortion
- Paralleling channels - to increase the maximum output current and output slew rate
- AC coupling - to extend the DC maximum output voltage and increase robustness
- DAC drive - to extend the maximum number of output levels and reduce distortion
- Pulse width modulation (PWM) - to reduce distortion and power consumption
- Cascading pulsers - to increase maximum common mode output voltage

1 Differential drive

In typical medical ultrasound applications, ST pulsers are used to drive transducers in single-ended mode (Figure 1) to simplify receiving sequence path in pulse-echo operation and because elements in high channel density probes are usually referred to a common reference.

When an external T/R switch is used or a transducer has to work only in transmission mode when both its terminals are available, ST pulsers can be simply used in differential mode (Figure 2) to increase output voltage as often required in NDT applications where high voltage bulk transducers are used.

Figure 1. Single-ended drive

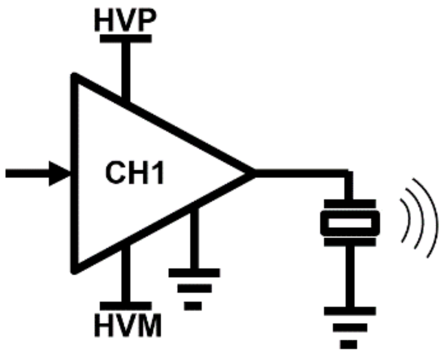
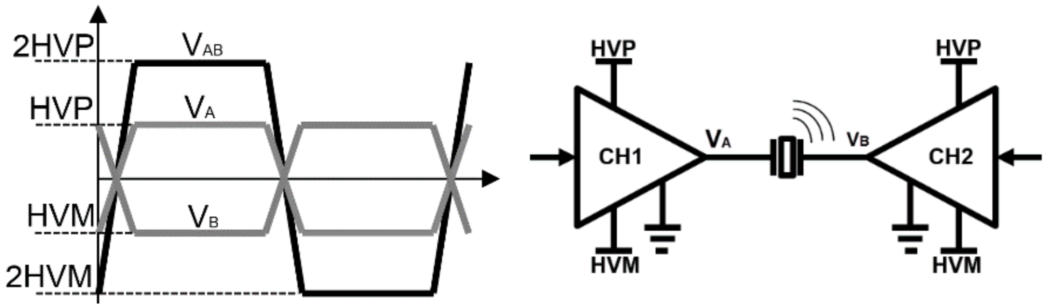
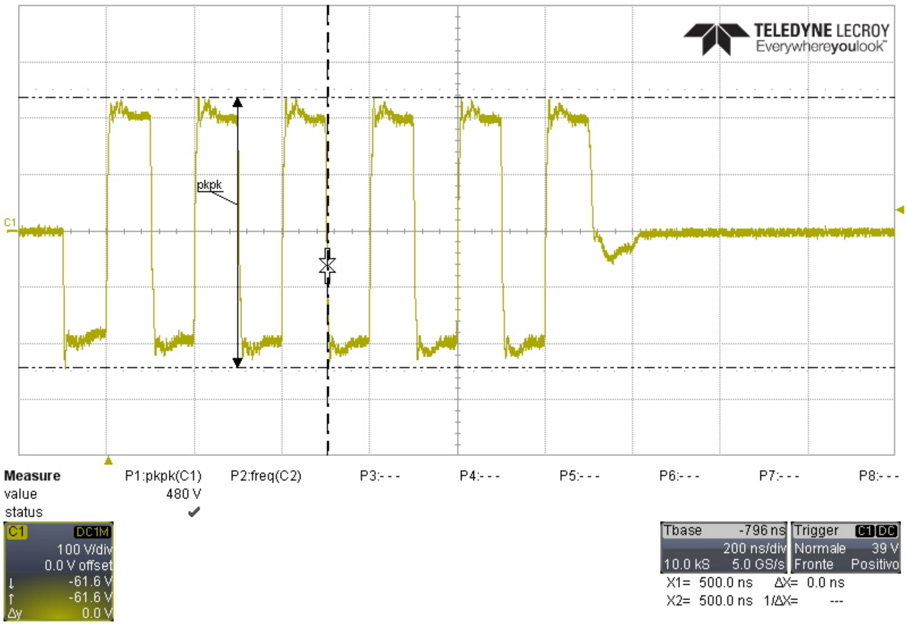


Figure 2. Differential driver



Differential drivers offer several advantages: the output voltage can be doubled (Figure 3) for the same supply voltage; the supply voltage can be halved for the same output voltage by using one more channels per element and a doubled path resistance.

