FAST HIGH VOLTAGE TRANSISTOR SWITCHES

DESCRIPTION

The high-voltage switches described here have a fixed on-time and are ideal for use in fast pulse and discharge applications. In contrast to switches with variable on-time, switches with fixed on-time are widely immune against any feedback effect from switch output to control input. The pulse width is stable even under worst case conditions (bad circuit layout, long open wiring, magnetic coupling, undefined load etc.). Switches with fixed on-time have a very short rise and propagation delay time, which makes them ideal for pockels cell applications.

BEHLKE HTS switches are actively controlled devices (no avalanche technique) and show highly reliable and reproducible switching behaviour regardless of temperature, voltage or load condition. Compared to conventional high voltage switching elements, such as gas discharge tubes and spark gaps, BEHLKE solid-state switches do not show aging effects and achieve life times by several orders of magnitude higher than any other classical high voltage switch.

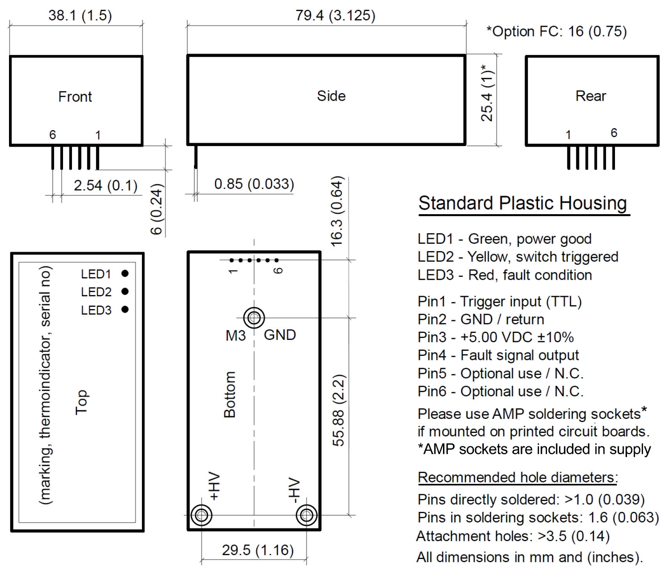
The switches are very easy to handle and only require a simple +5 VDC auxiliary supply (4.5 to 5.5 VDC) and a TTL-compatible trigger signal for the control. The trigger can be any positive going pulse of at least 25 ns duration and 2 to 10 volts amplitude. Due to the Schmitt-Trigger input characteristics and the very high signal amplification neither the switching behavior nor the turn-on rise time will influence by the waveshape of the trigger pulse. After being triggered, the switch turns on for about 100 nanoseconds. Longer lasting on-times are possible by means of the on-time extension options OT-1µs, OT-10µs and OT-100µs. Shorter on-times are realized by the on-time reduction options OT-25ns, OT-50ns and OT-75ns. Any other customized on-time between 25 ns and 100µs can be ordered under the option OT-C. The on-time can also be adjusted within certain limits by means of the option OT-P (programmable on-time). The recovery time after a switching cycle is less than 330 ns making burst frequencies of up to 3 MHz possible. Burst frequencies of up to 10 MHz can be achieved by means of option HFB.

The internal driving circuit provides signal conditioning, auxiliary voltage monitoring, frequency limitation, as well as driver and switch temperature protection. The operating conditions are indicated by three built-in LEDs. In case of a fault (auxiliary voltage < 4.5 VDC, frequency > f(max) and case temperature > 75°C), the red LED will indicate an error and the switch is inhibited for at least 2 seconds respectively for the duration of the fault condition. At the same time a TTL compatible fault signal occurs at pin 4 (Low = Fault). In case of over temperature the switch can be locked for several minutes, depending on the individual cooling conditions. A green LED indicates "Ready for Operation" and a yellow LED flashes if the switch has been triggered succesfully.

