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AVNET SILICA

SELECTING GAN OR SIC DEVICES IN HIGH-VOLTAGE SWITCHING TECHNOLOGIES

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THE PERFECT SWITCH

Every engineer dreams of a perfect switch; one that has zero loss characteristics during off- and on-states, and an instantaneous switch between the states. Achieving the lowest possible switching losses during transition between the two states relies on a number of key features:

- Infinite breakdown voltage
- Zero current through the switch, when the switch is off
- Zero voltage across the switch, when the switch is on
- Zero turn-on and turn-off transition times between the states

In an ideal switch, since either the voltage or the current is always zero, the instantaneous dissipation produced by an instantaneous voltage and instantaneous current is always zero.

In real life, however, this doesn't exist. A practical switch can only approximate as an ideal switch on a first order basis. The non-ideal properties of practical switches cannot be ignored and must be evaluated for every design, as they will have parasitic elements that result in:

- Finite breakdown voltage
- Leakage current in the off-state
- Non-zero voltage across the switch in the on-state
- Non-zero turn-on and turn-off transition times

This shows that, since there will be some voltage present across the switch during the on-state, and the transition times will be non-zero, a dissipation occurs that must be managed.

THE APPLICATION OF IGBT, SUPERJUNCTION, SIC AND GAN TECHNOLOGIES

Let's take a look at the various factors we need to consider for selecting devices.

In this example, we are designing an H-bridge to build an AC-DC converter. The DC-bus voltage is 370V, the current of the transformer is about 3A, and the switch run with a frequency of 15 to 25kHz. For safety reasons, we have selected a component in the 650V class and a continuous drain current of at least 30A. We have no glue logic, and plan to select either an IGBT, SJ, SiC or GaN device.

A step-by-step approach to selection is recommended.

1 Check the Conditions

The first step in identifying the best device for your application is to check the conditions in which it will be operating.

1 a)

- Is the switching frequency below ~20kHz?
- Is the power level above 3kW?
- If a low-cost solution is important, does it provide this?
- Is it supplied by a three-phase grid?

If the answer is 'yes' to any or all of the above, a silicon (Si) insulated-gate bipolar transistor (IGBT) is the preferred device. Example devices include:
https://www.onsemi.com/products/discretes-drivers/igbts
https://www.st.com/en/power-transistors/igbts.html
https://www.rohm.com/products/igbt
https://www.avnet.com/shop/emea/c/discretes/igbt/

1 b)

- Is the switching frequency the range of 20 kHz to 100kHz?
- Are there wide line and load conditions?
- Is high efficiency needed with moderate cost?
- Is it supplied by a single-phase grid?

In this case, a Si Superjunction (SJ) MOSFET is the best option. Example devices include:
https://www.onsemi.com/products/discretes-drivers/mosfets
https://www.st.com/content/st_com/en/products/power-transistors/power-mosfets.html
https://www.rohm.com/products/mosfets/high-voltage
https://www.avnet.com/shop/emea/c/discretes/transistors/mosfets/

1 c)

- Is the switching frequency above 100kHz?
- Are there wide line and load conditions?
- Are the conditions high-power (up to several kWs), requiring high efficiency?
- Is reverse power (bi-directional) flow required?
- Is it supplied by a three- phase grid?

If these conditions apply, then a silicon carbide (SiC) MOSFET is the device of choice. Examples include:
https://www.onsemi.com/products/wide-bandgap/silicon-carbide-sic-mosfets
https://www.st.com/en/power-transistors/stpower-sic-mosfets.html
https://www.rohm.com/products/sic-power-devices/sic-mosfet
https://www.avnet.com/shop/emea/search/SiC

1 d)

- Is the switching frequency above 100kHz in the MHz range?
- Are there wide line and load conditions?
- Are the load conditions medium power (up to several hundred Ws), and requiring the highest power density and efficiency?
- Is it supplied by a single-phase grid?

These conditions mean that a gallium nitride (GaN) MOSFET is the preferred device. Example devices include:
https://www.st.com/content/st_com/en/products/power-management/gate-drivers/high-voltage-half-bridge-gate-drivers/mastergan1.html
https://www.onsemi.com/products/discretes-drivers/gate-drivers/ncp51820

2) Consider the Application

Next, it's time to figure out what the application needs. How and where will the device be used? Consider these factors before making your selection:

2 a)

- Motor drives (>250W)?
- UPS and welding H-bridge inverters?
- High power PFCs (>3kW)?
- High power solar/wind inverters (>5kW)?

