FAST HIGH VOLTAGE TRANSISTOR SWITCHES

DESCRIPTION
The high-voltage switches described here have a variable on-time and are comparable to classical solid-state relays; they are turned on as long as a control signal is applied to the control input. BEHLKE HTS switches are actively controlled devices (no available 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 HTS solid-state switches do not only switch with high interruption capacity but also 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 control signal. The control signal can be any positive going pulse of at least 25 ns duration and 2 to 10 volts amplitude. Duty cycle of the Schmitt trigger input characteristics and the very high signal amplification neither the switching behavior nor the turn-on rise time will be influenced by the waveshape of the control pulse. The recovery time after a switching cycle is less than 150 ns, making burst frequencies of up to 6 MHz possible, but frequencies of even up to 10 MHz can be achieved by means of the option HFB. The maximum continuous switching frequency is primarily limited by the power capability of the internal driver and by the power dissipation of the high-voltage switch. Switching with the optional cooling and without optional HFB supply can reach several 10 kHz, depending on operating voltage and load capacitance. Higher frequencies require an additional auxiliary supply for the internal driver, which is provided by means of the option HFS. The switch must also be sufficiently cooled if the frequency depending power dissipation exceeds the specified $P_{\text{max}}$ value. For the individual cooling requirements are various cooling features available, such as option CCS (ceramic cooling surface), CF ( Grill cooling fins), GCF-CER (ceramic cooled fins), GCF-GRA (graphite cooling fins), GCF (grounded cooling fins) ILC (indirect liquid cooling) or DLC (direct liquid cooling). In connection with option DLC the continuous switching frequency can be increased up to 3 MHz.

The switches are equipped with the new "Intelligent" driving and control circuit VC4, which provides active input filtering, signal conditioning, auxiliary voltage monitoring, frequency compensation and temperature protection. The input filter allows an unshielded input wiring of at least 25 cm (10") length. Undefined control signals, noise and transients are uncritical to the switch. The high-voltage MOSFET stack is always safely controlled regardless to the pulse width or waveshape of the control signal. The control circuit has 3 integrated temperature triggers. One thermotriever with a response time of <60 seconds protects the high-voltage switch, two further sensors with <10 seconds response time are placed in the critical areas of the driver components (pin 5, L=Inductor) allows the connection of external thermostriever, over current detectors and / or coolant flow detectors from liquid cooling systems. The operating conditions are indicated by three built-in LEDs. In case of a fault (auxiliary voltage < 4.5 VDC, frequency $f_{\text{max}}$), case temperature $T_{\text{case}}$ > 70°C and Inductor = Low), the red LED can 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 occurrence of 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 indicates the on-state of the switch as well as short control pulses with a pulse duration down to 30 ns. The design concept of these switching modules offers a large selection of cooling and housing options as well as a very high flexibility regarding the adaption to individual OEM requirements. Please refer to the separate options page for some examples of individual switch configurations. In case the built-in cooling is the main design concern, then the HTS compact series (HTS xx-xx-C) is recommended, which has widely the same electrical data except for Max. Power Dissipation and Max. Continuous Frequency.

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 $R_S$, $C_P$ and $C_2$ must be "inductance-free" and should only be connected with shortest possible 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.

**Test Circuit (High-Side Switch)**

<table>
<thead>
<tr>
<th>Test Circuit (High-Side Switch)</th>
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<tbody>
<tr>
<td>High Voltage Power Supply, +HV</td>
</tr>
<tr>
<td>TTL Control Input 3 - 10 V</td>
</tr>
<tr>
<td>Logic GND / Return</td>
</tr>
<tr>
<td>Active Display 10-50 VDC</td>
</tr>
<tr>
<td>50 MHz Output &amp; Fault</td>
</tr>
<tr>
<td>TTL Input, L=Induit</td>
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<tr>
<td>N1.C. or optional HFS Input V1</td>
</tr>
<tr>
<td>N2.C. or optional HFS Input V2</td>
</tr>
<tr>
<td>N3.C. or optional HFS Return</td>
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</table>
| **Note:** Switching dynamic parameters such as delay, filter and burst capability, please also precision pulse generator with 50 Ohm output impedance and 10 ns pulse rise time (e.g. Stanford Research DS-535 or Agilent 33251A).
| **RS** R500 kΩ for $V_{\text{DS}}=0.5 \text{V} |
| **C1** 0.05 μF |
| **C2** 0.001 μF |
| Grounded common - Common Ground |
| **GND** |
| **Vin** |
| **Vout** |
| **Vcc** |

All dimensions in mm and (inches).
OPTIONS LIST for Behlke HTS switches with variable on-time

MBC  Mechanical Backward Compatibility to the previous switch models. All connectors, dimensions and attachment identical with the "historical" switch models such as HTS 81, 51, 31 ft.