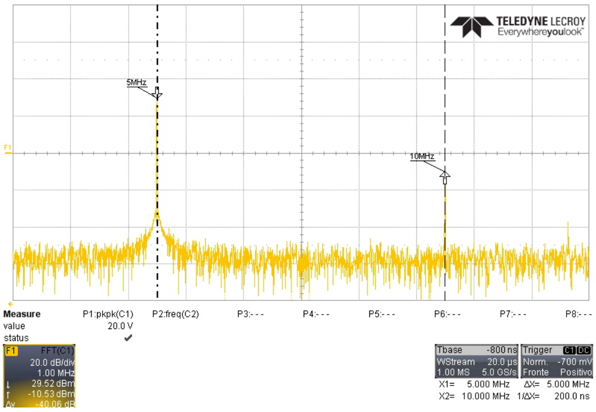
Figure 3. 400 Vpp differential pulsed wave obtained with two 3-level channels supplied at ±100 V

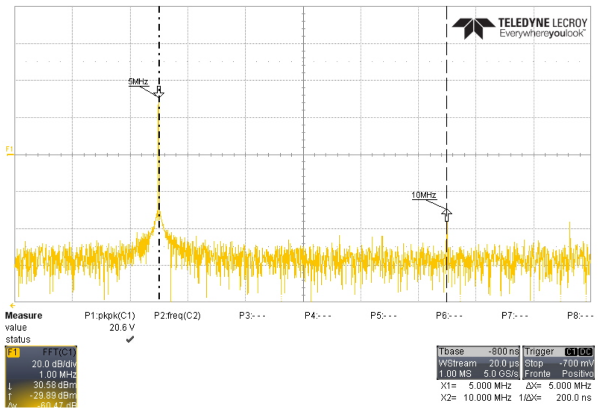


As reducing supply voltage decreases static consumption, bipolar pulses can be generated without a negative power supply and harmonic distortion can be lowered (Figure 4) because the differential mode compensates in part the high-low side switches and power supply rails mismatches.

Pulse-echo using internal ST HV pulser T/R switch is still possible if the receiving circuitry is also differential, or if one of the two transducer terminals can be clamped to ground during the receiving phase.

Figure 4. 20 Vpp continuous wave FFT spectrum respectively obtained with single ended and differential mode driving 100 Ohm/300 pF

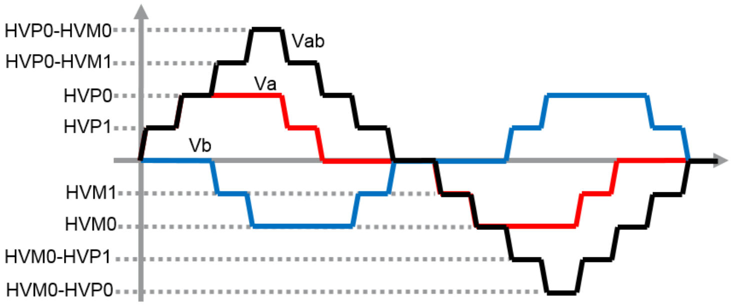




More complex waveforms can be achieved exploiting ST pulser multilevel functionality.

Differential mode allows obtaining 9 output levels from a 5 level pulser.

Figure 5. **Obtaining 9-levels from two 5-level channels**



Because of internal diodes, to decrease output magnitude level, single-ended dummy loads are required, to be connected to ground or left open using additional channels.