If these are your criteria, a Si IGBT is the optimum device. Examples include:
https://www.onsemi.com/products/discretes-drivers/igbts
https://www.st.com/en/power-transistors/igbts.html
https://www.rohm.com/products/igbt
https://www.avnet.com/shop/emea/c/discretes/igbt/

2 b)

- Motor drives (<250W)?
- Universal input AC-DC flyback?
- Forward converter power supplies?
- Low- to mid-power power factor correction (PFC) and LLC?
- DC-DC (75W to 3 kW)?
- Solar micro-inverter?

If these are important in your application, a Si SJ MOSFET is your preferred device. Examples include:
https://www.onsemi.com/products/discretes-drivers/mosfets
https://www.st.com/content/st_com/en/products/power-transistors/power-mosfets.html
https://www.rohm.com/products/mosfets/high-voltage
https://www.avnet.com/shop/emea/c/discretes/transistors/mosfets

2c)

- High power PFCs (>3 kW)?
- EV charger / OBC (AECQ needed)?
- High power solar (>5kW)?
- UPS?
- Embedded PFC and DC-DC?

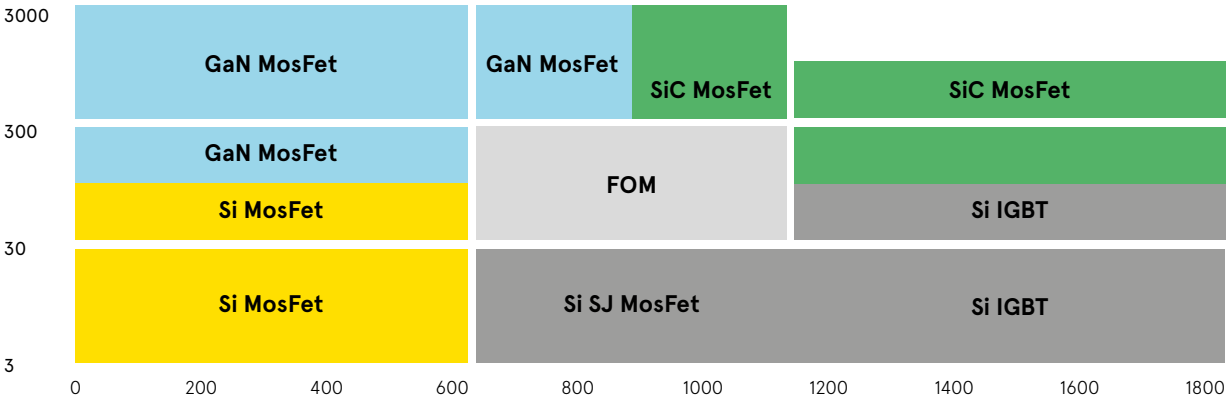
For applications with these requirements, a SiC MOSFET is your preferred device. Examples include:
https://www.onsemi.com/products/wide-bandgap/silicon-carbide-sic-mosfets
https://www.st.com/en/power-transistors/stpower-sic-mosfets.html
https://www.rohm.com/products/sic-power-devices/sic-mosfet
https://www.avnet.com/shop/emea/search/SiC

2 d)