HFS  High Frequency Burst: Improved burst capability of driver. Improved recovery time for shorter pulse spacing and connectors for external driver buffer capacitors, so far required.

HFS  High Frequency Switching: External supply of auxiliary driver voltage (50-350 VDC according to type). Necessary if the specified Max. Operating Frequency shall be exceeded. (2)

LPA  Low Pass: Low pass filter at the control input. Propagation delay time will be increased by “50 ns. (Jitter + 500 ps) Improved EMC, better noise immunity and less critical wiring. (3)

UFTR  Ultra Fast Thermotriger: Advanced temperature protection for the high-voltage switch. Switch shut down within 5 seconds if Pd(max) is exceeded by 300% @ ΔT=25K (50 to 75°C)

UFTS  Ultra Fast Thermosensing: Temperature measurement directly of the power semiconductors by means of a special sensor with high electrical isolation and low thermal impedance.

TT-C  Customized Transition Time: Customized rise & fall times to meet individual design requirements. (2)

MIN-ON  Minimum On-Time: Individually increased Minimum On-Time to ensure a minimum off duration independently of control signal. For safety relevant circuits.

MIN-OFF  Minimum Off-Time: Individually increased Minimum Off-Time to ensure a minimum off duration independently of control signal. For safety relevant circuits.

ST  Stage Tapping: Connectors at the individual stages of stack in order to utilize single power semiconductors. To achieve fast rise times also at very low operating voltages (<0.01V).

LL  Low Leakage Current: Off state current reduced to less than 10% of the specified value. Not available in connection with cooling fin options.

LN  Low Noise: Internal power driver modified for zero noise emission for a specific period at time. Relevant in conjunction with sensitive detector amplifiers (e.g. SEV/MCP) only. (2)

ISO-25  25 kV Isolation: Isolation Voltage increased to 25 kVDC. Housing dimensions may change for some models.

ISO-40  40 kV Isolation: Isolation Voltage increased to 40 kVDC. Housing dimensions may change for some models. Only in connection with option PT-HV.

ISO-80  80 kV Isolation: Isolation Voltage increased to 80 kVDC. Housing dimensions may change for some models. Only in connection with option PT-HV.

ISO-120  120 kV Isolation: Isolation Voltage increased to 120 kVDC. Housing dimensions may change for some models. Only in connection with option PT-HV.

I-PAC  Integrated Part Components: Integration of small part components according to customers specifications (e.g. capacitors, snubbers, damping resistors, diodes, opto couplers). (2)


FSS  Shunt Filter: Shunt filter for failure protection. In connection with inductive load only. (2)

LS-C  Shielded Socket for Control Connection: Shielding for all inputs. Input Impedance 100 Ohm. With 1m (3ft) linkage cable and 2nd socket. Improved noise immunity. (3)(4)

PT-C  Pigtails for Control Connection: Flexible leads (l=75 mm) with PCB connector (AMP-modul) instead of pins. Recommended for modules with options CF & GCP.

PT-HV  Pigtails for HV Connection: Flexible leads with cable lugs. For increased creepage. PT-HV is standard for all types with >25 kV switching voltage. Not for extremely fast circuits.

SEP-C  Separated Control Unit: Control unit with LED indicators in a separate housing (dimension 79 x 38 x 17 mm). Linkage cable (<1m) with plug. Control unit with soldering pins or pigtails.

PC  Pulse Configuration: Switch combined with custom specific part components. Integrated in a plastic flange housing with HV connectors according to the customers specifications. (2)

UL94  Flame Retardant Casting Resin: Casting resin according to UL-94 V0. Minimum order quantity required. (2)

TC  Tubular Housing: Tubular instead of rectangular housing. Adaptation to specific ambient conditions or in case of difficult assembly situations. (2)

ITC  Increased Thermal Conductivity: Special moulding process to increase the thermal conductivity of the module. Pd(max) will be increased by approx. 20-30% (2)

CF  Non-Isolated Cooling Fins: Standard sizes in categories A to F according to model. Nickel plated copper 0.5 mm, fin height 35 mm. For air and oil cooling.

