Transistor

Types and Features of Transistors

Transistor types can be classified based on their production processes, characteristics, internal circuits, and shapes. This application note explains the types of transistors and their features.

1. Categories based on production processes

Figure 1 shows the main categories of transistors based on their production processes. The grayed out items in the figure indicate the transistors that have not been productized by ROHM.

The transistors are classified into four large categories based on the production processes as follows.

1. BJT: Bipolar junction transistor

Bipolar transistors are categorized into NPN- and PNP-type transistors. An NPN-type transistor refers to a junction structure with a very thin p-type semiconductor sandwiched between two n-type semiconductors. Conversely, a PNP-type transistor refers to a structure with an n-type semiconductor sandwiched between p-type semiconductors. The term transistor was commonly used to refer to these transistors. However, they are now referred to as bipolar transistors to differentiate them from now prevalent FET products. In addition, transistors with built-in resistors are classified as digital transistors. ROHM developed digital transistors for the first time in the world.

2. FET: Field effect transistor

An FET is a transistor system that controls source-drain current with an electric field produced inside a semiconductor by applying voltage to the gate electrode. This type can further be classified into the MOS- and junction-types according to the gate junction structure. The MOS-type includes Si- and SiC-MOSFET, which utilize conventional silicon (Si) and silicon carbide (SiC) as a semiconductor material, respectively. The Si-MOSFET are commonly referred to as MOSFET. Super junction MOSFET are one type of Si-MOSFET that have achieved high power and increased speed as a result of improvement in the production process. In addition, there is another classification of the FET based on operation modes under the presence and absence of voltage application to the gate. While current flows in the enhancement type only when voltage is applied to the gate, current flows in the depression type when no voltage is applied. Currently, most of the MOSFET are the enhancement type and all of the JFET are the depression type. There are also HEMT (high electron mobility transistor), which are field effect power transistors that realize high speed operation by using compound semiconductors with extremely low impurities for a horizontal structure of the current path. In ROHM’s lineup, GaN devices that use gallium nitride for the compound semiconductor and contribute to energy conservation and downsizing of applications are listed as “EcoGaN^{TM} series”.

3. IGBT: Insulated gate bipolar transistor

Insulated gate bipolar transistors (IGBT) combine a MOSFET and bipolar transistor, providing power transistors with excellent characteristics from both. There are several types of production processes to improve characteristics including low V_{CE} (sat) and high-speed switching. Currently, the punch through (PT) and field stop (FS) types have been productized by ROHM. In addition, there are FS-type IGBT products with the same functions as the reverse conducting (RC) type, composed of two chips with a built-in SiC Schottky barrier diode (SiC-SBD) as the freewheeling diode of the switching circuit.

4. Phototransistor

Phototransistors are categorized as optoelectronics. They combine a photodiode and transistor in which the base current of the transistor is input with light. The semiconductor material is silicon.

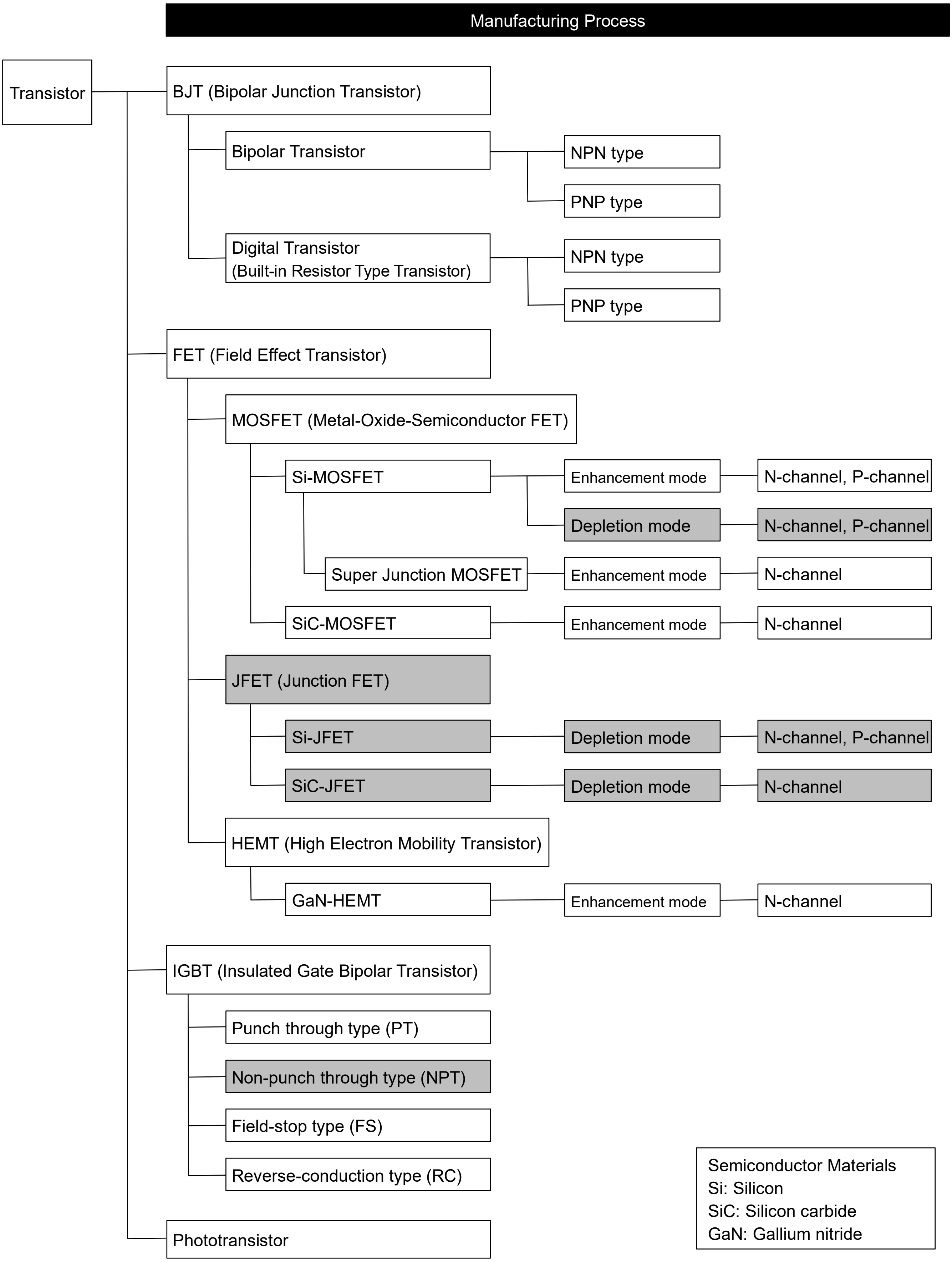


Figure 1. Main categories of transistors based on production processes

The grayed out items indicate the transistors that have not been productized by ROHM.

2. Categories based on power dissipation

Next, the classification based on the power dissipation is shown in Figure 2. The classification based on the power dissipation is used in “WSTS Product Classification 2021”. Transistors with a power dissipation less than 1 W are classified as “small signal transistors”, while those with a power dissipation of 1 W and higher are classified as “power transistors” (WSTS: World Semiconductor Trade Statistics).

The small signal transistors include general-purpose bipolar small-signal transistors, field effect transistors (FET), RF transistors and microwave small-signal transistors.

The power transistors include general-purpose bipolar transistors, field-effect general-purpose power transistors, IGBT, Darlington power transistors, RF transistors and microwave power transistors. The field-effect general-purpose power transistors are further classified into five categories (≤ 40 V, ≤ 100 V, ≤ 200 V, ≤ 400 V, > 400 V).

Other categorizations are possible based on characteristics and applications, such as general amplification, high-speed switching, and low-saturation type.

3. Categories based on internal circuits

The classification based on the internal circuits is shown in Figure 3. The single type has one element enclosed in one package. The complex type can have multiple built-in transistors or integrated resistors and diodes in addition to a standard transistor. The mounting area of the complex-type transistors can be downsized if they fit into the configuration and pin layout of individual application circuits. For applications with a large power loss, the thermal design must be considered because the heat generation source is concentrated in one element.

4. Categories based on shapes

Figure 4 shows the classification based on the shapes. Based on the mounting methods on the PCB and the heat dissipation performances, the transistors can be classified into the through-hole type and the surface-mounted type. The through-hole type has the package leads inserted into the holes in the PCB. With the surface-mounted type, the package is mounted on the surface of the PCB.

The surface-mounted type includes small packages for small signals and packages with FIN and/or a back electrode for power applications. Since heat is dissipated to the PCB, the power packages for surface mounting are limited to devices for which the power loss is up to several watts. Devices that require a larger power loss are designed using the through-hole type of the TO series equipped with a heatsink. In addition, some packages of the surface-mounted type have front electrodes, and a heatsink can be mounted.