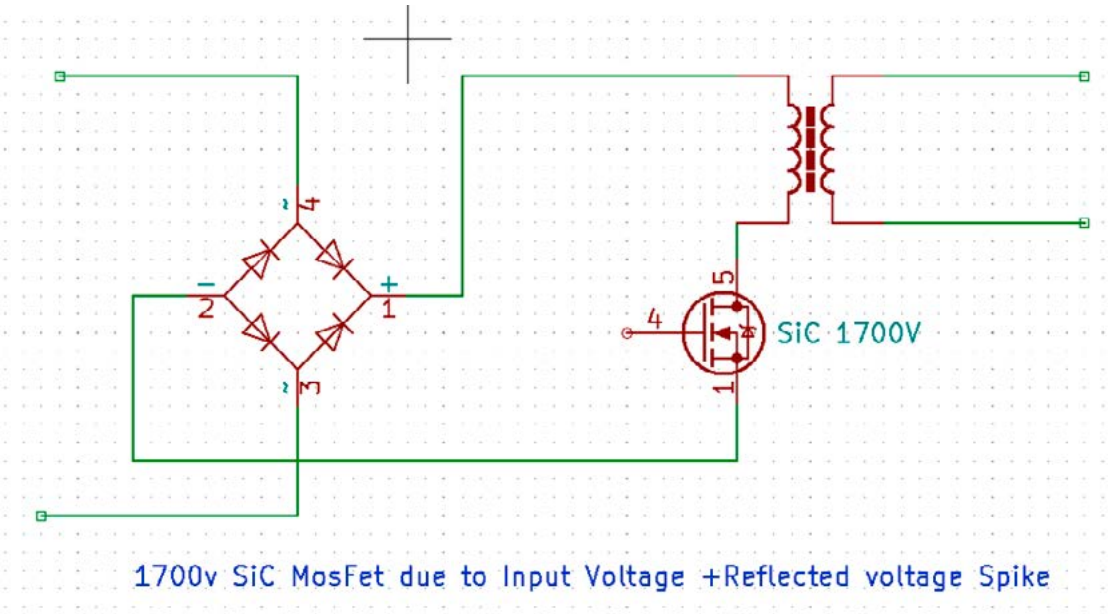
- Single line grid powered (<=650VClass)?
- Medium power range 75W to 750W?
- Need for highest mobility?
- Need to have the smallest dimensions?
- Need to keep cool?

With these requirements, a GaN MOSFET will most suit your application. Examples include:
https://www.st.com/content/st_com/en/products/power-management/gate-drivers/high-voltage-half-bridge-gate-drivers/mastergan1.html
https://www.onsemi.com/products/discretes-drivers/gate-drivers/ncp51820

