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/100µs) 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” **(http://www.behlke.com/separations/separation_c5.htm)** or consult BEHLKE for more details.

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. 1

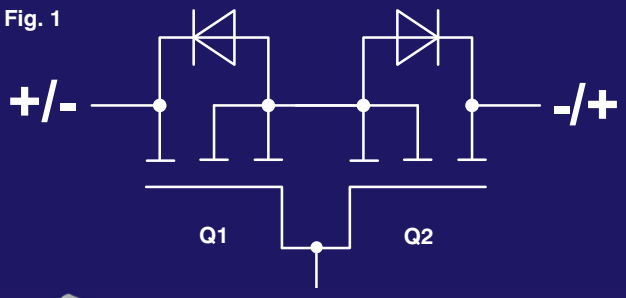


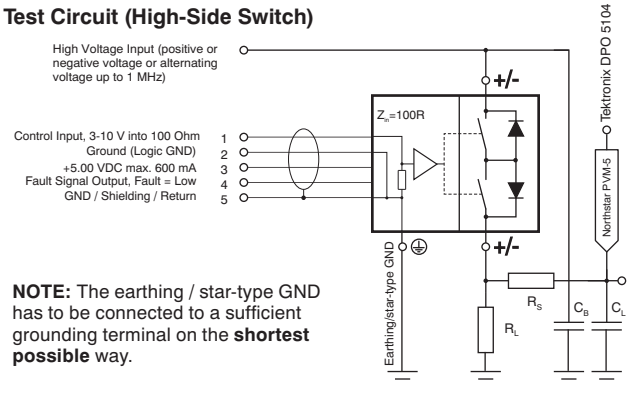
Fig. 2: HTS 701-10-AC (standard flange housing)

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

Test Circuit (High-Side Switch)



NOTE: The earthing / star-type GND has to be connected to a sufficient grounding terminal on the **shortest possible** way.

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 µADC, T_{case} = 70°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°C	t_p< 200 µs, duty cycle <1%		100		
				t_p< 1 ms, duty cycle <1%		59		
				t_p< 10 ms, duty cycle <1%		36		
				t_p<100 ms, duty cycle <1%		27		ADC
	Maximum Continuous Load Current	$I_{L(max)}$	T_{case} = 25°C	Flange & tubular housing	0.65	0.57	0.57	
			T_{fluid} = 25°C	Option DLC - 0.7 / 1.0 / 1.4 [1]	3.44	3.16	3.19	
				Option DLC - 2.1 / 3.0 / 4.2 [1]	5.96	5.48	5.54	ADC
	Max. Continuous Power Dissipation	$P_{d(max)}$	T_{case} = 25°C	Flange & tubular housing	25	32	45	
			T_{fluid} = 25°C	Option DLC - 0.7 / 1.0 / 1.4 [1]	700	1000	1400	
				Option DLC - 2.1 / 3.0 / 4.2 [1]	2100	3000	4200	Watts
	Linear Derating		Above 25°C	Flange & tubular housing	0.555	0.711	1	
				Option DLC - 0.7 / 1.0 / 1.4 [1]	15.55	22.22	31.11	
				Option DLC - 2.1 / 3.0 / 4.2 [1]	46.66	66.66	93.33	W/K
	Operating Temperature Range	T_O				-40…70		°C
	Storage Temperature Range	T_S				-40…90		°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 µADC	33	55	77	kVDC
	Typical Off-State Current	I_{off}	0.8xV_O, T_{case} =25°C, lower leakage current on request			20		µADC
	Typical Static On-Resistance	R_{stat}	t_p< 1 µs, duty cycle <1%	0.1 x $I_{P(max)}$, T_{case} = 25°C	24	41	56	
				1.0 x $I_{P(max)}$, T_{case} = 25°C	28	48	65	
				1.0 x $I_{P(max)}$, T_{case} = 70°C	59	100	137	Ohm
	Residual Voltage (Total voltage drop in on-state)	V_{res}	T_{case} = 25°C	I_L = 0.001 A	0.024	0.041	0.056	
				I_L = 0.01 A	0.24	0.41	0.56	
				I_L = 0.1 A	2.4	4.1	5.6	
				I_L = 1.0 A	32	52	72	
				I_L = 10.0 A	144	234	324	VDC
	Typical Turn-On Delay Time	$t_{d(on)}$	Resistive load, 0.1 x $I_{P(max)}$, 0.8 x $V_{O(max)}$, 50-50%			250		ns
	Typical Turn-On Rise Time	$t_{r(on)}$	Resistive load, 10-90%	0.1 x $V_{O(max)}$, 0.1 x $I_{P(max)}$	18	21	24	
				0.8 x $V_{O(max)}$, 0.1 x $I_{P(max)}$	45	63	78	
				0.8 x $V_{O(max)}$, 1.0 x $I_{P(max)}$	51	72	90	ns
	Typical Turn-Off Rise Time	t_{off}, t_q	Resistive load, 10-90%	0.8 x $V_{O(max)}$, 0.1 x $I_{P(max)}$		40		
				0.8 x $V_{O(max)}$, 1.0 x $I_{P(max)}$		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°C, switch will be turned off, if $f_{(max)}$ is exceeded	Standard	1.7	1.2	1	
				Option HFS		100		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 ≈ 100nF per additional pulse. The buffer capacitors are internally monitored.	Standard		10		
				Option I-HFB		>100		
				Option HFB		>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°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°C	0.1 x $f_{(max)}$	250	350	450	
				@ $f_{(max)}$	800	800	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 pigtails (L x W x H)		192 x 150 x 68	252 x 150 x 68	312 x 150 x 68	
			Tubular Housing , option TH (L x D)		240 x 90	360 x 90	480 x 90	mm
	Weight		Standard flange housing		2700	3200	4000	
			Tubular Housing, option TH		4800	5900	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 µs 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.