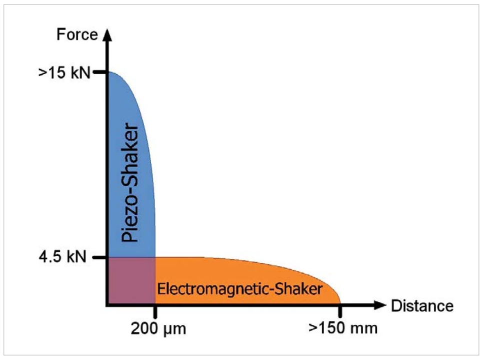
Shaker – Vibration Excitation

Shaker Applications for Piezocomposite Actuators

Piezo electric shakers based on piezocomposite actuators from ***piezosystem jena*** are used in a wide range of applications. Due to their char-acteristics Piezo-shakers are able to generate frequencies to over 100 kHz and accelerations up to 10’000 g. Force modulation in the tens of kN’s used in the smallest of installation spaces, is the benefit of piezo-composite actuators. Actuator sizes vary from a few millimeters to tens of centimeters. In comparison to other shaker types e. g. electro-magnetic shakers; piezo electric shakers have smaller size but much greater force generation. These characteristics make piezo electric shakers well suited for applications in material testing, active vibration damping and vibration excitation.



Comparison of electromagnetic and piezo electric shakers

Frequency Comparison of Piezoelectric and Electromagnetic Shakers:

manufacturer	shaker type	product	stroke	force	frequency
piezosystem jena	piezo electric	micro PiSha	to 5 µm	1 kN	100 kHz
	piezo electric	PiSha 1000/35/150	75 µm	± 15 kN	200 Hz*
other manufacturers	electromagnetic shaker		25.4 mm	< 350 N	30 Hz
	electromagnetic shaker		50 mm	4.5 kN	2,5 kHz
	electromagnetic shaker		-	50 N	2 kHz
	electromagnetic shaker		150 mm	900 N	200 Hz
	pneumatic shaker		-	< 1680 N	< 130 Hz

* with seismic mass of 80 kg (176 lbs)

Material Testing

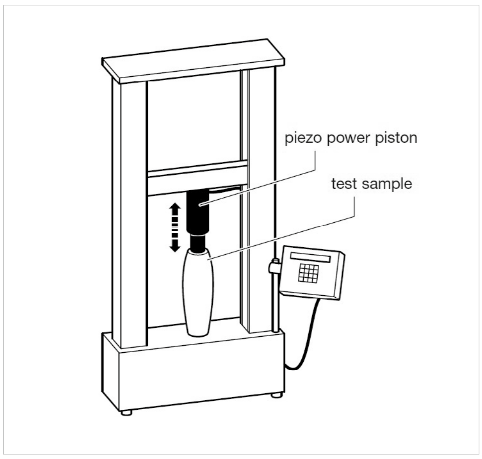
High Accelerations with Piezocomposite Pulse Generators

Piezo electric pulse generators (PIA) from ***piezosystem jena*** provide fast **accelerations up to 10’000 g** for testing objects, structures and materi-als. Using a special piezo electric ceramic material; they generate pulses with **energies up to nearly 4 Joule** twice as high as comparable ceram-ics from common actuators. The impact parameters, such as energy, ac-celeration, stroke etc. are **adjustable “on the fly”**. The impact partners (actuator and sample) are in contact before the shock, therefore high repeti-tion rates and precise triggering are possible. PIA impulse generators are used in material testing for instance; impact-echo-technique, sensor testing and calibration.

In a material testing set-up the impulse generator can impose a sample with an enormous high fre-quency fine modulation.

Pulse Generator

Technical Data:
Accelerations: > 10’000 g
Amplitude: 100 µm
Energy: < 4 J



High-load, long stroke piezo-actuator for material testing in a set-up for test-engi-neering

Piezocomposite Stack Actuators Series PSt and PSt VS

High power actuator for applications, requiring ***high loads*** *and* ***extreme dynamics***

PSt 1000/10/7

PSt 1000/35/7 VS45 and PSt 1000/35/40 VS45 (size comparison with pen)

Product Features

- **max. load up to 70'000 N**
- max. force generation 50'000 N
- **resonance frequency up to 60 kHz**
- **resolution in the nm and sub-nm range**
- travel range up to 260 µm (higher motion range on request)