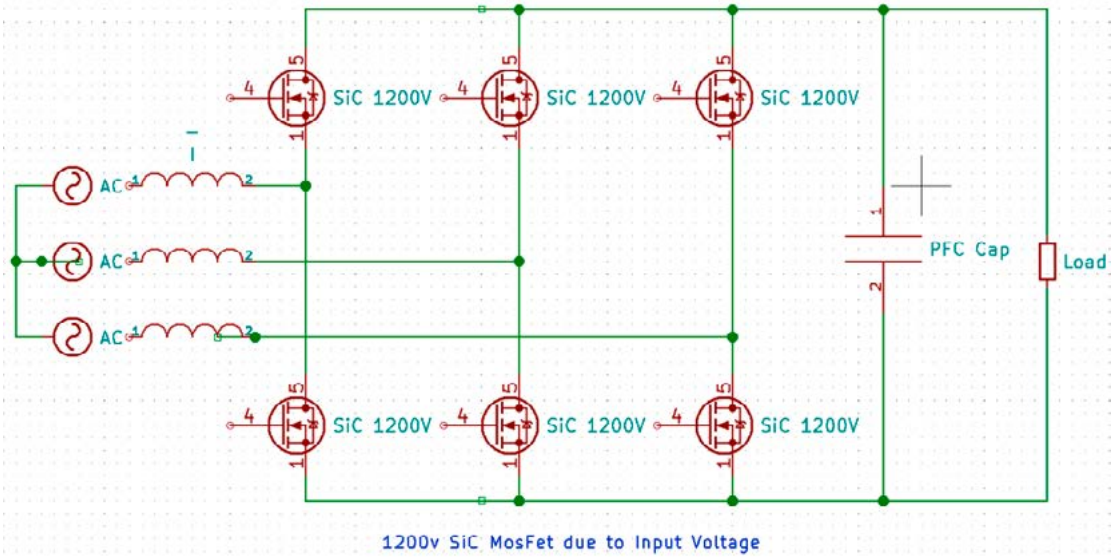
Switching Frequency kHz– Voltage Range



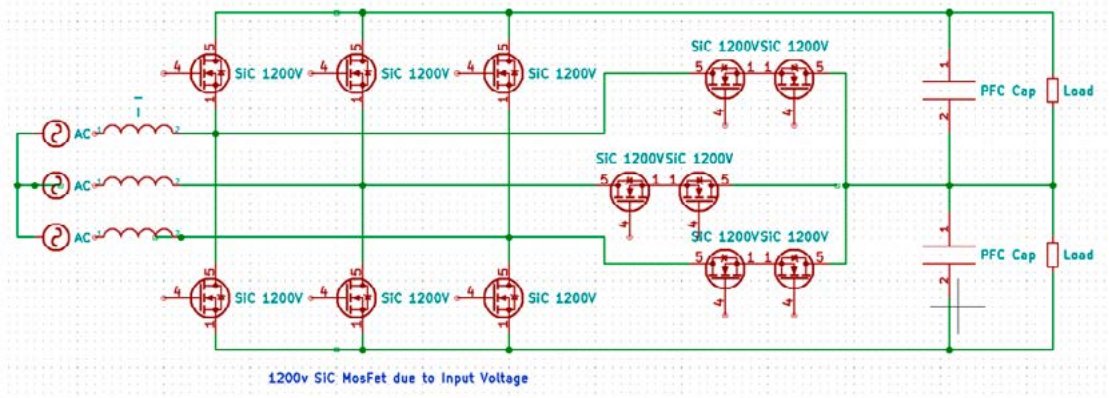
Simple Example of SiC in a 100W Auxiliary Power Supply



Mid Complex 10kW Sixpack PFC Converter for AC-DC application



Complex Bidirectional Active PFC Converter for AC/DC Application, Inverter or On-board Charger (OBC) with Power Back Function



OFFICES

AUSTRIA
Vienna
Phone: +43 186 642 300
Fax: +43 186 642 350
wien@avnet.eu

BELGIUM
Merelbeke
Phone: +32 9 210 24 70
Fax: +32 9 210 24 87
gent@avnet.eu

BULGARIA
Sofia
sofia@avnet.eu

CZECH REPUBLIC (SLOVAKIA)
Prague
Phone: +420 234 091 031
Fax: +420 234 091 030
praha@avnet.eu

DENMARK
Herlev
Phone: +45 432 280 10
Fax: +45 432 280 11
herlev@avnet.eu

ESTONIA
(LATVIA, LITHUANIA)
Pärnu
Phone : +372 56 637737
paernu@avnet.eu

FINLAND
Espoo
Phone: +358 207 499 200
Fax: +358 207 499 280
helsinki@avnet.eu

FRANCE (TUNISIA)
Rennes
Phone: +33 299 838 485
Fax: +33 299 838 083
rennes@avnet.eu

Illkirch
Phone: +33 390 402 020
Fax: +33 164 479 099
strasbourg@avnet.eu

Massy Cedex
Phone: +33 164 472 929
Fax: +33 164 470 084
paris@avnet.eu

Toulouse
Phone: +33 05 62 47 47
toulouse@avnet.eu

Vénissieux Cedex
Phone: +33 478 771 360
Fax: +33 478 771 399
lyon@avnet.eu

GERMANY
Berlin
Phone: +49 30 214 882 0
Fax: +49 30 214 882 33
berlin@avnet.eu

Freiburg
Phone: +49 761 881 941 0
Fax: +49 761 881 944 0
freiburg@avnet.eu

Hamburg
Phone: +49 40 608 235 922
Fax: +49 40 608 235 920
hamburg@avnet.eu

Holzwickede
Phone: +49 2301 919 0
Fax: +49 2301 919 222
holzwickede@avnet.eu

Kaarst
Phone: +49 2301 919 0
Fax: +49 2301 919 222
kaarst@avnet.eu

Lehrte
Phone: +49 5132 5099 0
hannover@avnet.eu

Leinfelden-Echterdingen
Phone: +49 711 782 600 1
Fax: +49 711 782 602 00
stuttgart@avnet.eu

Leipzig
Phone: +49 34204 7056 00
Fax: +49 34204 7056 11
leipzig@avnet.eu

Nürnberg
Phone: +49 911 24425 80
Fax: +49 911 24425 85
nuernberg@avnet.eu

Poing
Phone: +49 8121 777 02
Fax: +49 8121 777 531
muenchen@avnet.eu

Wiesbaden
Phone: +49 612 258 710
Fax: +49 612 258 713 33
wiesbaden@avnet.eu

HUNGARY
Budapest
Phone: +36 1 43 67215
Fax: +36 1 43 67213
budapest@avnet.eu

ITALY
Cusano Milanino
Phone: +39 02 660 921
Fax: +39 02 660 923 33
milano@avnet.eu

