

FAST HIGH VOLTAGE TRANSISTOR SWITCHES

These MOSFET switches are designed for high voltage DC applications with alternating voltage polarities and for general AC and high frequency applications. The ability to switch alternating voltages and currents arises from a special circuit topology which uses two anti-serially connected transistors in every stage of the MOSFET stack (please refer to Fig. 1). The anti-serial connection of the MOSFET's implicates also the anti-serial connection of their intrinsic diodes. Since one of the two anti-serial diodes is always blocking during the MOSFET's off-state, the switch reliably stays off at any polarity change or even with high frequency alternating current. Of course the maximum rate of polarity changes per second (the maximum AC frequency) is limited by the reverse recovery behavior of the intrinsic MOSFET diodes. Without additional measures, a load current frequency of up to 1 MHz is possible. Higher input frequencies require a fast free-wheeling diode (available as option I-FWDN). In this way it is possible to increase the maximum input frequency up to 10 MHz, at least at moderate load currents.

When the MOSFET's are in the on-state, both diodes are shorted by their related MOSFET. It is important to know, that any load-current related voltage drop over the additional switching path is limited by the forward voltage of the shorted intrinsic (serial) diode. This effect reduces the power loss of the additional MOSFET switching path significantly and must be considered in the total power dissipation calculation. Since the intrinsic (serial) diode is shorted by the static on-state resistance of their related parallel MOSFET, the forward voltage drop of the serial diode can never appear as a residual voltage across the switching path. That makes BEHLKE AC switches ideal for many applications with the highest demands on voltage stability (e.g. accelerators, mass spectrometers and other analytical instruments).

AC switch designs with MOSFET require twice the number of power semiconductors compared to a DC MOSFET switch. On the other hand, AC switches can reduce the overall system costs and high voltage wiring efforts dramatically, if, for example a relay-based polarity change unit becomes unnecessary due to the AC capability of the pulser switch.

The AC switches described here are based on the BEHLKE LC2 technology, which represents the state of the art in high voltage MOSFET stacks. Switches of the LC2 series have an extremely low coupling capacitance to the control respectively ground and are designed to withstand extreme dv/dt transients from the power supply.

Like all other BEHLKE solid-state switches, the Series LC2-AC switches are also triggered by a positive going control signal of 3 to 6 Volts at the control input (pin1). The shielded input is terminated by an internal 100 Ohm resistor. The on-time may simply be controlled by the input control pulse width and can range from 200 ns to infinity. The control electronics of the switching module requires an auxiliary supply of +4.75 to +9.0 VDC (pin 5). To ensure a safe off-state of the switch, the auxiliary supply should be permanently present when high voltage is applied, especially in the case of possible voltage fluctuations or fast transients at the high voltage input.

An interference-resistant driver and control circuit provides signal conditioning, auxiliary voltage monitoring, frequency limitation, and temperature protection. Any false operating condition (under voltage, over frequency or over temperature) will result in immediate switch deactivation and a TTL-compatible fault signal "L" (0V) will be generated at the fault signal output (pin 3), which is logically high "H" (approx. 4.5 VDC) under normal operating conditions. All operating states (pulse, on, off, fault) are indicated by LED's.

The switch control has also an inhibit input (pin 2), which can be used by external circuits such as over current detectors or for any other safety purpose. The inhibit input is activated by a logical "L" (0V). If the BEHLKE PU2 liquid cooling system is used, then the alarm contact of the PU2 unit can be simply connected between inhibit (pin 2) and GND (shield / pin 5).

The high frequency burst operation (>10 pulses/100 μ s) requires the option "HFB" (High Frequency Burst) respectively "I-HFB" (Integrated High Frequency Burst), depending on the number of pulses to be generated. In case of option HFB, external buffer capacitors must be connected to the internal driver circuitry. A continuous high frequency operation above the specified maximum switching frequency requires the option "HFS" (High Frequency Switching). With option HFS, two external supply voltages are connected to increase the power capability of the internal switch driver for higher switching frequencies. Those external voltages are +15 VDC and +380 to 480 VDC, depending on switch model. The +5 VDC auxiliary supply is not required then.