Applications

- high force generation
- material testing
- stabilization
- sensor testing
- test and acceleration damping
- active vibration cancelation
- fuel injection
- active engine mounting
- positioning tasks

Options

- high power piezo material for power applications
- vacuum version
- integrated strain gauge measurement system for highest accuracy
- low temperature modification

Additionally available for PSt VS:

- thermostable modification
- increased preload

Recommended Controller

- SVR-series: high voltage amplifier for quasistatic operation (e. g. positioning tasks)
- PosiCon-Series: closed loop system for precise positioning
- RCV-series: high power switching amplifier for extreme dynamics

Elements of series PSt or PSt VS are recommended for **use under high loads**. PSt VS versions include casing and preload, PSt have no casing and are not preloaded. Their **high stiffness and resonant frequency** make these actuators an excellent choice for applications that require an **outstanding dynamic**.
Extreme **temperatures from -60 °C to +200 °C** do not affect the reliability of elements series PSt and PSt VS.

Example Technical Data

	unit		PSt 1000/10/7		PSt 1000/35/200 VS45
max. stroke	*µm*	from	12	to	260
length	*mm*	from	9	to	194
capacitance	*nF*	from	20	to	6500
stiffness	*N/µm*	from	300	to	150
resonant frequency	*kHz*	from	60	to	4

Piezocomposite Ring Actuators Series HPSt and HPSt VS

Ring actuators with free aperture
for static and dynamic applications

HPSt 1000/25-15/20 VS35

HPSt in different sizes

Product Features
- **max. load: 35’000 N**
- max. force generation: 20’000 N
- **resonant frequency up to 50 kHz**
- travel range: up to 130 µm (more on request)

Applications
- adjustment of optical components
- sensor testing
- test and acceleration damping
- active vibration cancelation
- fuel injection
- active engine mounting
- positioning tasks

Options
- high power piezo material for power applications
- vacuum design
- integrated strain gauge measurement system for highest accuracy
- low temperature modification

Additionally available for HPSt VS:
- low temperature modification
- thermostable modification
- optics adaptor

Recommended Controller
- SVR-series: high voltage amplifier for quasistatic operation (e. g. positioning tasks)
- PosiCon-Series: closed loop system for precise positioning
- RCV-series: high power switching amplifier for extreme dynamics

Elements of series HPSt or HPSt VS are recommended for use under high loads. HPSt VS versions include **housing and preload**, HPSt are unhoused and without preload. Because of a **free central opening** the ring actuators are applicable for laser applications. The opening can be used for a more effective cooling for high dynamical applications.

Example Technical Data

	unit		HPSt 1000/10-5/7		HPSt 1000/35-25/100 VS45
max. stroke	*µm*	from	12	to	130
length	*mm*	from	9	to	107
capacitance	*nF*	from	15	to	1800
stiffness	*N/µm*	from	210	to	160
resonant frequency	*kHz*	from	50	to	10

Piezoelectric PIA Shock Generators

Piezoelectric shock generators producing
exactly triggered mechanic pulses

PIA 300/10/3

Shock wave generator

Product Features

- adjustable impact parameters such as energy, acceleration and stroke **E < 4 Joule; a > 10’000 g, ΔL > 100 µm**
- high repeatability of the impact parameters, precise time behavior
- pulse energies up to Joule values
- variable collision- and repetition rates
- lowest rise times in the µs’s
- pulse width at about 10 µs
- µs precise triggering

Applications

- shock wave generation
- material testing
- short pulse excitation
- sensor testing and calibration
- modal analysis

Recommended Controller

- High Voltage Pulser HVP

PIA shock generators are able to produce **mechanic pulses with highest accelerations and shortest pulse widths**. Furthermore these shocks can be precisely triggered and show a remarkable repeatability. With these properties PIA shock generators **are perfect for** material testing, sensor testing, modal analysis or acceleration tests.