Firenze
Phone: +39 055 428 2301
Fax: +39 055 431 035
firenze@avnet.eu

Modena
Phone: +39 059 348 933
Fax: +39 059 344 993
modena@avnet.eu

Padova
Phone: +39 049 807 368 9
Fax: +39 049 773 464
padova@avnet.eu

Turin
Phone: +39 011 204 437
Fax: +39 011 242 869 9
torino@avnet.eu

Roma Tecnocittà
Phone: +39 06 412 319 10
Fax: +39 06 413 116 1
roma@avnet.eu

NETHERLANDS
Breda
Phone: +31 765 722 700
Fax: +31 765 722 707
breda@avnet.eu

NORWAY
Asker
Phone: +47 667 736 00
Fax: +47 667 736 77
asker@avnet.eu

POLAND
Gdansk
Phone: +48 58 307 81 51
Fax: +48 58 307 81 50
gdansk@avnet.eu

Katowice
Phone: +48 32 259 50 10
Fax: +48 32 259 50 11
katowice@avnet.eu

Warszawa
Phone: +48 222 565 760
Fax: +48 222 565 766
warszawa@avnet.eu

PORTUGAL
Vila Nova de Gaia
Phone: +35 1 223 779 502
Fax: +35 1 223 779 503
porto@avnet.eu

ROMANIA (BULGARIA)
Bucharest
Phone: +40 21 528 16 32
Fax: +40 21 529 68 30
bucuresti@avnet.eu

RUSSIA (BELARUS, UKRAINE)
Moscow
Phone: +7 495 737 36 70
Fax: +7 495 737 36 71
moscow@avnet.eu

Saint Petersburg
Phone: +7 812 245 1571
stpetersburg@avnet.eu

SLOVAKIA
Bratislava
Phone: +421 232 242 211
Fax: +421 232 242 210
bratislava@avnet.eu

SLOVENIA
(BOSNIA AND HERZEGOVINA, CROATIA, MACEDONIA, MONTENEGRO, SERBIA)
Ljubljana
Phone: +386 156 097 50
Fax: +386 156 098 78
ljubljana@avnet.eu

SPAIN
Barcelona
Phone: +34 933 278 530
Fax: +34 934 250 544
barcelona@avnet.eu

Galdàcano. Vizcaya
Phone: +34 944 572 777
Fax: +34 944 568 855
bilbao@avnet.eu

Tres Cantos
Phone: +34 913 727 100
Fax: +34 916 369 788
madrid@avnet.eu

SWEDEN
Sundbyberg
Phone: +46 8 587 461 00
Fax: +46 8 587 461 01
stockholm@avnet.eu

SWITZERLAND
Rothrist
Phone: +41 62 919 555 5
Fax: +41 62 919 550 0
rothrist@avnet.eu

TURKEY (GREECE, EGYPT)
Kadikoy Istanbul
Phone: +90 216 528 834 0
Fax: +90 216 528 834 4
istanbul@avnet.eu

UNITED KINGDOM (IRELAND)
Maidenhead
Phone: +44 1628 512 900
Fax: +44 1628 512 999
maidenhead@avnet.eu

Bolton
Phone: +44 1204 547 170
Fax: +44 1204 547 171
bolton@avnet.eu

Stevenage, Herts, Meadway
Phone: +44 1438 788 310
Fax: +44 1438 788 250
stevenage@avnet.eu

ISRAEL
Tel-Mond
Phone: +972 (0)9 7780280
Fax: +972 (0)3 760 1115
avnet.israel@avnet.com

SOUTH AFRICA
Cape Town
Phone: +27 (0)21 689 4141
Fax: +27 (0)21 686 4709
sales@avnet.co.za

Durban
Phone: +27 (0)31 266 8104
sales@avnet.co.za

Johannesburg
Phone: +27 (0)11 319 8600
Fax: +27 (0)11 319 8650
sales@avnet.co.za

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