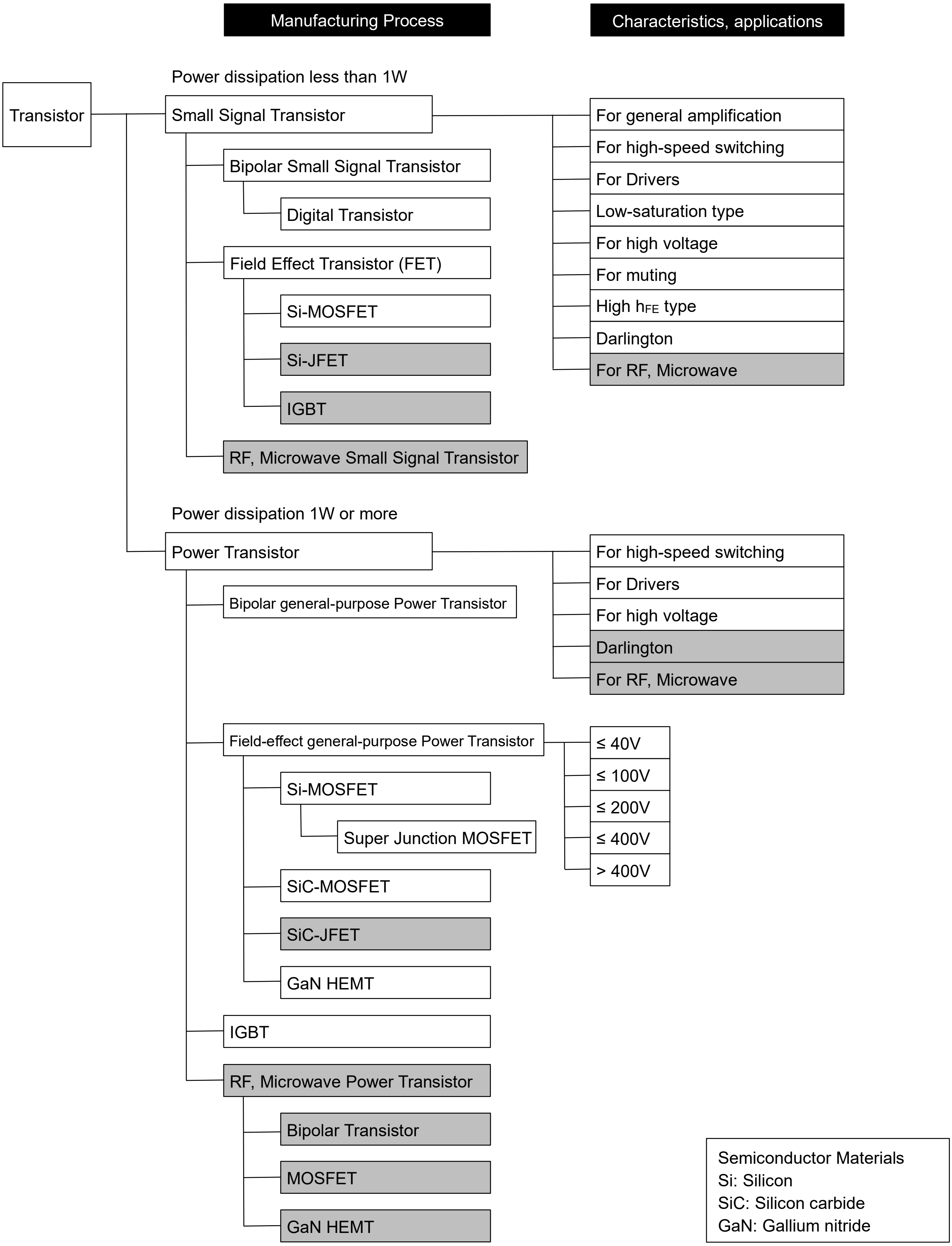


Figure 2. Categories based on power dissipation and categories based on characteristics and applications

The grayed out items indicate the transistors that have not been productized by ROHM.