Figure 6. **Differential driver with resistive single-ended dummy loads**

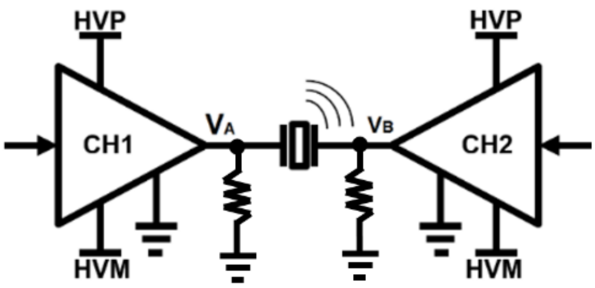
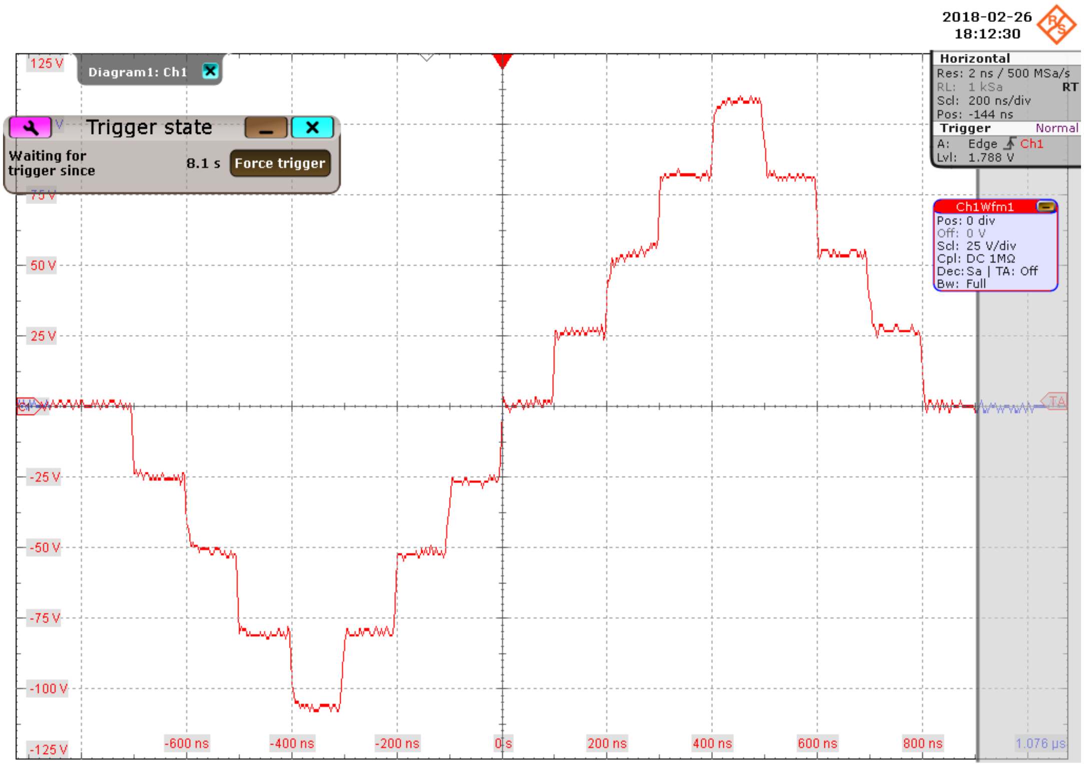


Figure 7. **9-level 200 Vpp differential pulsed wave obtained with two 5-level channels and two 100 Ohm single-ended dummy loads**



2 Paralleling channels

Pulser channels can be paralleled to obtain more output current.

Figure 8 shows the pulser internal resistance, which helps to reduce propagation delay channel mismatch effects, even if it is advisable to match channel path length on the PCB.

Paralleled channels reduce the output resistance, allow very high output slew rates and help to drive low impedance loads such as coils, transformers or transducer arrays.