The standard plastic housing is the cost efficient solution in any low power / low frequency application with up to 5 watts power dissipation. For a power dissipation above 5 Watts there are various cooling options available. Those options include copper cooling fins for liquid immersion (option CF-LC), ceramic cooling fins for forced air (option CF-C), grounded cooling flange (potential-free) for classical heatsinks (option GCF), indirect liquid cooling for conductive water (option ILC) and direct liquid cooling with non-conductive coolants (e.g. Galden) for best cooling performance and lowest capacitive power losses at very high operating frequencies.

CIRCUIT DESIGN RECOMMENDATIONS

In order to achieve the minimum turn-on rise time and the best HV pulse shape, all leads and circuit paths should be of lowest possible inductance. This can be achieved by means of very wide and short circuit tracks on the printed circuit board, if necessary in several layers (multi layer PCB). Part components such as RS, CBP and CB must be "inductance-free" and should only be connected with shortest possible wires / circuit tracks. Ground conducting tracks including the logic ground must be connected to a common ground point (star-type ground). Induction loop areas of dynamically current-carrying circuit paths should always be as small as possible. HV wiring and control circuitry should always be separated by a proper distance. For further design recommendations please refer to the general instructions.



Standard Plastic Housing

LED1 - Green, power good
LED2 - Yellow, switch triggered
LED3 - Red, fault condition

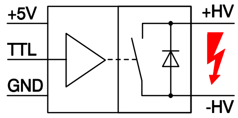
Pin1 - Trigger input (TTL)
Pin2 - GND / return
Pin3 - +5.00 VDC ±10%
Pin4 - Fault signal output
Pin5 - Optional use / N.C.
Pin6 - Optional use / N.C.

Please use AMP soldering sockets*
if mounted on printed circuit boards.
*AMP sockets are included in supply

Recommended hole diameters:
Pins directly soldered: >1.0 (0.039)
Pins in soldering sockets: 1.6 (0.063)
Attachment holes: >3.5 (0.14)
All dimensions in mm and (inches).

HTS 40-06 4 kV / 60 A
HTS 50-05 5 kV / 50 A
HTS 80-03 8 kV / 30 A
HTS 160-01 16 kV / 15 A

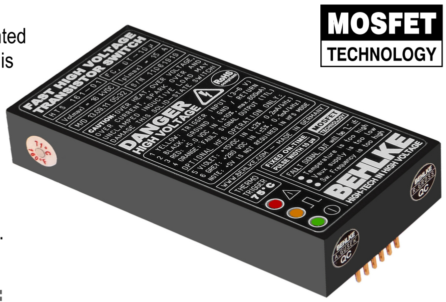
FIXED ON-TIME



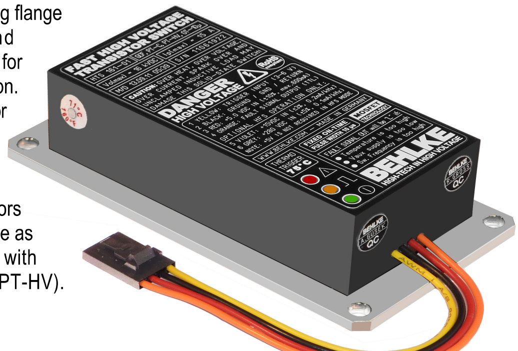
1ns Rise Time • 5MHz Rep Rate
10MHz Burst • tp=25ns...100µs

MOSFET TECHNOLOGY

Option FC:
Flat case specially for printed circuit boards. The height is reduced from 25 to 16 mm. The soldering pins can optionally be replaced by a pig tail with AMP-modu plug (opt. PT-C). The HV connectors are located at the bottom side.