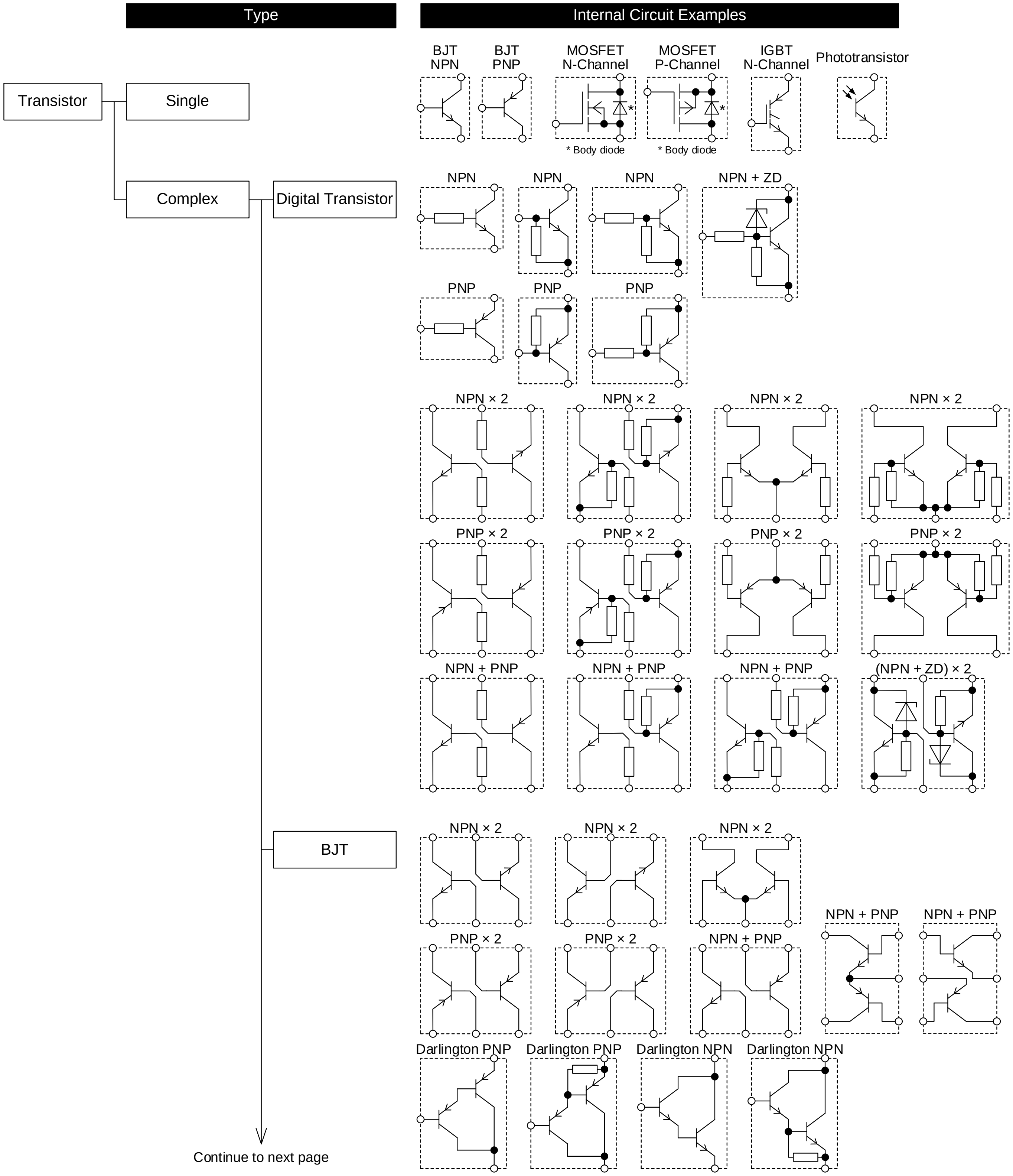


Figure 3. Categories based on internal circuits

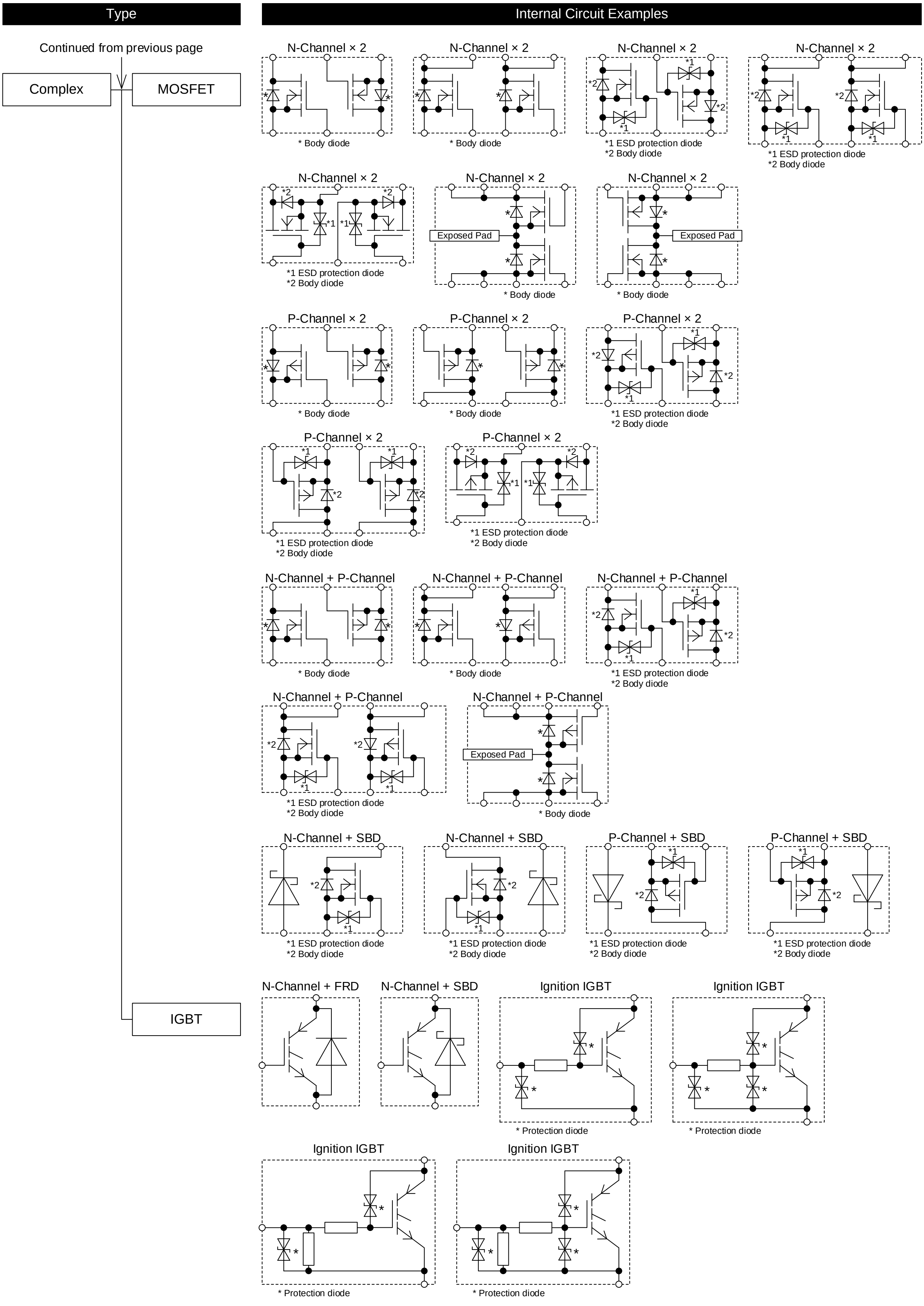


Figure 3. Continued

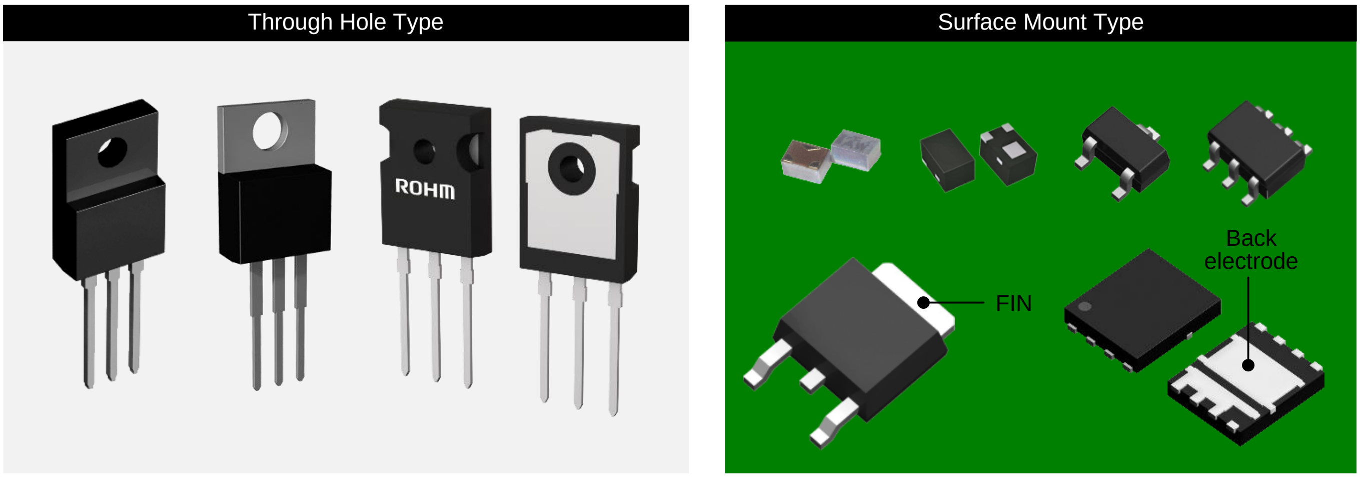


Figure 4. Categories based on shapes

From here, an overview of each transistor type is provided.

Bipolar transistor

A bipolar transistor is configured with the pn junction. Current flows between the collector and the emitter by passing through the base. Here, the NPN-type transistor in Figure 5 is used as an example for explaining the operation principle. When the forward voltage is applied between the base and the emitter (V_{BE}), electrons (negative charges) of the emitter flow into the base and a part of the electrons combine with holes (positive charges) of the base. This is the small current of the base, I_B. As the base is a thin structure made from p-type semiconductor, many of the electrons flowing from the emitter into the base slip out to the collector.

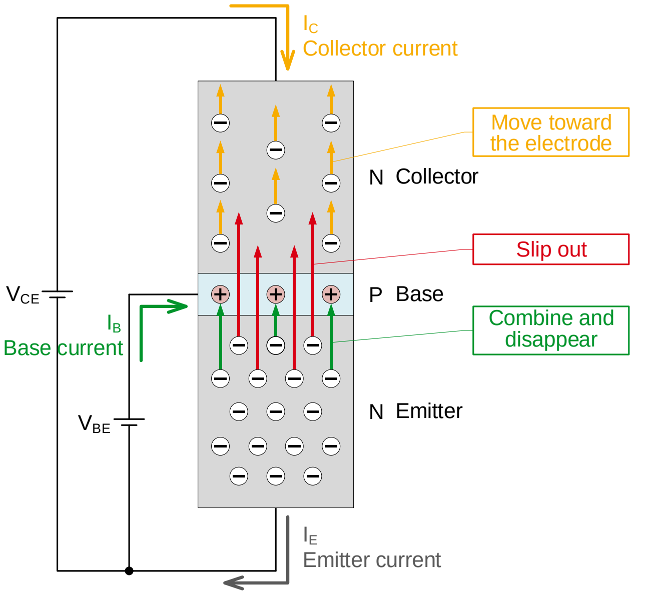


Figure 5. Operation principle of NPN-type bipolar transistor

Electrons (negative charges) move toward the collector electrode guided by collector-emitter voltage V_{CE}. This is collector current I_C. This current flows in the opposite direction to the electron movement.

The carriers are electrons (negative charges) in the NPN type, while they are holes (positive charges) in the PNP type. For the PNP type, voltage is applied so that positive and negative voltages are generated at the emitter and base, respectively. Then, holes (positive charges) of the emitter flow into the base. Some holes combine with electrons (negative charges) of the base and the rest slip out to the collector, generating the collector current.

There are two types of bipolar transistors: the NPN and PNP types. Select which type is to use based on whether the collector terminal side draws or discharges the current as shown in Figure 6.

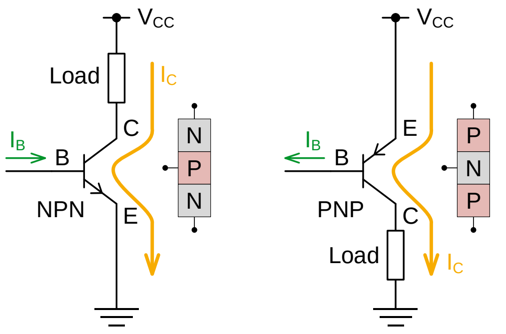


Figure 6. NPN- and PNP-type bipolar transistors
Common emitter circuit

There are three connection methods if a bipolar transistor is used as an amplifier. Table 1 summarizes the features of these methods. The three connection methods differ in the grounding scheme: common emitter, common base, or common collector. The common collector is also referred to as an emitter follower. Since the input impedance, output impedance, voltage gain, current gain, frequency characteristics, phase relationship between the input and output, etc. depend on the grounding scheme, the connecting method should be selected based on the application in which the transistor is used.

The common emitter is commonly used as a general circuit when the transistor is used as an amplifier. Note that, if the transistor is used as a high-frequency amplifier, a practical range is up to several MHz due to a high output impedance.

Applications of the common base are limited to high-frequency amplification due to a low input impedance. A common base circuit can be used alone or incorporated into the load part of a common emitter to be used as a cascode circuit.

Since the common collectors (emitter followers) have a high input impedance and low output impedance, they can perform impedance conversion. Therefore, they are commonly used as voltage buffer circuits. In addition, they are also used as op-amps and current boosters for the microcontroller output because of their high current gain.