This driving mode is very useful also for discrete laser diode-based LIDAR applications where very high current short pulses are required.

Figure 8. Increasing output current by paralleling channels

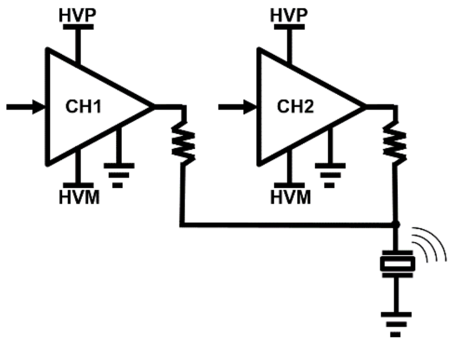
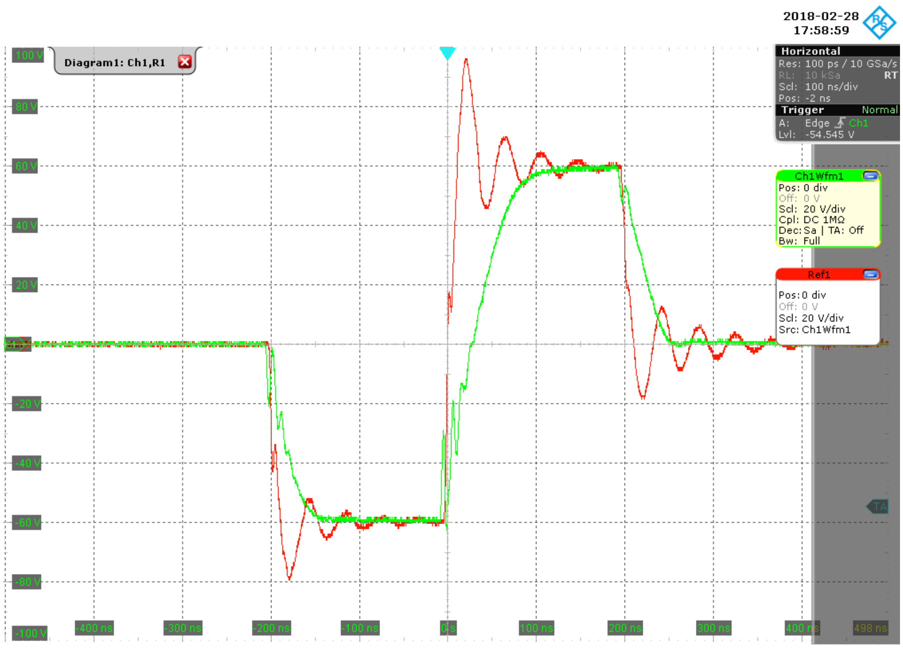


Figure 9. 1 channel (green) vs 16 paralleled channels (red) driving a 1 nF load at ±60 V



3 AC coupling

The AC coupling channel (Figure 10) allows shifting the entire output voltage dynamic of ST pulsers in a higher or lower DC level.

This mode is very useful for unipolar voltage excited transducers used in some NDT applications.

Capacitor CX value has to be much higher than the transducer capacitance: in the first circuit output offset, it is proportional to the duty cycle at steady state after an initial transient.

DC level can also be forced with a resistor or a diode to shift the waveform immediately at the first cycle. An optional diode has to work at full voltage but it does not have to be fast as it works only at startup.

The output series capacitor also protects the system from damage in case of transducer short-circuit.