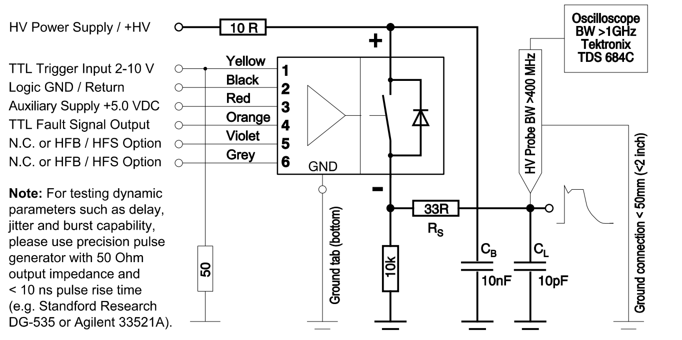
Option GCF / PT-C:
Grounded cooling flange with pig tail and AMP-modu plug for control connection. The HV connector terminals are at the front side of module. The HV connectors can also be made as flexible pig tails with cable lugs (opt.PT-HV).



Option CF-C / PT-C:
Isolated cooling fins made of special ceramics with a thermal conductivity similar to Aluminum. The control connection is made by a pig tail with AMP-modu plug. The HV connector terminals are at the front or bottom side of module. The V connectors can also be made as flexible pig tails with cable lugs (option PT-HV).

For further options please refer to the catalog section B1 under www.behlke.com or consult BEHLKE directly.

Test Circuit (High-Side Switch)



Note: For testing dynamic parameters such as delay, jitter and burst capability, please use precision pulse generator with 50 Ohm output impedance and < 10 ns pulse rise time (e.g. Standford Research DG-535 or Agilent 33521A).