Table 1. Three connection methods of bipolar transistors

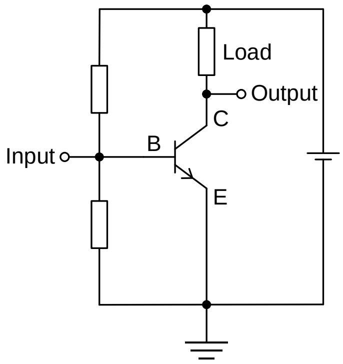
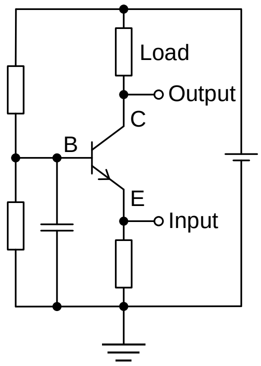
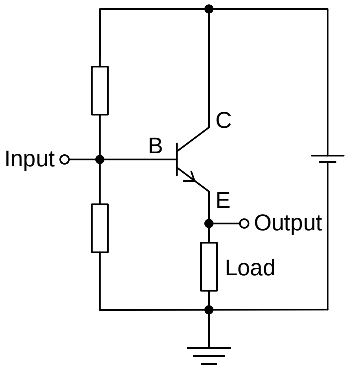
Connection method	Common emitter	Common base	Common collector (emitter follower)
Circuit			
Input impedance	Low (several hundred Ω to several kΩ)	Low (several tens of Ω to several hundred Ω)	High (several tens of kΩ to several hundred kΩ)
Output impedance	High (≃ load resistance)	High (≃ load resistance)	Low (several tens of Ω to several hundred Ω)
Voltage gain	High	High	≃ 1 time
Current gain	High	≃ 1 time	High
Frequency characteristics	Low	High	High
Phase between input and output	Reverse	Same	Same
Main applications	• Low frequency amplification • High frequency amplification	• Current buffer • High frequency amplification	• Voltage buffer • Current booster

Figure 7 shows the structure, which employs the general epitaxial planar type. In the manufacturing process, an n^- layer with a low impurity concentration is formed on an n^+ silicon substrate with a high concentration of n-type impurities. This provides a low collector saturation voltage and high breakdown voltage. In addition, since an n^- layer with a low impurity concentration is used for the collector-base junction, the collector-base junction capacitance is decreased. Next, p-type impurities are diffused from the top of the n^- layer to form the base. Furthermore, n^+ type impurities are diffused into a part of the base to form the emitter. Finally, an NPN-type bipolar transistor is completed by forming the protective film on the top and the electrodes on the top and bottom.

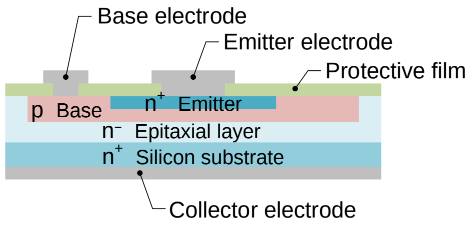


Figure 7. Structure of bipolar transistor

Bipolar Transistors Product Family:

- Bipolar Transistors
- Darlington Transistors
- Complex Transistors

Digital transistor

When using a bipolar transistor, it is common to insert a current limiting resistor in series into the base for stable control with the base voltage or insert a resistor between the base and the emitter for leakage absorption to prevent a malfunction of the transistor due to the leakage current flowing into the base (Figure 8). A reduction in the number of parts and the mounding area can be achieved if the transistor has built-in resistors from the beginning. This idea has led to the creation of digital transistors. With the two built-in resistors, the transistor can be controlled with digital signals consisting of the high and low levels of the input voltage, rather than with the input current. Accordingly, this type of transistor is named a digital transistor (Figure 9).

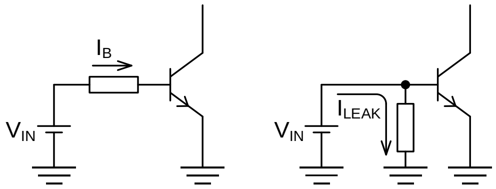


Figure 8. Resistors added to transistor circuit

Left: Resistor for base current limit

Right: Resistor for leakage current absorption

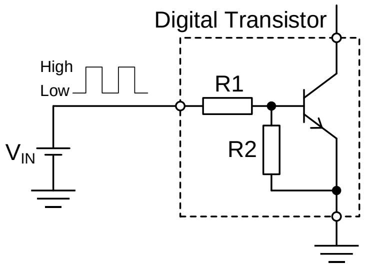


Figure 9. Digital transistor configured with bipolar transistor with two built-in resistors

The circuit configuration of digital transistors can have either built-in R1 or R2, built-in R1 and R2, or two built-in system circuits. In addition, the transistor polarity can be NPN or PNP (refer to the digital transistor part in Figure 3).

Their applications include various circuits such as inverters, drivers, and interfaces. Figure 10 shows an example in which an inverter is inserted into the interface wiring that controls an ASIC from an MCU. Figure 11 shows an example in which a digital transistor is connected with an MCU output as an LED driver.

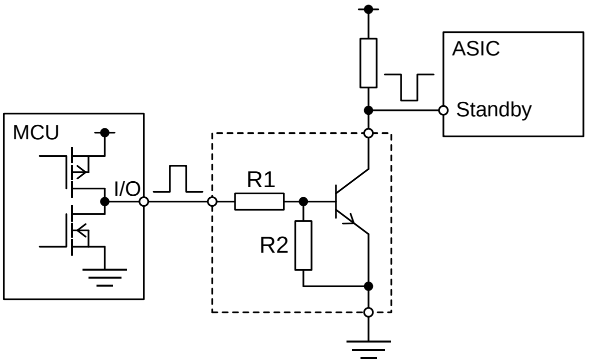


Figure 10. Example in which inverter is inserted into interface wiring that controls ASIC from MCU

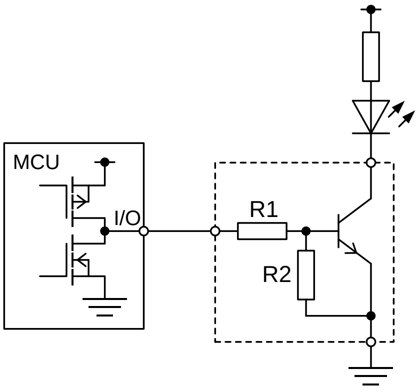


Figure 11. Example in which digital transistor is connected to MCU output as LED driver

Figure 12 shows the structure. The right half is the bipolar transistor structure as explained in the previous section. For the built-in resistor, produce an insulating layer on the same chip as this transistor and form a polysilicon resistor on top of the insulating layer. Next, wire this resistor and the transistor terminal (the base in this case) with aluminum.

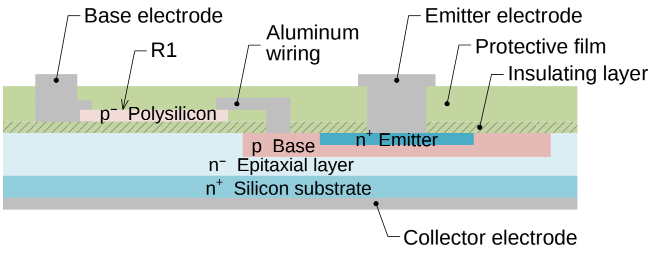


Figure 12. Structure of digital transistor
NPN transistor and R1

Differences in the characteristics between polysilicon and general chip resistors need to be considered. For example, the tolerance of the resistor value is ±1% to ±5% for the chip resistors in contrast to ±30% for the polysilicon resistors. Furthermore, the temperature coefficient is ±100 to ±400 ppm/°C for the chip resistors in contrast to -1,500 ppm/°C for the polysilicon resistors.

Digital Transistors Product Family:
- Standard Digital Transistors
- Automotive Digital Transistors

Si-MOSFET

An N-channel type MOSFET has an NPN structure between the drain and the source. Therefore, no current flows from the drain to the source when the gate voltage is zero (left panel of Figure 13). When the gate voltage is applied, electrons (negative charges) in the P-type semiconductor are attracted directly below the gate insulating film, forming an N-channel region. As a result, an N-type semiconductor is formed between the drain and the source and the drain current flows (right panel in Figure 13). A P-channel MOSFET has a structure in which N and P in this figure are reversed and holes (positive charges) are attracted directly below the gate insulating film.

In addition, since an oxide film insulates the gate of the MOSFET from the drain and the source, no static current flows, unlike the base of the bipolar transistor. Therefore, the MOSFET are driven by voltage and the driving voltage can be low.

