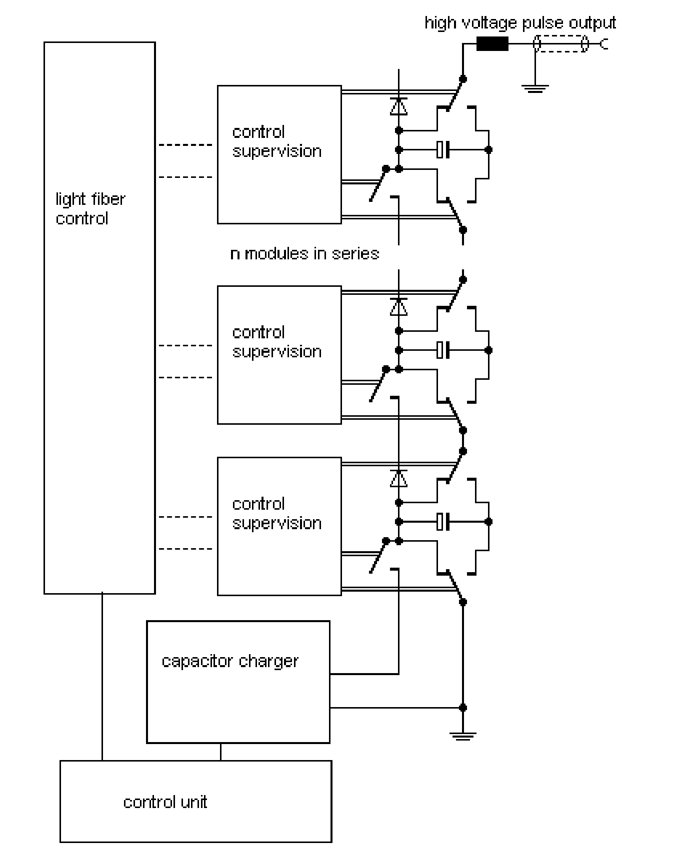
RUP6-18bip v6

Bipolar high voltage pulse generator with variable rise and fall times

- True square wave pulses with active switching off and both polarities
- pulse width and form nearly arbitrarily adjustable
- rise time adjustable in the range 600ns to 60µs
- frequency up to 2.5 kHz
- voltage up to +/-18 kV
- peak pulse current up to 50 A
- short circuit proof

RUP6 is a universal high voltage pulse generator concept, which can be built for voltages from 2kV to 30kV. Prominent features are high pulse current, very high efficiency, scalability of the voltage and ultrafast switch off in case of arcs.
The RUP6 consists of a number of 1kV pulse modules which are charged in parallel and are switched in series during pulse. Power supply and modulator are integrated within this principle.
The pulse modules of the RUP6bip contain full bridges instead of half bridges as the standard RUP6 design.
Absolute synchronous switching is not necessary with the RUP6 principle; furthermore, the bipolar version definitely uses sequential switching to achieve variable rise and fall times and even completely arbitrary pulses.



Principal scheme RUP6 bip

GBS ELEKTRONIK GmbH

Technical Data

Current and voltage

- Maximum output voltage -18 kV to +18 kV.
- Maximum average output power 2 kW, decreasing with increasing duty cycle. Pout=Pmax *(1 - frequency * (pulse width + 150µs)).
- Average output current up to 110 mA max., corresponding to an internal power supply current of 2A.
- Output impedance (DC) about 11 Ohm, corresponding to 0.6 Ohm per module; in series to this is an output inductor of 40µH, which internally can be adjusted to 80µH, 160µH or 320µH by choosing the corresponding tap.
- Internal pulse capacity around 10 µF, corresponding to 180 µF per module.
- peak current up to 50 A.
- Maximum tolerable load capacity depends on voltage and rise time. Capacities up to 200nF can be connected as long as the product of rise rate and capacity dU/dt*C does not exceed 50A.
- Reactive power: The RMS output current must not exceed 5A.

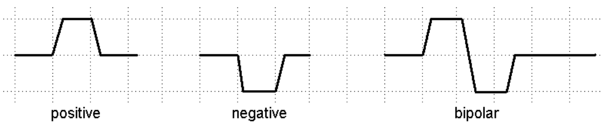
Current surveillance

The pulse generator is proof to short circuit and flashover. Overcurrents will be detected and lead to switch off, and therefore will not damage the device:

- Exceeding a free adjustable level of average current of the internal power supply will switch off high voltage. A LED indicates operation close (90%) to the switch-off level.
- Overcurrent >50A and RMS current >5A will also shut down the pulse generator. Also here, operation at >90% of maximum current will be indicated by a flashing LED.
- Any error on module level (overcurrent, overtemperature,..) will also lead to shutdown.
- Maximum possible peak short circuit currents are limited to around 90A.