Due to high galvanic isolation, the switches can be operated in floating circuits or in high-side switching applications without any additional isolation transformer or optical coupler. Several housing, cooling and connector options are available to meet individual design requirements. Please refer to product survey "C5 Variable On-Time, AC MOSFET"

HTS 301-10-AC +/- 30 kV, 100 A
HTS 501-10-AC +/- 50 kV, 100 A
HTS 701-10-AC +/- 70 kV, 100 A

MOSFET AC SWITCHES
 polarity change made easy

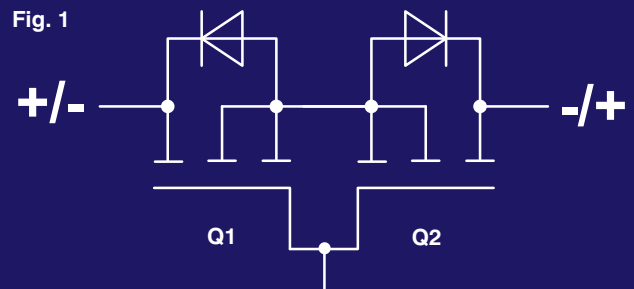


Fig. 2: HTS 701-10-AC (standard flange housing)



Fig. 3: HTS 701-10-AC with tubular housing option TH, liquid cooling option DLC and optional corona rings (opt. COR).

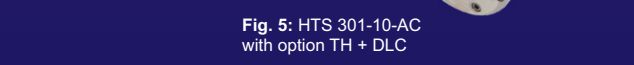
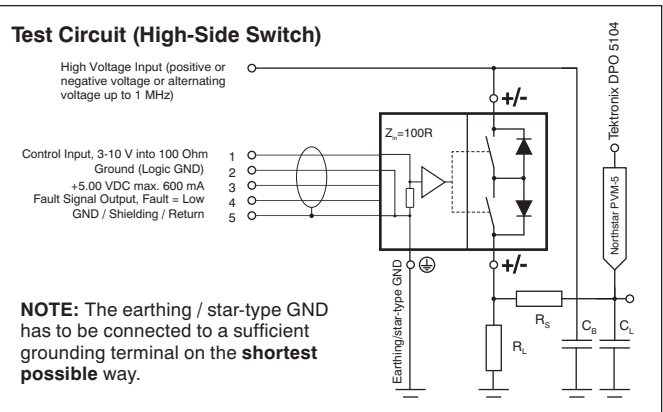