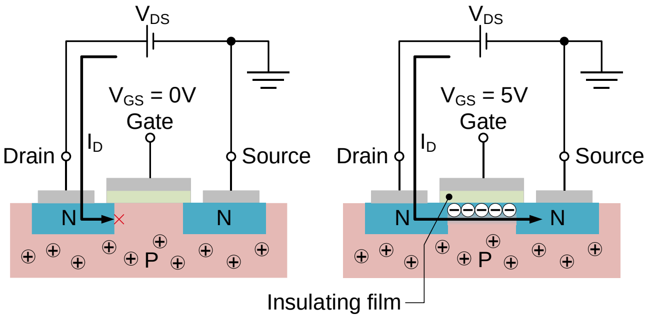


Figure 13. Operation principle of N-channel type MOSFET

There are N-channel and P-channel type MOSFET. Select which type is to use based on whether the drain terminal side draws or discharges the current on the circuit as shown in Figure 14. For the N-channel type, the drain current flows when a positive voltage is applied to the gate. For the P-channel type, the drain current flows when negative voltage is applied to the source.

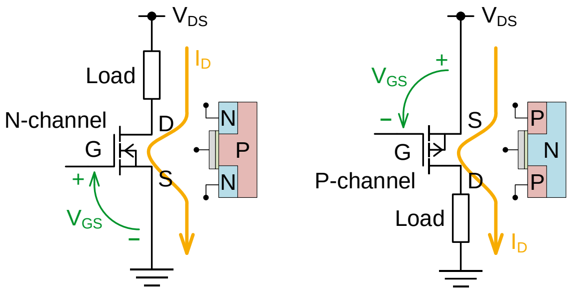


Figure 14. N-channel and P-channel type MOSFET
Common source circuit

Additionally, there are the enhancement type and the depression type based on the difference in how the drain current flows when the gate-source voltage is zero. Figure 15 shows the difference in their characteristics. When the gate-source voltage is zero, the drain current does not flow in the enhancement type, but it flows in the depression type. To turn OFF the drain current in the depression type, apply a negative or positive voltage across the gate and the source for the N-channel or P-channel type, respectively. In addition, their symbols on circuit diagrams are also different. The vertical line from the drain to the back gate and the source is broken for the enhancement type, while it is drawn with a straight line for the depression type.

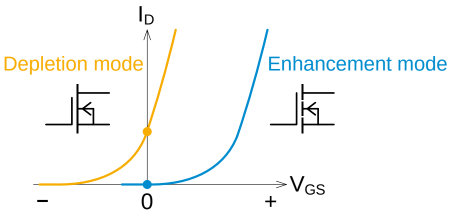


Figure 15. Differences in characteristics and symbols on circuit diagram between enhancement and depression type N-channel type

The MOSFET have a wide range of applications. They are used for switching elements of AC-DC, DC-DC, and other types of power supply circuits, driver elements of driver circuits that rotate motors or turn LEDs ON, switching elements of load switch circuits that turn ON/OFF the power supply, and amplifier elements of amplifier circuits for analog signals in audio and other applications (Figures 16 to 21).

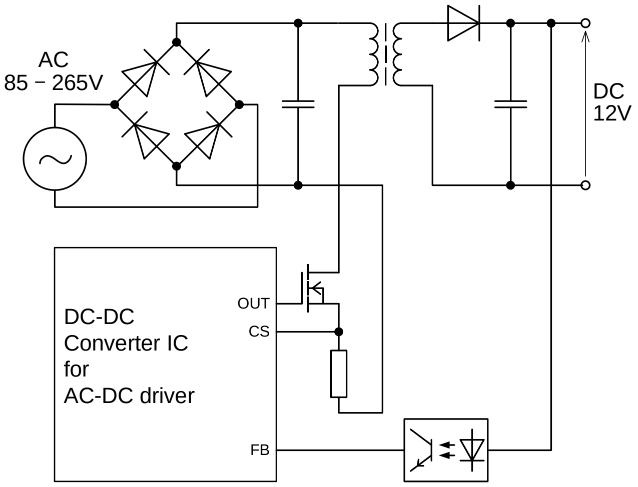


Figure 16. AC-DC converter circuit

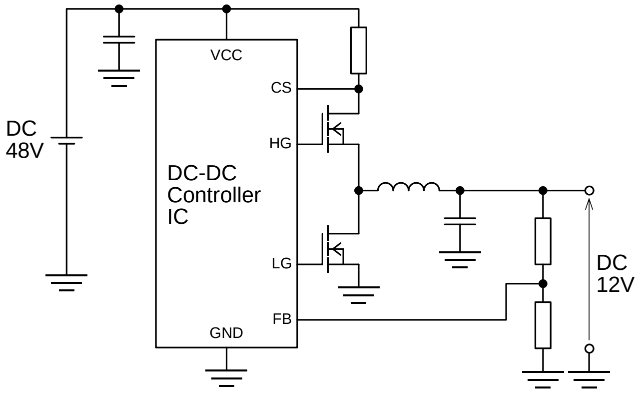


Figure 17. DC-DC converter circuit

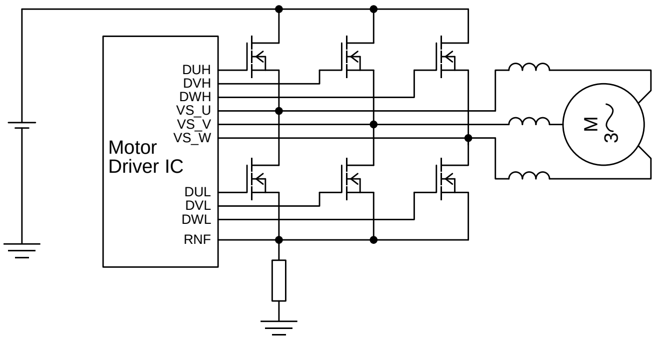


Figure 18. Motor driver circuit

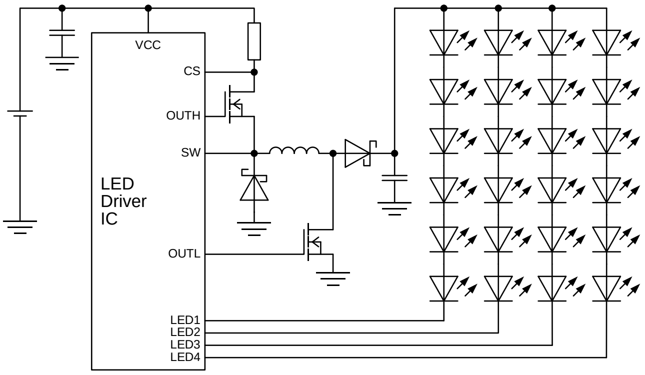


Figure 19. LED driver circuit

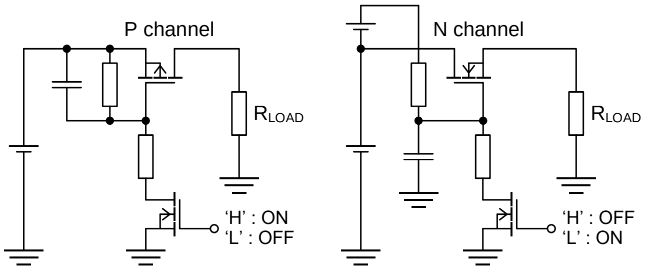


Figure 20. Load switch circuit

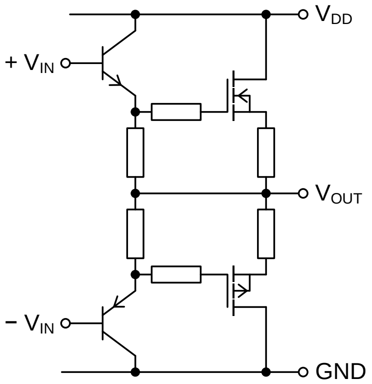


Figure 21. Output stage of audio power amplifier

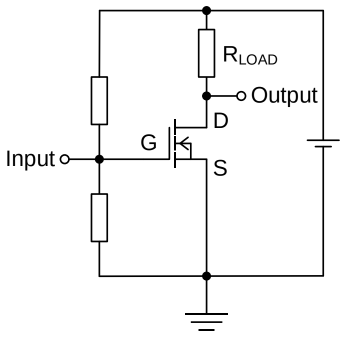
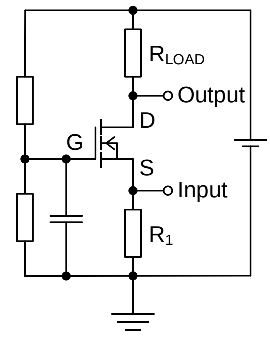
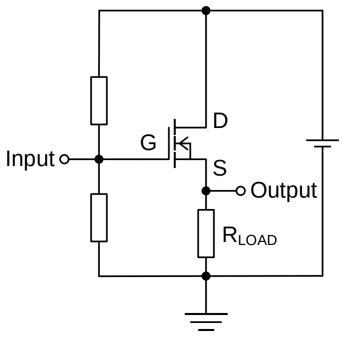
When a MOSFET is used as an amplifier, there are three connection methods, as for the bipolar transistors. Table 2 summarizes the features of these methods. The three connection methods differ in the grounding scheme: common source, common gate, or common drain. The common drain is also referred to as a source follower. Since the input impedance, output impedance, voltage gain, current gain, phase relationship between the input and output, etc. depend on the grounding scheme, the connecting method should be selected based on the application in which the transistor is used.