Example Technical Data

series PIA	operating voltage	amplitude @ max. voltage	capacitance	max. acceleration
	V	*µm*	*nF*	*m · s⁻²*
PIA 300/10/3	0 … +300	7	140	up to <100’000
PIA 1000/10/7	0 … +1000	7	80	up to <100’000
PIA 800/35/80	-200 … +800	80	6.6	up to <100’000

Piezoelectric Shaker - PiSha

Piezo-Shaker for ***vibration excitation*** *with* ***high frequencies*** *and* ***large forces***

Geo-Shaker with a glass of water to show the vibration

Product Features

- **frequency range over 100 kHz**, depending on the configuration of the shaker
- **high accelerations up to 10’000 g**
- amplitudes from micrometers to multi hundred micrometers
- **force modulation of multi tens of kN** (measured under blocking conditions – depending on shaker dimensioning, frequency of operation and installation conditions)
- compact dimensions of the piezoelectric structures down to the millimeter range
- high forces
- thermal management

Applications

- material characterization with respect to frequency/velocity/acceleration
- modal analysis
- investigation on structure borne noise/sound of machine parts
- fatigue testing of mechanical components
- fretting arrangements
- flaw detection in composite materials

Recommended Controller

- LE 150/100 EBW for high frequency operation
- RCV switching amplifier for high power applications

In comparison to conventional shaker systems piezoshakers exhibit a **high stiffness** and **high force generation** combined with rather small sizes. This results from the high energy density of the piezo material leading to a very wide frequency range. The tunability makes them perfect for applications like **modal analysis, material characterization or acceleration tests**.

Example Technical Data

series PiSha	operating voltage	oscillation amplitude	force modulation (blocking limit)	1st resonant frequency
	V	*µm*	*N*	*Hz*
PiSha 150/16/3	0 … +150	1.5	1200	35’000
PiSha 1000/35/150	0 … +1000	75	±15’000 with 80 kg seismic mass	200
Micro PiSha	0 … +150	< 5	1000	100’000

High Voltage Piezo Amplifiers

SVR 1000/1 (1 channel)
SVR 1000/3 (3 channels)

Low voltage noise guarantees excellent positioning accuracy

Product Features Analog Amplifier SVR

- **1 or 3 channel** amplifier
- manual setting of DC-Offsets
- LCD + BNC-Monitor output (1:1000)

Technical Data

series SVR	voltage range	max. current	noise
	V	mA	mV_{PP}
SVR 350 bip	-350 … +350	12	1 (≥100 nF load)
SVR 500	-100 … +500	15	1 (for 1 µF load)
SVR 1000	-200 … +1000	8	1 (for 0.47 µF load)

RCV 1000/7

High Power Switching amplifier developed for dynamic control of high volume piezo actuators.

Product Features Switching Amplifier RCV

- 1 channel switching amplifier
- manual setting of DC-Offset
- LCD + BNC-Monitor output (1:1000)

Technical Data

series RCV	voltage range	max. current	noise
	V	A	V_{PP}
RCV 1000/3	0 … +1000	3	≤ 1 (depends on the load)
RCV 1000/7	0 … +1000	7	≤ 2 (depends on the load)

HVP 300/20

High voltage pulser with high peak currents for driving of piezoelectric shock generators

Product Features High Voltage Pulser HVP

- 1 channel voltage pulser
- max. charging voltage: 1000 V
- **peak currents: up to 200 A**
- manual setting of charging voltage
- LCD + BNC-Monitor output (1:1000)

of the object will be generated, if the object is clamped tight (blocking condition). Adding seismic masses to the shaker allows a tuning of the system for frequency and forces. The vibration is detected via an accelerometer.

3. Clamped Setup:

The piezo shaker and the test object are mounted in a stiff clamping mechanism. The resulting amplitudes and forces depend on the shaker's and the test object's stiffness. The vibrations can be measured with a force sensor.

Depending on the setup the shaker can be integrated so that an additional clamping mechanism is not necessary.

Such kind of setup is often used for experiments for structure-borne sound investigations.

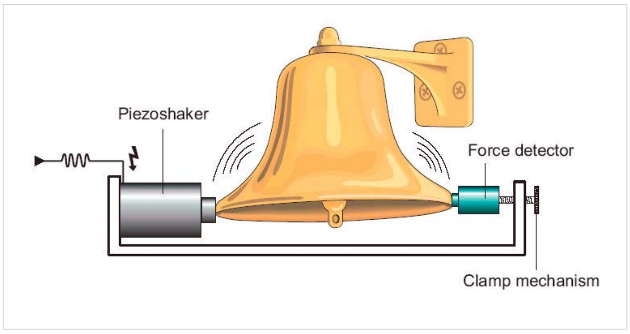


***Figure 7:** Clamping arrangement of a piezo shaker*

Piezo Shock Generators PIA

Shock generators are used to transfer short pulses to objects, to investigate their properties.