Figure 10. AC coupling driving modes

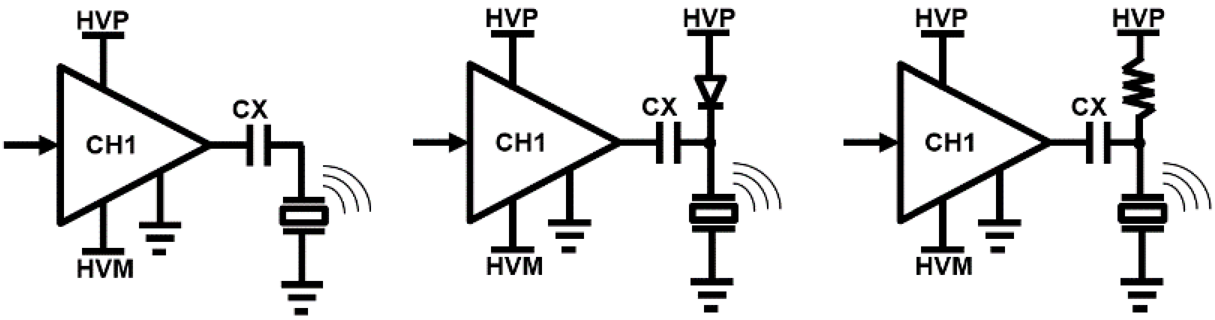
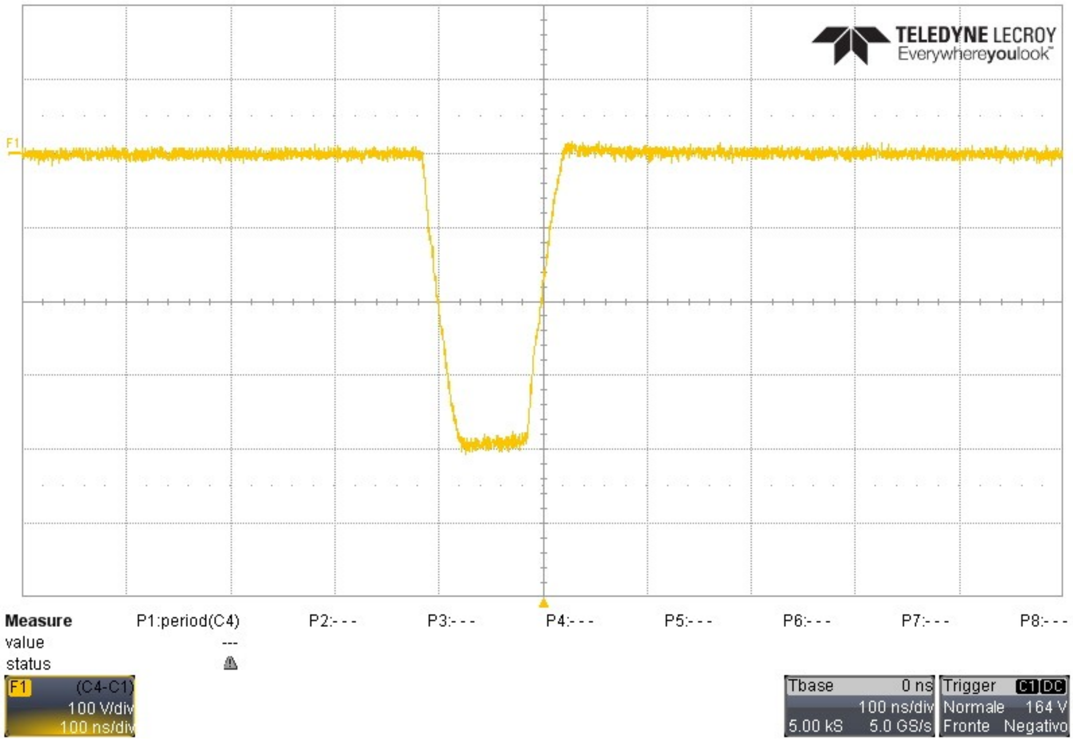


Figure 11. 400 V negative differential pulse obtained with two AC coupled channels supplied at ±100 V driving a capacitive load of 100 pF



4 DAC drive

Instead of directly driving the load, a resistive or capacitive ladder network can be used between two or more channels to provide intermediate levels to the transducer.

This mode is used to create high voltage or current analog waveforms as well as a digital to analog converters, with a lower efficiency, higher power consumption and lower channel density but a very high resolution and dynamic output.