The common source is commonly used as a general circuit when the transistor is used as an amplifier, corresponding to the common emitter for the bipolar transistors. Although the input impedance is several kΩ for the bipolar transistors, the MOSFET feature an almost unlimited value of the input impedance. The voltage gain can be represented with the product of the load resistance and g_m as in the case of the bipolar transistors. However, the gain is lower because a g_m value cannot be obtained that is as high as that of the bipolar transistors.

The common gate corresponds to the common base for the bipolar transistors. It is mainly used for high-frequency amplification because of its low input impedance. A common gate circuit can be used alone or incorporated into the load part of a common source to be used as a cascode circuit.

The common drain (source follower) corresponds to the common collector (emitter follower) for the bipolar transistors. Since the common drains have a high input impedance and low output impedance, they can perform impedance conversion. Therefore, they are commonly used as voltage buffer circuits. The input impedance is higher than that of the bipolar transistors, featuring an almost unlimited value.

Table 2. Three connection methods of MOSFET

Connection method	Common source	Common gate	Common drain (source follower)
Circuit			
Input impedance	High (infinite)	Low (several tens of Ω to several hundred Ω)	High (infinite)
Output impedance	High (≃ R_{LOAD})	High (≃ R_{LOAD})	Low (several tens of Ω to several hundred Ω)
Voltage gain	High ($R_{LOAD} \times g_m$)	High ($R_{LOAD} \times g_m$)	≃ 1 time
Current gain	–	≃ 1 time	–
Frequency characteristics	Low	High	High
Phase between input and output	Reverse	Same	Same
Main applications	• Low frequency amplification • High frequency amplification	• High frequency amplification • Current buffer	• Voltage buffer

In recent years, three types of MOSFET structures have been mainstream, helping to achieve reduction in the on-resistance, increase in speed, and increase in breakdown voltage. These structures are described in order below.

Figure 22 shows a general planar gate structure. In the manufacturing process, an n^- layer with a low impurity concentration is formed on an n^+ silicon substrate with a high concentration of n-type impurities. The charge concentration is mitigated and the breakdown voltage is improved by diffusing p-type impurities from the top to the peripheral part of the chip and forming a guard ring. Next, a gate insulating film is formed by thermal oxidation of silicon, and the gate electrode is formed with polysilicon on top of the gate insulating film. The source region is formed by ionizing and accelerating n-type impurities with a high voltage to inject the ions into the wafer. Finally, a planar-type MOSFET is completed by forming the electrodes for the source and the drain.

Figure 23 shows the trench gate structure. The channel is also created in the vertical direction by forming the gate electrode deeply in the vertical direction. As a result, the length of the epitaxial layer (drift layer) between the drain and the source is decreased, reducing the on-resistance. However, since the length of the epitaxial layer is decreased, the breakdown voltage is decreased compared with the planar structure.

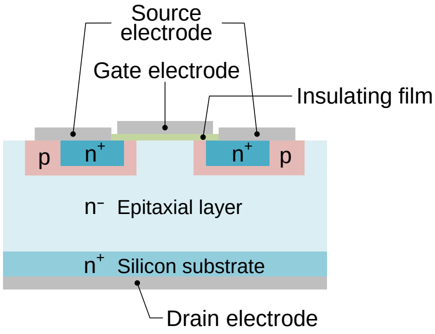


Figure 22. Structure of planar-gate Si MOSFET N-channel type

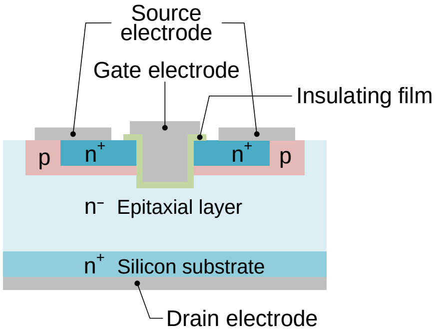


Figure 23. Structure of trench-gate Si MOSFET N-channel type

Figure 24 shows the super junction structure. A columnar p-type layer is formed inside the n-type region. Since the p- and n-types are placed alternately, the field strength is uniform inside the n region. As a result, this structure has a higher breakdown voltage compared with the conventional structures described above. In addition, a low on-resistance is simultaneously achieved because a highly concentrated n region is formed.

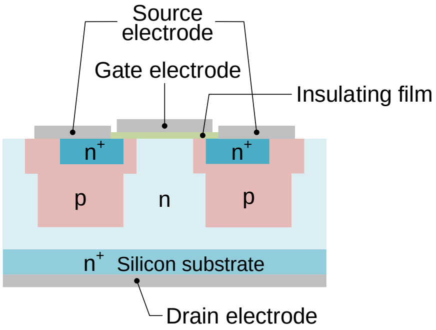


Figure 24. Structure of super junction Si MOSFET N-channel type

Si-MOSFETs Product Family:

- 12 to 150V MOSFETs
- 190 to 800V Power MOSFETs
- Automotive MOSFETs

SiC MOSFET

Silicon carbide (SiC) is a compound semiconductor that is very stable thermally, chemically, and mechanically. The important parameters for power devices are excellent. As an element, it can surpass silicon (Si) semiconductors in terms of low resistance, high-speed operation, and high-temperature operation. As a result, energy loss during various power conversions can be significantly reduced.

Under current circumstances, SiC MOSFET are considered useful in a breakdown voltage region above 600 V and especially advantageous at 1 kV and higher. As advantages, since the on-resistance is lower compared with the super junction MOSFET with an equivalent breakdown voltage, the chip area can be reduced and the recovery loss can significantly be decreased with the same on-resistance. Furthermore, compared to Si-IGBT, which are currently mainstream products at 1 kV and higher as described below, SiC MOSFET achieve loss reduction during switching OFF and downsizing of applications by realizing high-frequency operation can be expected with the SiC MOSFET.

Compared with the Si MOSFET, the SiC MOSFET show a lower resistance of the epitaxial layer (drift layer), but a higher channel resistance. Therefore, the SiC MOSFET have the following characteristic: the higher the gate drive voltage (V_{GS}), the lower the on-resistance. The recommended V_{GS} is about 18 V to obtain a sufficiently low on-resistance. Therefore, if only the MOSFET elements are replaced in a circuit using Si MOSFET, the circuit stops operating and requires redesign of the gate driver circuit.

The SiC MOSFET are used for applications handling a higher power compared with the Si MOSFET (Figures 25 to 28). For example, it is expected that the SiC MOSFET will be introduced to a wide range of fields including pulse power supplies, induction heating devices, and electric infrastructure in addition to converter and inverter applications, such as automotive battery chargers, power trains for electric vehicles, motor drives for railways, power supplies for data centers, power supplies for cellular base stations, and power conditioners in solar power generation.

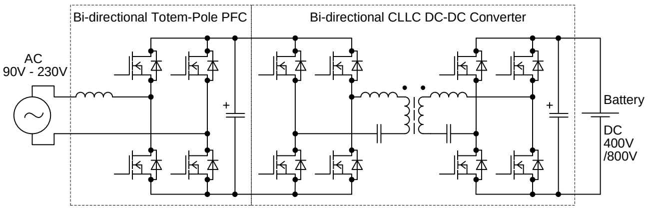


Figure 25. On-board charger for EV

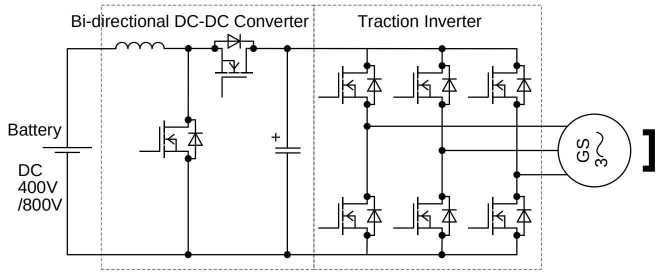


Figure 26. Main traction inverter for EV

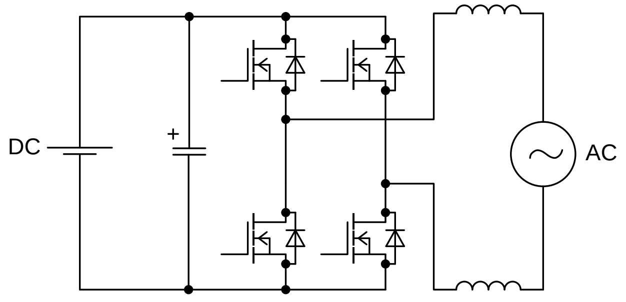


Figure 27. DC-AC inverter

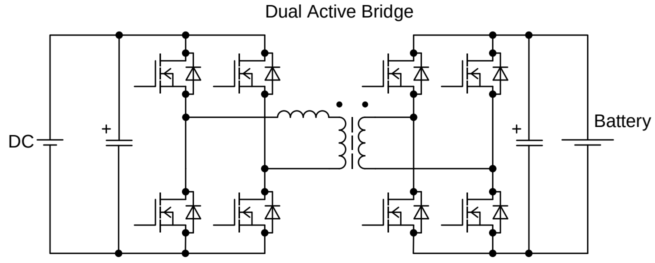


Figure 28. DC-DC converter for battery charger

Figures 29 and 30 show the structure of the SiC MOSFET. The basic structure is the same as the Si MOSFET. However, the semiconductor material for the substrate and the epitaxial layer (drift layer) is changed from silicon (Si) to silicon carbide (SiC). The thickness of the epitaxial layer can be reduced compared with Si MOSFET because high breakdown voltage characteristics can still be obtained with a thinned epitaxial layer with SiC thanks to its physical properties. As a result, the vertical distance between the source and the drain is decreased, significantly reducing the on-resistance.