Fig. 4: HTS 501-10-AC with option TH + DLC



Fig. 5: HTS 301-10-AC with option TH + DLC



Technical Data

	Specification	Symbol	Condition / Comment	HTS 301-10-AC	HTS 501-10-AC	HTS 701-10-AC	Unit	
ABSOLUTE MAXIMUM RATINGS	Maximum Operating Voltage	$V_{O(max)}$	$I_{off} < 50 \mu ADC$, $T_{case} = 70^\circ C$	± 30	± 50	± 70	kVDC	
	Maximum Isolation Voltage	V_i	Between HV switch and control input / GND	50	70	100	kVDC	
	Max. Housing Insulation Voltage	V_{INS}	Between switch and housing surface, 3 minutes		150		kVDC	
	Maximum Turn-On Peak Current	$I_{P(max)}$	$T_{case} = 25^\circ C$	$t_p < 200 \mu s$, duty cycle $< 1\%$ $t_p < 1 ms$, duty cycle $< 1\%$ $t_p < 10 ms$, duty cycle $< 1\%$ $t_p < 100 ms$, duty cycle $< 1\%$	100 59 36 27			ADC
	Maximum Continuous Load Current	$I_{L(max)}$	$T_{case} = 25^\circ C$ $T_{fluid} = 25^\circ C$	Flange & tubular housing Option DLC - 0.7 / 1.0 / 1.4 ¹⁾ Option DLC - 2.1 / 3.0 / 4.2 ¹⁾	0.65 3.44 5.96	0.57 3.16 5.48	0.57 3.19 5.54	ADC
	Max. Continuous Power Dissipation	$P_{d(max)}$	$T_{case} = 25^\circ C$ $T_{fluid} = 25^\circ C$	Flange & tubular housing Option DLC - 0.7 / 1.0 / 1.4 ¹⁾ Option DLC - 2.1 / 3.0 / 4.2 ¹⁾	25 700 2100	32 1000 3000	45 1400 4200	Watts
	Linear Derating		Above $25^\circ C$	Flange & tubular housing Option DLC - 0.7 / 1.0 / 1.4 ¹⁾ Option DLC - 2.1 / 3.0 / 4.2 ¹⁾	0.555 15.55 46.66	0.711 22.22 66.66	1 31.11 93.33	W/K
	Operating Temperature Range	T_o				-40...70		$^\circ C$
	Storage Temperature Range	T_s				-40...90		$^\circ C$
	Maximum Auxiliary Supply Voltage	$V_{aux(max)}$	5.00 VDC recommended for best driver efficiency			9		VDC
	Maximum Control Voltage	V_{ctrl}	Control input, inhibit input, fault output			12		VDC
	ELECTRICAL CHARACTERISTICS	Permissible Operating Voltage Range	V_o		0... ± 30	0... ± 50	0... ± 70	kVDC
Typical Breakdown Voltage		V_{br}	CAUTION: V_{br} is a test parameter only for quality control purposes and is not applicable in normal operation! $I_{off} > 500 \mu ADC$	33	55	77	kVDC	
Typical Off-State Current		I_{off}	$0.8 \times V_o$, $T_{case} = 25^\circ C$, lower leakage current on request		20		μADC	
Typical Static On-Resistance		R_{stat}	$t_p < 1 \mu s$, duty cycle $< 1\%$	$0.1 \times I_{P(max)}$, $T_{case} = 25^\circ C$ $1.0 \times I_{P(max)}$, $T_{case} = 25^\circ C$ $1.0 \times I_{P(max)}$, $T_{case} = 70^\circ C$	24 28 59	41 48 100	56 65 137	Ohm
Residual Voltage (Total voltage drop in on-state)		V_{res}	$T_{case} = 25^\circ C$	$I_L = 0.001 A$ $I_L = 0.01 A$ $I_L = 0.1 A$ $I_L = 1.0 A$ $I_L = 10.0 A$	0.024 0.24 2.4 32 144	0.041 0.41 4.1 52 234	0.056 0.56 5.6 72 324	VDC
Typical Turn-On Delay Time		$t_{d(on)}$	Resistive load, $0.1 \times I_{P(max)}$, $0.8 \times V_{O(max)}$, 50-50%		250			ns
Typical Turn-On Rise Time		$t_{r(on)}$	Resistive load, 10-90%	$0.1 \times V_{O(max)}$, $0.1 \times I_{P(max)}$ $0.8 \times V_{O(max)}$, $0.1 \times I_{P(max)}$ $0.8 \times V_{O(max)}$, $1.0 \times I_{P(max)}$	18 45 51	21 63 72	24 78 90	ns
Typical Turn-Off Rise Time		t_{off} , t_q	Resistive load, 10-90%	$0.8 \times V_{O(max)}$, $0.1 \times I_{P(max)}$ $0.8 \times V_{O(max)}$, $1.0 \times I_{P(max)}$	40 90			ns
Maximum On-Time		$t_{on(max)}$			Infinitely			
Minimum On-Time		$t_{on(min)}$	$t_{on(min)}$ can be customized. Please consult factory.		250			ns
Maximum Off-Time		$t_{off(max)}$			Infinitely			
Minimum Off-Time		$t_{off(min)}$	$t_{off(min)}$ can be customized. Please consult factory.		250			ns
Typical Turn-On Jitter		$t_{j(on)}$	$V_{aux} / V_{tr} = 5.00 VDC$		3			ns
Max. Continuous Switching Frequency		$f_{(max)}$	$V_{aux} = 5.00 VDC$, $T_{case} = 25^\circ C$, switch will be turned off, if $f_{(max)}$ is exceeded	Standard Option HFS	1.7 100	1.2 100	1	kHz