Shock Generator versus Shaker

In comparison to shakers, shock generators are operated by short electrical pulses or rectangular signals to achieve single pulses with high acceleration rates. These accelerations are independent of the repetition rate which can reach values in the kHz range.

Shakers usually work with a steady sine wave form. The frequency and amplitude of this oscillation determines the accelerations and forces reached.
Both systems are used for material and structure research; however the type of excitation is different: Shakers generate an oscillation of the material; shock generators realize single pulses to the material.

Conventional Shock Generators

Classic shock generation is usually realized by accelerating a specific mass (for example a hammerhead) which then hits its collision partner. During that short contact phase energy and momentum are transferred (the so – called impulse). Time and shape of the impulse strongly depend on the acoustical and elastic properties of the involved bodies. Due to the uncertainties during acceleration and contact phase it is extremely difficult to achieve reproducible shocks. Furthermore, the achievable repetition rates of these ballistic methods are strongly limited. A precise triggering (timing in µs-range) of the shock event which is needed in metrology is not possible. All these restrictions can be overcome with the use of piezo shock generators.

Piezo Shock Generators

Piezo shock generators overcome disadvantages of conventional generators. They provide:

- Adjustable shock parameters: energy (< 4 Joule); acceleration (> 10'000 g); amplitude (> 100 µm)
- High repeatability of the pulse parameters
- Precise time behavior triggering in the µsec range
- Variable repetition rates up to several kHz (burst)
- Fast rise time: down to µs values
- Adjustable pulse width down to 10 µs

Synchronization of several pulse generators is possible!

Piezo shock generators have to be specially designed to survive the high mechanical stress occurring during shock generation. Extreme preloads are necessary to withstand the high accelerations and resulting forces. Standard actuators are not sufficiently preloaded and would be immediately damaged under these conditions.

Please contact our team for more Technical Advice!

Applications

- Acceleration tests Shock experiments
- Shockwave propagation
- Material characterization (for example in Split-Hopkinson-Bar arrangements)
- Hardness testing
- Modal analysis
- Impact based measurements (like solid-borne sound investigations)
- Impact-echo-measurements (for example in geological and structural investigations)
- Sonic logging

The Piezo Stack as Shock Generator

If a piezo stack is charged with a very short rise time, the mechanical axial pressure in the ceramic material immediately increases to a high value. This so-called blocking pressure is generated over the full length of the piezo stack and leads to an accelerated expansion of the piezo bar. In this way a propagating pressure front can be created in the coupled shock-partner. Hence, the piezo represents an "active-bar", which then produces mechanical shocks.

The Physical Shock

In metrology usually bars are used for shock wave propagation, due to the easier mathematical modeling. The compression can be measured using strain-gages whereas Laser-Doppler anemometers can be used to determine the particle velocity. Changes in the bar's cross section lead to a splitting of the shock wave into a transmitted and a reflected part. This behavior is used in the Split-Hopkinson-Bar experiment (Fig. 8) to determine material characteristics subjected to high strain-rates.

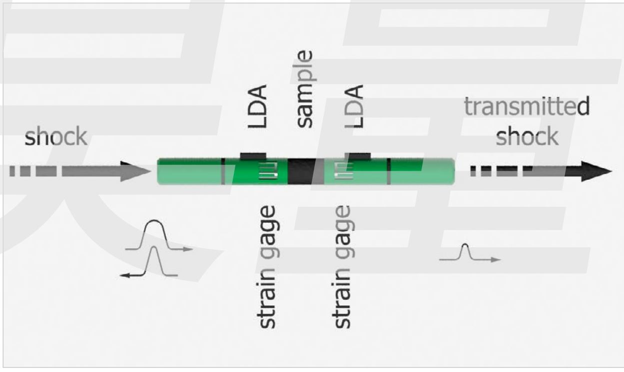


Figure 8: Hopkinson-Bar for material testing. By strain gauge and laser-Doppler anemometer the triggered and the reflected shock can be compared.