The figures below show examples of DAC implementation with ST pulsers.

Figure 12. **Capacitive unary coded high voltage DAC**

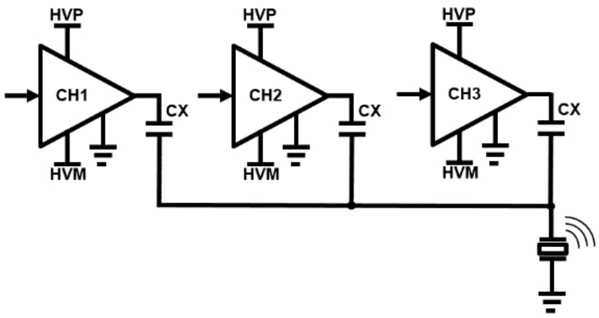


Figure 13. **17 level 100 V pulsed waveform obtained with 16 capacitive coupled channels supplied at +100 V, unfiltered (left), 20 MHz low pass filtered (right)**

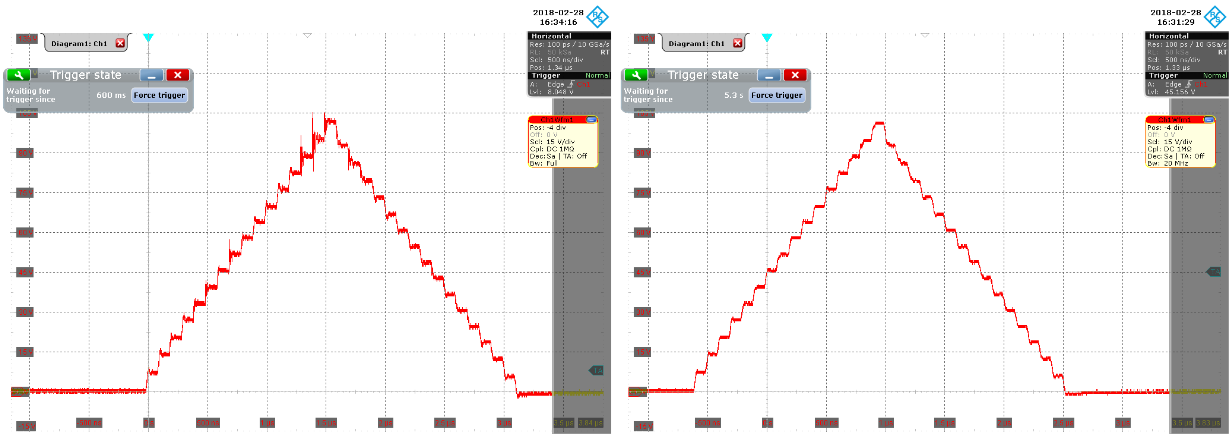


Figure 14. **3-trit resistive ternary high voltage DAC**

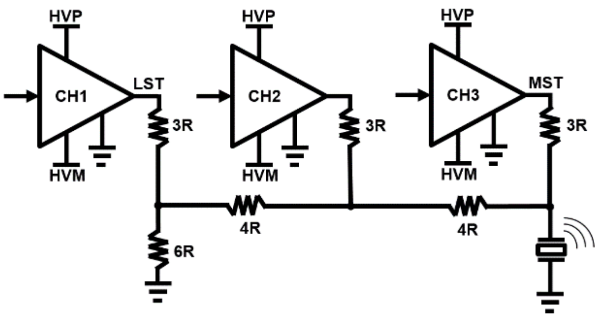
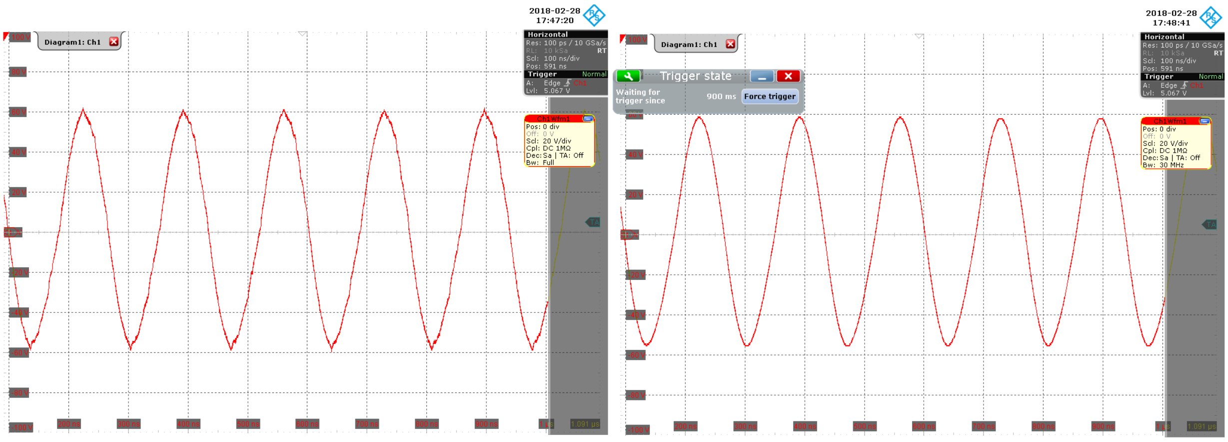


Figure 15. **27 level 120 Vpp sine-shaped pulsed waveform obtained with circuit in figure 15 supplied a +/-100V, unfiltered (left), 30MHz low pass filtered (right)**