Figure 29 shows the planar structure employed for ROHM's second-generation SiC MOSFET. Figure 30 shows the trench structure employed for the third- and fourth-generation SiC MOSFET with the on-resistance reduced further.

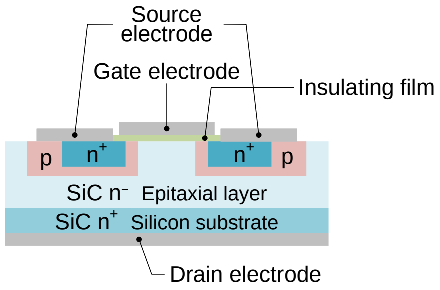


Figure 29. Structure of planar-gate SiC MOSFET

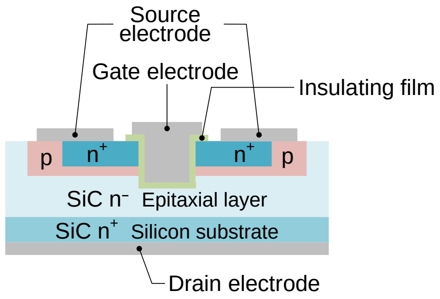


Figure 30. Structure of trench-gate SiC MOSFET

SiC-MOSFETs Product Family:

- 2nd Generation: SCT2xxx series
- 3rd Generation: SCT3xxx series
- 4th Generation: SCT4xxx series

GaN-HEMT

GaN HEMT is a wide-bandgap semiconductor like SiC MOSFET, which can realize a high breakdown voltage and low on-resistance with a thin drift layer. Furthermore, the current between the drain and the source flows at a high speed horizontally along the channel of two-dimensional electron gas with a high mobility, providing excellent switching characteristics. The breakdown voltage is 650 V for the GaN HEMT in contrast to several kV for the SiC MOSFET.

Therefore, GaN HEMT are suitable for applications at a medium power, medium voltage, and high frequency. For example, these applications include servers for data centers and power supplies for cellular base stations (Figure 31), consumer AC adapters, automotive on-board chargers, and DC-DC converters, all of which require a high power conversion efficiency and switching operation at a higher frequency than SiC (200 kHz and higher). The high-frequency operation enables downsizing of surrounding components, contributing to downsizing of final products.

In addition, GaN HEMT with a breakdown voltage of 150 V are used for drivers of laser diodes for LiDAR (Figure 32) and DC-

DC converters, utilizing the high-speed switching performance at 1 MHz and higher.

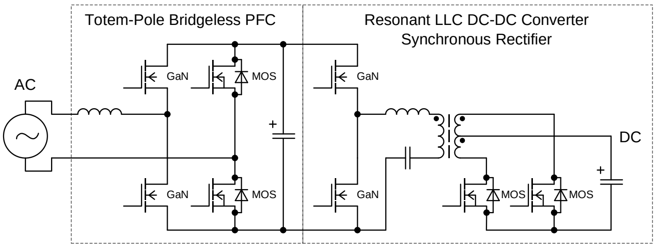


Figure 31. AC-DC power supply for servers and cellular base stations

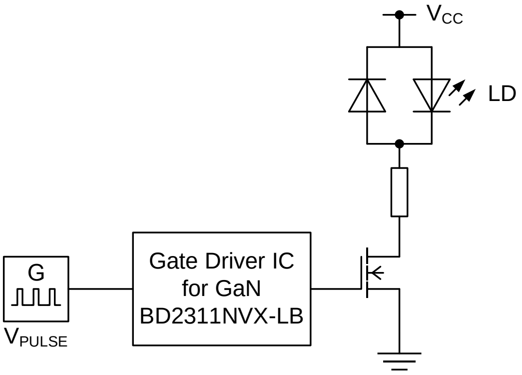


Figure 32. Laser diode circuit for LiDAR

Figure 33 shows the structure of the general enhancement type (normally off type) GaN HEMT using p GaN for the gate. An AlN (aluminum nitride) nucleation layer is deposited on a silicon substrate. Then, a buffer layer composed of GaN or AlGaN (aluminum gallium nitride) is stacked to mitigate the difference in the lattice constants between Si and GaN. A channel layer (active layer) of GaN and a barrier layer of AlGaN are stacked on top of the buffer layer. A layer of two-dimensional electron gas is formed at the interface of both layers and utilized as a channel along which electrons flow at a high speed.

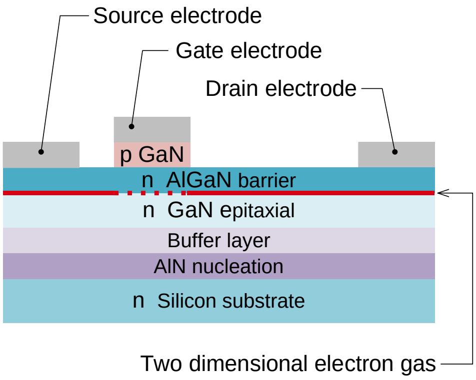


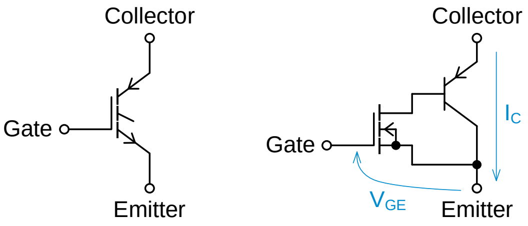
Figure 33. Structure of enhancement-type GaN HEMT

GaN HEMT Product Family:
- GaN HEMT
- Gate Drivers for GaN
- GaN HEMT Power Stage ICs

IGBT

The IGBT combine a MOSFET and bipolar transistor, providing power transistors with excellent characteristics from both. There are two types of IGBT: N-channel and P-channel types. The N-channel type is currently the main type and it is explained here as an example.

Figure 34 shows the circuit diagram symbol and the equivalent circuit. An IGBT has three terminals for the gate, collector, and emitter. It can be considered that the gate is the same as the MOSFET, while the collector and the emitter are the same as the bipolar transistors. The IGBT perform operations similar to the MOSFET as voltage control elements. For the N-channel type, when a positive gate voltage (V_{GE}) is applied to the emitter, collector current I_C is conducted between the collector and the emitter.



Circuit diagram symbol Equivalent circuit

Figure 34. Circuit diagram symbol and equivalent circuit for N-channel type IGBT

Next, the operation principle of the IGBT is explained using the equivalent circuit and the structure in Figure 35. A p^+ collector layer is formed on the drain side of an N-channel type MOSFET. The structure has a p-n-p-n arrangement from the collector to the emitter. The drain of the N-channel type MOSFET and the base of the PNP transistor in the equivalent circuit are identical and located on the n^- drift layer of the IGBT. The gate is the thin film wiring on the insulating film. The gate of the N-channel type MOSFET is the gate of the IGBT. The emitter of the IGBT is the n^+ layer, corresponding to the source of the N-channel type MOSFET. The collector of the PNP transistor is p^+, forming a junction with the emitter N^+ layer of the IGBT. The emitter of the PNP transistor is the p^+ layer, which is the collector of the IGBT.

The IGBT is turned ON when a positive collector voltage (V_{CE}) and a positive gate voltage (V_{GE}) are applied to the emitter simultaneously. In this state, collector current I_C is conducted between the collector and the emitter. If this operation is applied to the equivalent circuit, the N-channel type MOSFET is turned ON when a positive V_{GE} is applied. This allows base current I_B to flow into the PNP transistor. As a result, I_C is conducted through the PNP transistor, flowing from the collector to the emitter of the IGBT.

The structure diagram shows the movement of internal electrons (-) and holes (+). When a positive V_{GE} is applied to the gate, electrons (-) are attracted to the p^+ layer directly below the gate electrode, forming a channel. This principle is basically the same as the conduction of MOSFET. As a result, the electrons supplied from the IGBT emitter move to the n^+ layer, channel, n^- drift layer, and p^+ collector layer in order. Meanwhile, the p^+ collector layer supplies holes (+) to the n^- drift layer. This layer is referred to as a drift layer because both carriers, i.e., electrons and holes, move in this layer. Therefore, the electron movement from the emitter to the collector generates current I_C from the collector to the emitter.