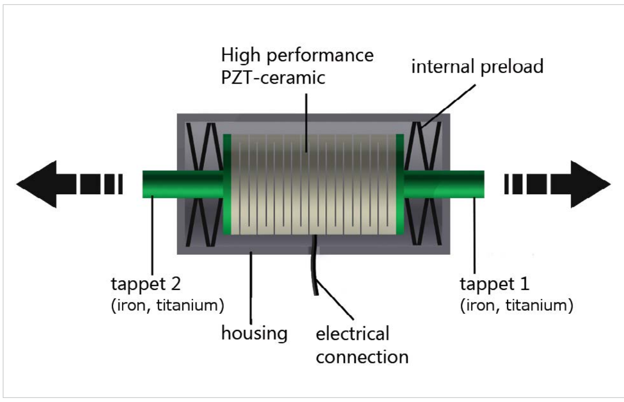


Figure 9: Schematic representation of a symmetric piezo shock-wave generator.

Layout of Piezo Shock Generators

Symmetric Shockwave Generators

Due to conservation of momentum, a piezo shock generator always creates two shocks propagating in opposite directions. This is used for the design of symmetric shockwave generators. (Fig. 9)

Single Sided Shockwave Generators

By applying a seismic mass on one side of the shock generator the backward running pulse can be reflected, resulting in a superposition of both pulses. The resulting pulse has nearly twice the energy and has an increased pulse duration showing a typical double-pulse profile. This concept is used for single-sided shock generators.

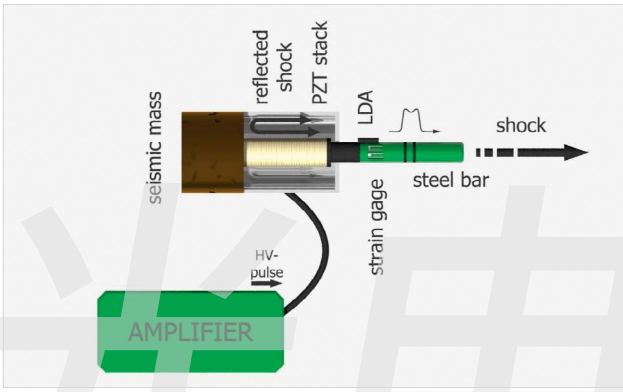


Figure 10: Schematic representation of a single-sided shock generator with a seismic mass. The double pulse is build by the overlay of reflected and forward pulse

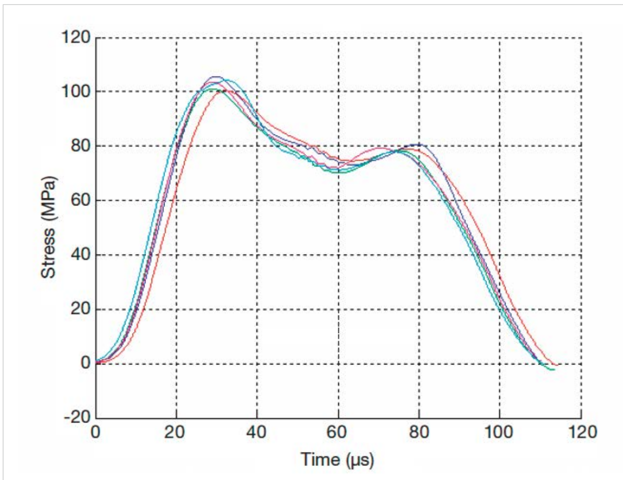


Figure 11: Typical pulse shape of a shock-wave generator with a seismic mass.

Electrical Operation of Piezo Shock Generators

For piezoelectric shock generation the piezo's capacitance has to be charged very fast. Considerations about position accuracy or voltage noise are irrelevant in such applications.

To reach electrical rise times in the microseconds range extremely high currents are necessary. These currents are provided using high power pulse switches as shown in Figure 12.

A capacitor bank (several 100 µF) is charged to the selected voltage (up to 1000 V). The piezo is then rapidly charged to the selected voltage via a small resistor leading to the actual mechanical shock. The piezo is then slowly discharged again. With the sufficient power of the amplifier pulse repetitions up to 100 Hz are possible. Due to the limited cooling of the actuators high repetition rates should be done in burst-mode.