SPECIFICATION	SYMB.	CONDITION / COMMENT	HTS 40-06	HTS 50-05	HTS 80-03	HTS 160-01	UNIT
Maximum Operating Voltage	$V_{O(max)}$	T_{case} = 25 °C, I_{off} < 100 μADC	4000	5000	8000	16000	VDC
Minimum Operating Voltage	$V_{O(min)}$	$t_{r(on)}$ and $t_{r(off)}$ may increase sligthly if operated below 5% of $V_{O(max)}$	0				VDC
Typical Breakdown Voltage	V_{Br}	Typical value (±5%), I_{off} > 1mADC, T_{case} = 70 °C	4400	5500	8800	17600	VDC
Galvanic Isolation Voltage	V_I	HV switch against control. Higher isolation optionally available.	20000				VDC
Maximum Peak Current	$I_{P(max)}$	T_{case} = 25 °C, t_p <100 μs, DC 1%. Further SOA data on request.	60	50	30	15	ADC
Static On-Resistance	R_{stat}	T_{case} = 25 °C — 0.1 x $I_{P(max)}$	3.2	4.8	12.8	56	
		@ $I_{P(max)}$	6.7	10.5	27	140	Ω
Maximum Off-State Current	I_{off}	T_{case}=25°C, 0.8 x V_O, low leakage (<1μA) optionally available	10				μADC
Turn-On Delay Time	$t_{d(on)}$	Typical value (±5%), rising edges 50-50%, 0.8 x V_O, @ $I_{P(max)}$	55				ns
Typical Turn-On Rise Time (Output Pulse Rise Time)	$t_{r(on)}$	R $_L$ = 10kΩ, C_L = 10pF, R_S = 33Ω. The rise time $t_{r(on)}$ may increase by approx. 10-30% with options OT-xn. — 0.2 x $V_{O(max)}$	0.9	1.0	3.0	6	
		0.8 x $V_{O(max)}$	1.4	1.5	3.9	15	ns
Typical Turn-Off Rise Time (Output Pulse Fall Time)	$t_{r(off)}$	Resistive load — Standard devices	20				
		Devices with on-time reduction options (OT-xn)	10				
		Devices with on-time extension options (OT-xμ)	$t_{r(off)} \approx t_{on}$			Note 1)	ns
On-Time	t_{on}	Resistive load, 50-50% — Standard devices	100				ns
		Devices with on-time reduction options (OT-xn)	25 / 50 / 75 or customized				ns
		Devices with on-time extension options (OT-xμ)	1 / 10 / 100 or customized			Note 1)	μs
Switch Recovery Time	t_{rc}	Trigger pulse width <50ns — Standard devices	330				
		Option HFB, I-HFB	100				ns
Typical Turn-On Jitter	$t_{j(on)}$	V_{aux} = 5.0 V, V_{tr} = 5.0 V, t_{rtr} < 10 ns	100				ps
Max. Continuous Switching Frequency	$f_{(max)}$	Please consider frequency dependent power dissipation. Cooling options may be required. — Standard devices	0.12				
		Option HFS + DLC	5				MHz
Maximum Burst Frequency	$f_{b(max)}$	@ $t_{ptr(min)}$. Please select an adequate on-time option when generating high frequency bursts. — Standard devices	3				
		Option HFB, I-HFB	10				MHz
Maximum Number of Pulses / Burst	n	Option I-HFB / HFB is recommended for >100 pulses / burst to ensure a constant $t_{r(on)}$. — Standard devices	300				
		Option HFB, I-HFB	Only limited by buffer capacitance and temperature.				Pulses
Maximum Power Dissipation	$P_{d(max)}$	Standard plastic case, forced air >4m/s, T_{case} = 25 °C	5				
		Devices with opt. CF-C, ceramic fins in forced air, >4m/s, T_{fin}= 25°C	32				
		Devices with opt. GCF (grounded cooling flange), T_{flange} = 25°C	100				
		Devices with opt. ILC (indirect liquid cooling), water 1l/min, T_{inlet}= 25°C	100				
		Devices with opt. CF-LC, Cu fins in Galden®, >0.1m/s, T_{fin} = 25°C	192				
		Devices with opt. DLC, Galden® coolant, flow 3 l/min, T_{inlet} = 25°C	1500				Watts
Linear Derating		Above — Standard plastic case	0.11				
		Option CF-C (ceramic cooling fins in forced air)	0.71				
		T_{case} = 25°C — Option GCF (grounded cooling flange)	2.22				
		T_{fin} = 25°C — Option ILC (indirect liquid cooling with water)	2.22				
		T_{flange} = 25°C — Option CF-LC (Cu cooling fins in forced Galden®)	4.27				
		T_{inlet} = 25°C — Option DLC (direct liquid cooling with Galden®)	42.9			(T_O for option DLC is <60°C)	W/K
Operating Temperature Range	T_O	Extended temperature range on request	-40...70				°C
Storage Temperature Range	T_{ST}		-50...90				°C
Natural Capacitance	C_N	Capacitance of the switching path (MOSFET capacitance) @ $V_{O(max)}$	35	35	35	12	pF
Coupling Capacitance	C_C	Stray capacitance between HV side and grounded control side	<9			(Options ILC / GCF: <30pF)	pF
Diode Reverse Recovery Time	t_{rrc}	Recovery time of intrinsic MOSFET diode @ I_F = 0.2 x $I_{P(max)}$	500				ns
Max. Ambient Magnetic Field	B	Homogeneous steady-field, surrounding the whole switching module	25				mT
Aux. Supply Voltage Range	V_{aux}	V_{aux} has **no** impact on the dynamic switching behavior.	4.5 to 5.5				VDC
Auxiliary Supply Current	I_{aux}	Typical value (±10%), @ V_{aux} = 5.0 V, T_{case} = 25°C. I_{aux} is a linear function of the operating frequency. — @ f < 100 Hz	60				
		@ f = 100 kHz	500				mADC
Trigger Signal Voltage Range	V_{tr}	3 to 5 V recommended for low jitter. V_{tr} >5.5V will be clamped.	2-10				VDC
Trigger Input Impedance	Z_{tr}	Note: TTL trigger input is equipped with protection and filter network.	3.3				kΩ
Minimum Trigger Pulse Width	$t_{ptr(min)}$	The trigger pulse has **no** impact on the dynamic switching behavior.	25				ns
Max. Trigger Pulse Rise Time	$t_{rtr(min)}$	Slew rate is uncritical due to "Schmitt Trigger" input characteristics.	∞				ns
Fault Signal Output Voltage		"L" indicates switch over temperature (>75°C / 167°F), driver overload, over frequency and low aux. supply. — "H" signal	5				
		"L" signal	0.01				VDC
Fault Signal Output Current		Source and sink current, output short circuit proof.	10				mADC
Fault Detector Response Time		Switch cannot be damaged by false control conditions.	<100				ns
LED Indicator Function		Green LED, illuminated continuosly in normal operation	„Ready / auxiliary power good“				
		Yellow LED, illuminated for 20 ms if a valid trigger is applied	„Switch succesfully triggered“				
		Red LED, illuminated for ≥ 2 sec in a case of fault condition	„Fault / switch is locked for ≥ 2 sec“				
Dimensions		Standard case	79.5 x 38 x 25				mm^3
Weight		Standard case	150				g