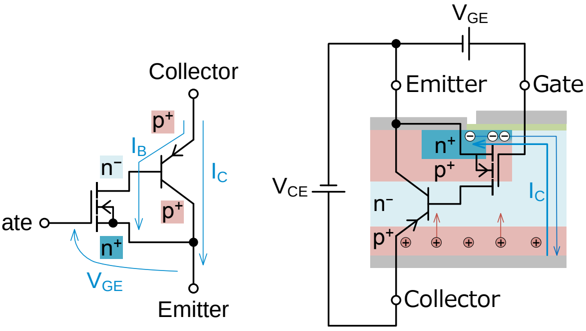


Figure 35. Equivalent circuit and structure of N-channel type IGBT

Discrete products of IGBT cover applications of home appliances and small industrial devices with an operating frequency of approximately 1 kHz to 60 kHz and an output capacitance of 1 kVA or less. IGBT modules in combination with other components support the range over 100 MVA and are used for electric trains, EV, etc. Figure 36 shows a motor driver circuit for electric compressors and Figure 37 shows an example of an inverter system using a resonance circuit for electromagnetic cooking devices for home use.

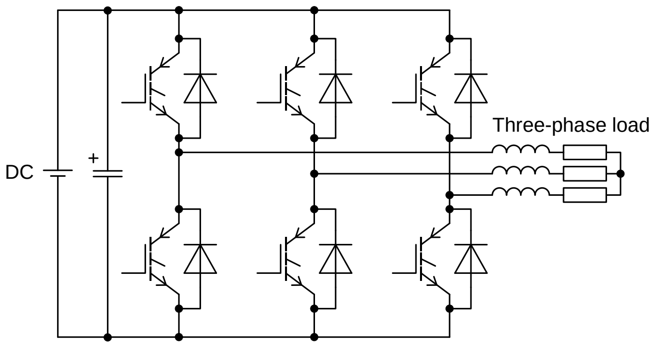
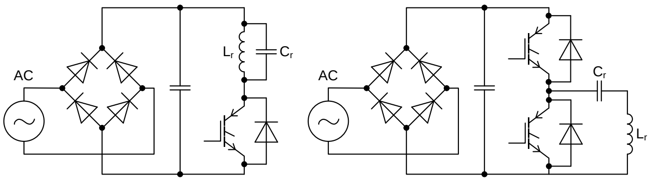


Figure 36. Three-phase full-bridge inverter circuit of motor driver for electric compressors



Voltage resonant inverter Current resonant inverter

Figure 37. Inverter system using resonance circuit for electromagnetic cooking devices for home use

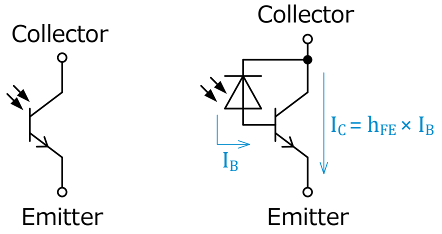
IGBT Product Family:

- Field Stop Trench IGBT
- Ignition IGBT
- IGBT Bare Die

Phototransistor

Phototransistors have an integrated structure consisting of a photodiode and transistor. The output current (photocurrent) of the photodiode is output after being amplified with the transistor. The photocurrent of photodiodes is several μA. Since it is difficult to handle such a small current as is, the phototransistors output the photocurrent after amplifying it to the order of mA. Furthermore, in terms of the sensitivity, a sufficient output can be obtained even if the illuminance is low.

Figure 38 shows the circuit diagram symbol and the equivalent circuit. In the equivalent circuit, the photodiode appears to be connected between the collector and the base of the NPN transistor. However, the pn junction of the base (p-type) and the collector (n-type) of the NPN transistor function as a photodiode actually. The photocurrent generated here becomes base current I_B of the transistor, and collector current I_C is output after being amplified by a factor of h_{FE} of the transistor. This output current is proportional to the illuminance. In addition, the response speed of phototransistors is slower than that of photodiodes due to differences in their configurations and operations.



Circuit diagram symbol Equivalent circuit

Figure 38. Circuit diagram symbol and equivalent circuit for phototransistor

The peak sensitivity wavelength of ROHM's phototransistors is set to the infrared region (800 nm typ). The outer layer employs resin cutting wavelengths at 750 nm and longer to prevent visible light from entering. Therefore, the phototransistors are scarcely affected by the ambient light. As for shapes, the through-hole and surface mounted types are listed in the lineup so that you can make a selection according to the mounting.

Through-hole type Surface mounted type

Figure 39. Appearance of phototransistor

The phototransistors are used for the light receiving section of photosensors. Their applications include infrared remote controllers, optical communications, and photometers. Figure 40 shows an example of a circuit for an infrared radiation receiving section.

Figure 41 shows the structure, which employs the general epitaxial planar type. The manufacturing process is similar to the NPN-type bipolar transistors. An n^- layer with a low impurity concentration is formed on an n^+ silicon substrate with a high concentration of n-type impurities. Next, p-type impurities are diffused from the top of the n^- layer to form the base. Furthermore, n^+ type impurities are diffused into a part of the base to form the emitter. A difference from the NPN transistors is that the chip is entirely covered with an opaque film on the top and an opening is created over the base of the p layer. When a light corresponding to the energy gap of the silicon semiconductor enters through this opening, electrons in the valence band are excited to the conduction band. As a result, electrons (negative charges) are moved from the p layer to n layer and holes (positive charges) are moved from the n layer to p layer, causing current to flow. Finally, the chip for a phototransistor is completed by forming the electrodes on the top and bottom.

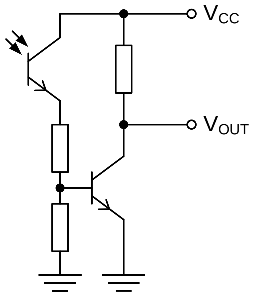


Figure 40. Example of circuit for infrared radiation receiving section

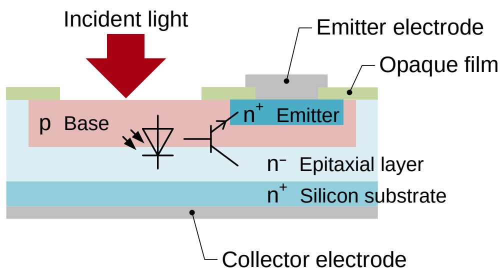


Figure 41. Structure of phototransistor

Phototransistors Product Family

Notice

1) The information contained in this document is intended to introduce ROHM Group (hereafter referred to asROHM) products. When using ROHM products, please verify the latest specifications or datasheets before use.

2) ROHM products are designed and manufactured for use in general electronic equipment and applications (such as Audio Visual equipment, Office Automation equipment, telecommunication equipment, home appliances, amusement devices, etc.) or specified in the datasheets. Therefore, please contact the ROHM sales representative before using ROHM products in equipment or devices requiring extremely high reliability and whose failure or malfunction may cause danger or injury to human life or body or other serious damage (such as medical equipment, transportation, traffic, aircraft, spacecraft, nuclear power controllers, fuel control, automotive equipment including car accessories, etc. hereafter referred to as Specific Applications). Unless otherwise agreed in writing by ROHM in advance, ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties arising from the use of ROHM Products for Specific Applications.

3) Electronic components, including semiconductors, can fail or malfunction at a certain rate. Please be sure to implement, at your own responsibilities, adequate safety measures including but not limited to fail-safe design against physical injury, and damage to any property, which a failure or malfunction of products may cause.

4) The information contained in this document, including application circuit examples and their constants, is intended to explain the standard operation and usage of ROHM products, and is not intended to guarantee, either explicitly or implicitly, the operation of the product in the actual equipment it will be used. As a result, you are solely responsible for it, and you must exercise your own independent verification and judgment in the use of such information contained in this document. ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties arising from the use of such information.

5) When exporting ROHM products or technologies described in this document to other countries, you must abide by the procedures and provisions stipulated in all applicable export laws and regulations, such as the Foreign Exchange and Foreign Trade Act and the US Export Administration Regulations, and follow the necessary procedures in accordance with these provisions.

6) The technical information and data described in this document, including typical application circuits, are examples only and are not intended to guarantee to be free from infringement of third parties intellectual property or other rights. ROHM does not grant any license, express or implied, to implement, use, or exploit any intellectual property or other rights owned or controlled by ROHM or any third parties with respect to the information contained herein.

7) No part of this document may be reprinted or reproduced in any form by any means without the prior written consent of ROHM.

8) All information contained in this document is current as of the date of publication and subject to change without notice. Before purchasing or using ROHM products, please confirm the latest information with the ROHM sales representative.

9) ROHM does not warrant that the information contained herein is error-free. ROHM shall not be in any way responsible or liable for any damages, expenses, or losses incurred by you or third parties resulting from errors contained in this document.

Thank you for your accessing to ROHM product informations.
More detail product informations and catalogs are available, please contact us.

ROHM Customer Support System

https://www.rohm.com/contactus

© 2023 ROHM Co., Ltd. All rights reserved.