5 Pulse width modulation

The output voltage can also be changed linearly using PWM (pulse width-modulation) as shown in Figure 16, modulating a carrier at a much higher frequency than the desired output signal.

The waveform can be reconstructed by an additional LC filter or by the load itself.

This mode is useful for low frequency ranging applications, class D audio amplifiers and DC-DC converters.

External diodes are necessary to protect pulser device from Lx flyback (Figure 17).

Figure 16. 100 V 1 MHz PWM (red) obtained with a pulser channel and the mathematical equivalent filtered output voltage (green)

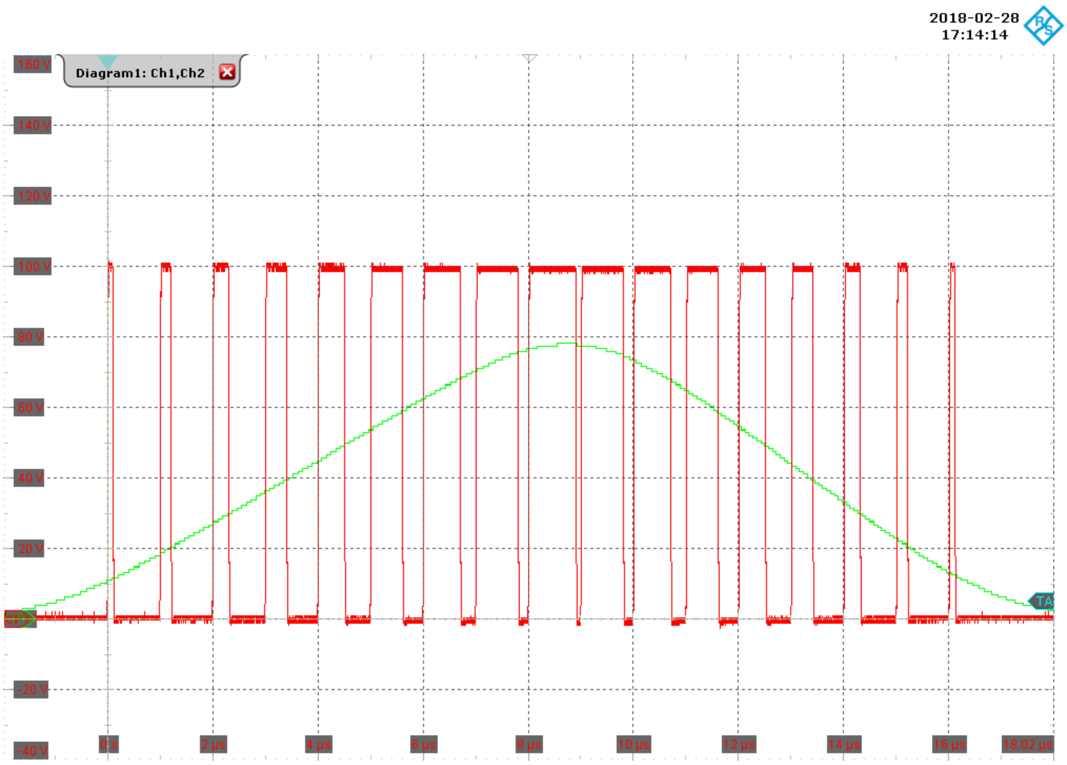
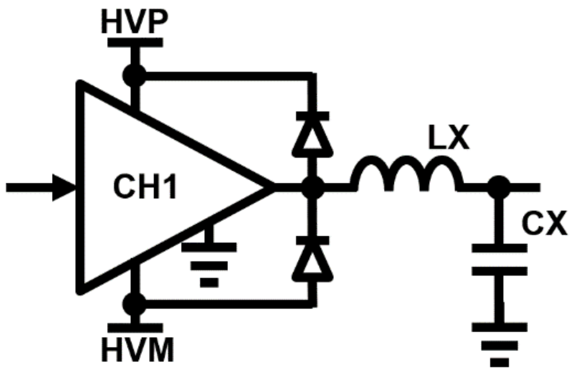