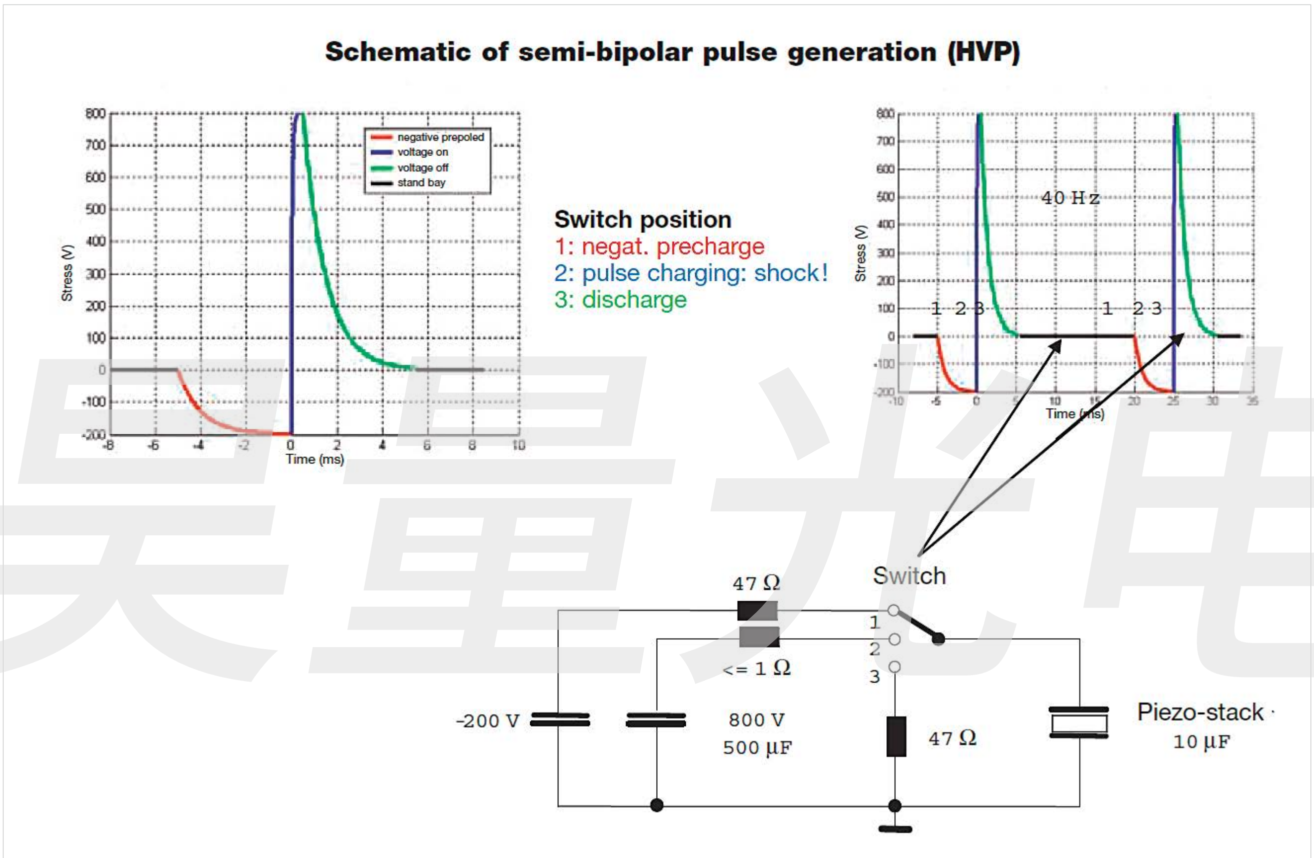


Figure 12: *Semi bipolar control with a high voltage pulser. The switch with three settings represents a combination of high power transistors, which are driven by a logic device.*
1. Negative charging to -200 V, 2. Shock like charging to +800 V, 3. Discharge to 0 V

Piezosystem Jena provides a wide range of Power Supplies for Piezo Shaker as well as for Shock Wave Generators:

amplifier	output voltage	peak output current	bandwith	description
for Piezo Shaker				
RCV 1000/7	1000 V	7 A	2 kHz	high power switching amplifier
LE 150/100 EBW	150 V	1 A	70 kHz	linear amplifier with enhanced bandwidth
for Shock Generator				
HVP 1000	1000 V	200 A	-	high voltage pulse switch amplifier
HVP 300/20	300 V	20 A	-	pulse switch amplifier