Note 1) Due to their relatively slow turn-off rise time / pulse fall time ($t_{r(off)} \approx t_{on}$), devices with on-time extension options OT-1μ, OT-10μ and OT-100μ should not be used in hard switching applications!

Ordering Information (for further options please refer to the product survey B1 of the on-line catalog)

HTS 40-06	Transistor switch, 4000 VDC, 60 A, 100 ns on-time	**Option HFS**	High frequency switching (>120kHz). Connectors for external driver supply (+15 VDC, +280 VDC, 0.1 mA/kHz)
HTS 50-05	Transistor switch, 5000 VDC, 50 A, 100 ns on-time	**Option UL**	Flame retardant casting resin, UL94-V0 (option refers to the resin only, the housing is always UL-94-V0 conform)
HTS 80-03	Transistor switch, 8000 VDC, 30 A, 100 ns on-time	**Option FC**	Flat case, housing dimensions 79.5 x 38 x 16 mm^3 instead of 79.5 x 38 x 25 mm^3 (no cooling options available)
HTS 160-01	Transistor switch, 16000 VDC, 15 A,100 ns on-time	**Option CF-C**	Cooling fins made of highly heat conductive ceramics. Designed for forced air convection with air flow > 4m/s.
Option OT-1u	On-time extension to approx. 1 μs (-5%, +30%)	**Option CF-LC**	Cooling fins optimized for liquids. Immersion in non-conductive liquids only (mineral oil, silicone oil or Galden®).
Option OT-10u	On-time extension to approx. 10 μs (-5%, +30%)	**Option GCF**	Grounded cooling flange for classical heatsinks. The stray capacitance (C_C) will be increased to 30 pF.
Option OT-100u	On-time extension to approx. 100 μs (-5%, +30%)	**Option ILC**	Indirect liquid cooling for conductive liquids such as water. The stray capacitance (C_C) will be increased to 30pF.
Option OT-25n	On-time reduction to approx. 25 ns (-5%, +10%)	**Option DLC**	Direct liquid cooling for non-conductive liquids (e.g.Galden HT135). For high frequency operation. $T_{O(max)}$=60°C
Option OT-50n	On-time reduction to approx. 50 ns (-5%, +10%)	**Option PT-C**	Pigtails for control connection instead of pins. Self-latching AMP-modu plug. Recommended if not used on PCB's.
Option OT-75n	On-time reduction to approx. 75 ns (-5%, +10%)	**Option PT-HV**	Pigtails for HV at the front side instead of the screw terminals at the bottom. Good for free wiring (no PCB design).
Option OT-C	Customized on-time, please indicate demanded on-time with order	**Option I-PC**	Integrated part components (R, C, D etc.) according to customers specification. Additional components must fit in empty space.
Option HFB	High frequency burst. Reduced recovery time + buffer connector	**Option PC**	Pulser configuration. The PC configuration includes buffer caps., working and damping resistors, EMC filters and HV sockets.