CF-I  Non-Isolated Cooling Fins d=1mm: Nickel plated copper 1.0 mm instead of 0.5 mm. The max. Power Dissipation will be increased by ~80 %. For air and oil cooling.


CF-CS  Non-Isolated Cooling Fins with customized shape: Individual shape to meet specific OEM requirements. (2)

CF-LC  Non-Isolated Cooling Fins optimized for liquid cooling: Double fins, nickel plated copper, 0.5 mm thickness, height 20 mm.

CF-GRA  Non-Isolated Cooling Fins made of graphite. Very light weight compared to copper at similar heat transfer, but reduced heat capacity. 0.5 or 1 mm thickness, height 35 mm.

CF-CER  Isolated Cooling Fins made of ceramics. Heat transfer properties similar to alumina. Forced convection recommended. Height 35 mm.

CCS  Ceramic Cooling Surface: Top side of switching module made of special ceramics. Heat transfer properties similar to alumina. 10 kVDC isolation. Forced convection recommended.

C-DR  Cooling for Driver: Extra cooling for the driver and control electronics. Recommended in combination with option HFS at higher switching frequencies. (2)

GCF  Grounded Cooling Flange: Nickel plated copper flange for High Power applications. Max. isolation voltage 40 kV. Increased coupling capacitance CC.

Indirect Liquid Cooling: Liquid cooling for all kind of conductive coolants incl. mains water. Internal heat exchanger made of ceramics. For medium power and medium frequencies.

DLC  Direct Liquid Cooling: Internal cooling channels around the power semiconductors. The most efficient cooling for high frequency applications. For non-conductive coolants only.

HI-REL  High Reliability / MIL Versions: Available on request. (2)

Examples of standard options and modifications for switches with variable on-time:

1) HTS 101-03 with shielded control input (LS-C)
2) HTS 101-03 in flat case (FC) with pins (PIN-C)
3) HTS 101-03 with ceramic cooling surface (CCS)
4) HTS 101-03 with nickel plated copper fins (CF)
5) HTS 101-03 with graphite cooling fins (CF-GRA)
6) HTS 101-03 with ceramic cooling fins (CF-CER)
7) HTS 101-03 with potential-free Cu cooling flange (GCF)
8) HTS 101-03 for indirect liquid cooling with water (ILC)
9) HTS 101-03 for direct liquid cooling with Galadon (DLC)
10) HTS 101-03 in pulser configuration (PC)
11) HTS 101-03 with separated control unit (SEP-C)
12) The HTS compact series for lower power dissipation

(1) New option code: Data sheets may differ from this coding system (especially older ones) and do not indicate all possible options as per above table. (2) Please consult factory for detailed information. (3) These options are recommended for industrial applications, difficult noise environments, protoboard experiments with thyristors and for users who do not have special EMC design experience. (4) This option is not available in connection with SYNC, 10 for parallel connection.

Note: Mechanical drawings for the options below are available on request.

1. Reduced height of standard plastic housings reduced to 19 mm or less. Not in combination with cooling options CF, GCF and DLC.
2. Low pass filter at the control input. Propagation delay time will be increased by ~50 µs. Jitter + 500 ps. Improved EMC, better noise immunity and less critical wiring. (3)
3. Isolation Voltage increased to 40 kVDC. Housing dimensions may change for some models. Only in combination with option PT-HV.
4. Isolation Voltage increased to 80 kVDC. Housing dimensions may change for some models. Only in combination with option PT-HV.
5. Isolation Voltage increased to 120 kVDC. Housing dimensions may change for some models. Only in combination with option PT-HV.
6. Separated Control Unit: Control unit with LED indicators in a separate housing (dimension 79 x 38 x 17 mm). Linkage cable (<1m) with plug. Control unit with soldering pins or pigtails.
7. Non-Isolated Cooling Fins with customized shape. Individual shape to meet specific OEM requirements. (2)
8. Double fins, nickel plated copper, 0.5 mm thickness, height 20 mm.
11. Cooling for Driver: Extra cooling for the driver and control electronics. Recommended in combination with option HFS at higher switching frequencies. (2)
12. Grounded Cooling Flange: Nickel plated copper flange for High Power applications. Max. isolation voltage 40 kV. Increased coupling capacitance CC.
13. Direct Liquid Cooling: Internal cooling channels around the power semiconductors. The most efficient cooling for high frequency applications. For non-conductive coolants only.