Waveform and frequency

- Square wave pulses with variable frequency and pulse width of both polarities.
- Selectable modes of operation are: Unipolar positive, unipolar negative and bipolar.



- Adjustable pulse width 0.5 µs - 100 µs. Basically, the internal pulse capacity should discharge during pulse not more than 10% of the maximum voltage (1.8 kV in this case).
- With an external trinary logic (0V, +5V, -5V) control signal, almost arbitrary pulse waveforms can be generated.
- Ramp times can be adjusted in two ranges of 0.6...7µs and 6µs ... 60µs. Variable rise times are realized by sequentially driving the pulse modules. This results in a staircase-like output signal. The actual waveform depends on the chosen output inductor and may exhibit a certain amount of ringing. However, by fine adjusting the ramp time of the pulse to the ringing frequency, any overshoot can be limited in any case to <8%.
- Duty cycle can be chosen nearly arbitrarily, but average output power will decrease with increasing duty cycle. The reason for this is that during a pulse until 150µs after the pulse the internal power supply is not working.
- Maximum frequency 2.5 kHz.
- Control of voltage, pulse width, frequency an operation mode can by done by switches and potentiometers on the front.

mechanical, included items

- 19" rack, 600 * 6000 * 1800 mm
- supply voltage 230-240 V.
- monitor outputs for voltage and current
- meters for module voltage (0-1000V) and average internal power supply current (0-2A).
- resettable operation time counter for "high voltage on".
- documentation including circuit diagrams.

Additional metering and other modifications on request.

safety

- external Interlock
- A fast short circuit detection protects the generator modules to a far extend from arcs and short circuits in the load.
- Short circuit currents a short transients are limited to 90 A.
- The pulse generator is conformal to laws about electromagnetical compatibility.

16.10.2017 Dr. Jörg Brutscher

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Modifications for version 3:
Higher rated IGBTs, 100A peak short circuit, 50A peak max. in normal operation.
2kW average power
Ramp time adjustable in the range 0.7..7µs and 7µs...70µs
Internal inductor: Default (recommended) is 40µH, can be extended to 80µH, 160µH and 320µH.
Omit internal controller and RS232.

Load fault shutdown:
-As already implemented, exceeding a free adjustable level of current of the internal power supply will switch off high voltage. A LED indicates operation close to the switch-off level.
-Additionally, exceeding 50A peak current will immediately switch off high voltage operation and pulse. A LED will flash if peak currents are >90% of allowable peak current.

Calculation :

For resonant charging with a ramp, peak current is $Ipeak = C \cdot \frac{dU}{dT}_{peak}$. Average peak current during ramp is half the peak current, as well as average dU/dt is half of the peak dU/dt. The ramp time is therefore $t_{ramp} = \frac{2 \cdot Upp}{\frac{dU}{dt}_{peak}}$.

For resonant charging, the ramp time should be a multiple of the period of oscillation of inductor and load capacity. The necessary inductance is then $L = \frac{t_{ramp}^2}{4\pi^2 \cdot C}$, for 2nd resonance it is $L = \frac{t_{ramp}^2}{16\pi^2 \cdot C}$ and for 3rd resonance it is $L = \frac{t_{ramp}^2}{36\pi^2 \cdot C}$. Stored energy with the bipolar is $E = \frac{C}{2} \cdot \left(\frac{U_{pp}}{2}\right)^2$ and charging frequency is 2*f.

Case	Upp (kV)	dU/dt peak (kV/µs)	Freq. (kHz)	load C (nF)	Ipeak (A)	t ramp (µs)	Inductor recommended (2nd, 3rd resonance)	stored energy * charging frequency
1	3.8	1	2	50	50	7.6	29µH	360VA
2	11.4	0.7	0.25	28	20	32.6	960 (240, 107) µH	230V
3	23.4	0.7	0.25	28	20	67	4 (1, 0.45) mH	960A
4	11.4	1	0.25	28	28	23	480 (120, 53) µH	230VA
5	29.4	2	2	28	56	29.4	780(200, 87) µH	12kVA
no load	36	100	2.5	0.4	40	0.72	33	
no load	36	18	2.5	0.4	7.2	4	1000 (250, 110) µH	

Remarks
Case 1 is close to the current limit. Rise rate may have to be adjusted a bit to lower values
Case 5 is already a bit over the current limit and blind power (frequency) seems high. Rise rate and frequency may have to be decreased.

Answers:

Voltage is set by a 10 turn potentiometer, Ramp time is set by a 10 turn potentiometer with a range switch. The set voltage corresponds to the output of the semiconductor, any overshoot is not considered.

In principle, additional measurements as effective rise speed or overshoot can be implemented. But more economical and trustworthy is to use an oscilloscope for that.

If inductance is not well fitting to ramp time you just get excessive overshoot; typically you fine adjust ramp time.

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