Maximum Burst Frequency		$f_b(max)$	CAUTION: Applications with long lasting high frequency bursts may require special cooling measures to prevent MOSFET junction overheating. Please consult factory.		2			MHz
Maximum Number of Pulses / Burst		N	@ $f_b(max)$ NOTE: Option HFB requires external buffer capacitors with a voltage rating of $> 630 VDC$ and a capacitance of $\approx 100nF$ per additional pulse. The buffer capacitors are internally monitored.	Standard Option I-HFB Option HFB	10 >100 >10000			Pulses
Coupling Capacitance		C_C	HV side against control side		25	33	46	pF
Natural Capacitance		C_N	Between switch poles		45	27	20	pF
Auxiliary Supply Voltage Range		V_{aux}	5.00 VDC recommended for best driver efficiency		4.75 – 9.00			VDC
Intrinsic Parallel Diode Fwd Voltage		V_F	$T_{case} = 25^\circ C$, $I_F = 10 A$		24	42	58	VDC
Diode Reverse Recovery Time		t_{rrc}	CAUTION: Intrinsic diodes must not be used in normal operation. Inductive load requires fast free-wheeling diodes (series FDA) in parallel to the switch!	$I_F = 10A$	<250			ns
Auxiliary Supply Current		I_{aux}	$V_{aux} = 5.00 VDC$, $T_{case} = 25^\circ C$	$0.1 \times f_{(max)}$ @ $f_{(max)}$	250 800	350 800	450 800	mADC
Control Input Voltage Range		V_{tr}	$> 5 VDC$ recommended for best EMC, L (0V) = switch off		3 - 10			VDC
Inhibit Input			TTL compatible, L(0V) = Switch inhibited					
Fault Signal Output		TTL compatible, short circuit proof, L (0V) = Fault						
MECHANICAL / OPTIONS	Dimensions	Standard flange housing, without pigtailed (L x W x H) Tubular Housing, option TH (L x D)		192 x 150 x 68 240 x 90	252 x 150 x 68 360 x 90	312 x 150 x 68 480 x 90	mm	
	Weight	Standard flange housing Tubular Housing, option TH		2700 4800	3200 5900	4000 7700	g	
Recommended Options:								
Option LP	Low Pass: Low pass filter at the control input. Propagation delay time will be increased by ~200 ns. Improved noise immunity and less critical wiring in high speed applications.							
Option S-TT	Soft Transition Time: Reduced switching speed (approx. 50% slower) for less noise emission and simplified EMC design.							
Option MIN-ON	Minimum On-Time: Individually increased "Minimum On-Time" to avoid unwanted triggering by input noise during this time. Please indicate the demanded $t_{on(min)}$ with order.							
Option MIN-OFF	Minimum Off-Time: Individually increased "Minimum Off-Time" to avoid unwanted triggering by input noise during this time. Please indicate the demanded $t_{off(min)}$ with order.							
Option HFB	High Frequency Burst: Improved burst capability of driver by means of external buffer capacitors. Recommended for burst operation with > 100 pulses within a burst of $< 100 \mu s$ duration.							
Option HFS	High Frequency Switching: Connector for additional auxiliary voltages (+12 VDC and +350 VDC to +450 VDC, model depending). Necessary for operation above standard $f_{(max)}$.							
Option DLC - X.X	Direct Liquid Cooling: Internal liquid channel in direct contact with the power semiconductors. Excellent cooling method for very high voltages. GALDEN® & non-conductive liquids only.							
Option TH	Tubular Housing: Self-supporting axial housing. Attachment & HV connection by M12 bolts at the tube ends. Housing made of POM. Radiation proof plastic materials on request.							
Option CR	Corona Rings: Removable rings to control the electrical field at the HV connector bolts. Only in connection with Option TH.							

Note 1) Customized switching units with max. power dissipation of up to 15 kW are available on request.

All data and specifications subject to change without notice!

701-10-AC_REV_06.16