Figure 17. Flyback diodes and output filter for PWM operation



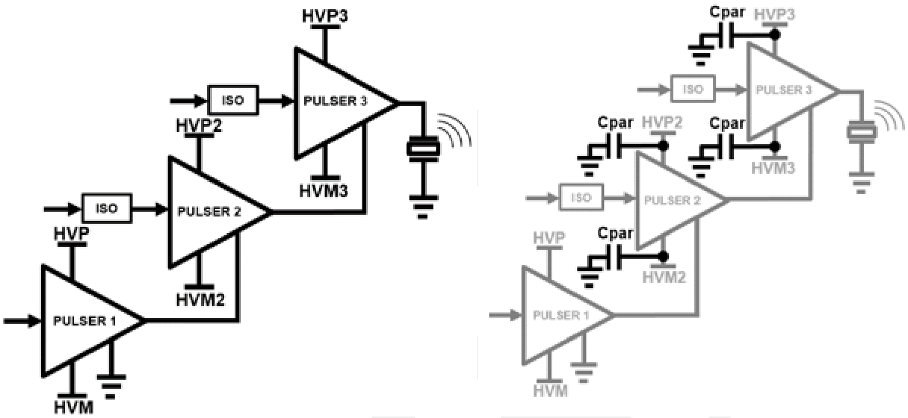
6 Cascading pulsers

Common mode transducer excitation voltage can be extended to cascading pulser devices (see the figure below).

The output pulser has to shift the reference of a successive floating pulser and its power supplies to achieve very high output voltage and power by using two or more isolated ST pulser devices per channel.

Each device channel can be paralleled or left floating: common mode parasitic capacitance has to be charged at every cycle and this can decrease output slew rate.

Figure 18. **Cascading pulsers and power supplies stray capacitance highlighted**



7 Driving mode summary

Table 1. **Driving mode summary chart**

Driving mode	Improving output				
	Voltage	Current	Frequency	Levels	Distortion
Differential	Yes	No	No	Yes	Yes
Paralleled	Yes	Yes	Yes	No	No
AC coupled	Yes	No	No	No	No
DAC	No	No	No	Yes	YES
PWM	No	Yes	No	Yes	Yes
Cascaded	Yes	No	No	Yes	No

Revision history

Table 2. **Document revision history**

Date	Version	Changes
16-Nov-2018	1	Initial release.
09-Jan-2019	2	Updated Introduction.

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