Application Note

Breakthrough In Small Signal - Low VCEsat (BISS) Transistors and their Applications

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Breakthrough In Small Signal - Low VCEsat (BISS) Transistors and their Applications

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1. INTRODUCTION

Nowadays, the trend in electronics is towards miniaturisation and higher efficiency. Mobile phones, handheld computers and laptops are getting smaller and lighter while performance increases.

For decades, the performances of small signal bipolar transistors like BC547 and BC338 in SOT54-package, or its respective counterparts BC847 and BC817 in SOT23-package were sufficient for hundreds of applications. Even so medium-power transistors like the 3 A-transistor BDP31 in SOT223.

But, today's application requirements are more and more far beyond the performance of these general application transistors. Packages become smaller and smaller. The ultra small package SOT490 (SC-89) measures only 1.6 x 0.8 x 0.7 mm^3 compared to the still very popular SOT23 (2.9 x 1.3 x 0.9 mm^3). And, there is a tendency to introduce even smaller packages.

In opposite, required collector currents raised from 0.1 A to more than 2 A in SOT23, to give just one example. Further, the demand for higher efficiency to have lower power loss and the need for increased battery life time asks for new transistors with less collector-emitter-saturation voltage and higher current gain.

Last, but not least, environmental issues become more and more important. An inventory of the environmental impact shows that a transistor used in a TV-set needs more than 100 times more energy during operational life than for production. Thus, operational efficiency is most important to save the environment.

These requirements brought Philips Semiconductors to develop low-V_{CEsat}-transistors and to introduce them with a continuously expanding portfolio to the market available in large volumes. Philips called them BISS (Breakthrough In Small Signal) transistors, due to significant improvements in characteristics.

The following application note provides information on the technology background, product performance improvements, and typical applications of BISS transistors and is exemplary done for

- the 2 A BISS transistor PBSS4350T in SOT23,
- the 0.5 A BISS transistor PBSS2540F in SOT490 (SC-89),
- the 3 A BISS transistor PBSS4350Z in the SOT223 (SC-73),
- the 5 A BISS transistor PBSS4540Z in SOT223 (SC-73).

For reference the conventional transistors BC817-40 ($I_{C\,max}$ = 0.5 A; SOT23) and BDP31 ($I_{C\,max}$ = 3 A; SOT223) are used.

2. PRODUCTS

2.1 Technology Background

To understand the root causes for the improvements in characteristics a short excursion inside a transistor is necessary.

Figure 1 shows a simplified cross section of a discrete bipolar NPN transistor, and Figure 2 a typical die layout (top view) of commonly used conventional transistors.

The transistor is built up from three different layers, a highly doped emitter layer, a medium doped base area and a low doped collector area. The highly doped substrate serves as carrier and conductor only. During the assembly process the transistor die is attached to a lead frame by means of gluing or eutectic soldering. The emitter and base contacts are connected to the lead frame through bond wires.

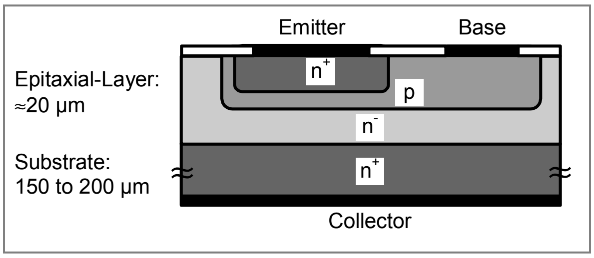


Figure 1: Simplified cross section of a discrete NPN transistor

To develop a high performance transistor nothing can be left untouched: The die and lead frame layouts have to be optimised, the electrical resistances of the die metal, die attach and bond wires to be minimised.

Using the mesh-emitter technology, which is shown in Figure 3 and Figure 4, it is possible to increase the efficiency of the active area significantly by minimising the distributed base resistance.

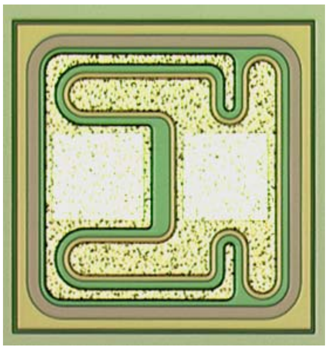


Figure 2: Die layout of a conventional transistor (BC337/BC817)

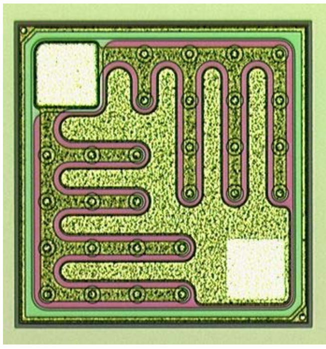


Figure 3: Die layout of a mesh-emitter (BISS) transistor, 1st generation

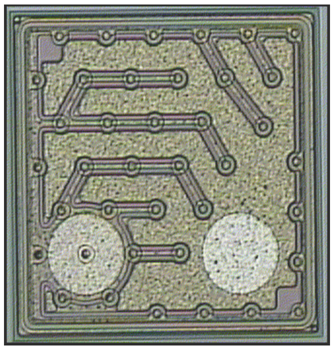


Figure 4: Die layout of a mesh-emitter (BISS) transistor, 2nd generation

Further, some single transistors are assembled in 6 pin packages. They contain lead frames, which allow a maximum die size per package and a lower thermal resistance than the size comparable 3-pin package (Figure 5 and Figure 6).

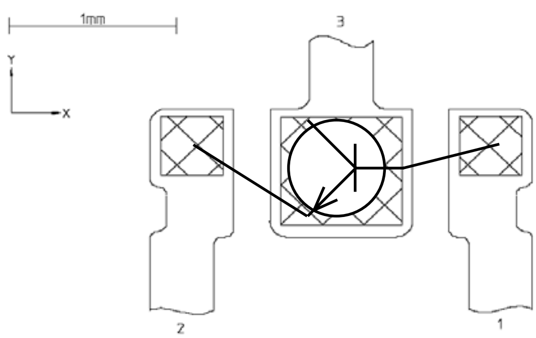


Figure 5: SOT23 Standard lead frame

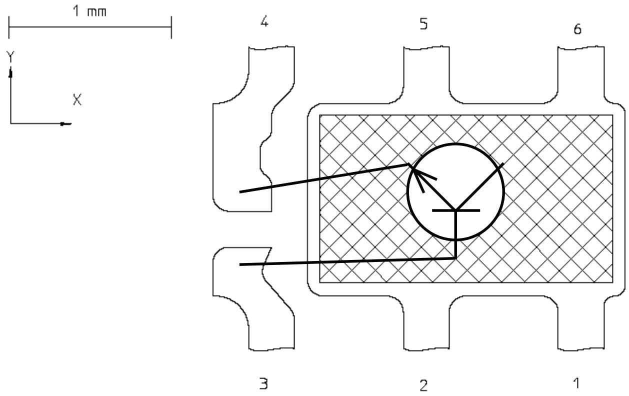


Figure 6: SOT457 (SC-74) MaxSi lead frame

2.2 Product performance improvements

Due to the technology described above BISS transistors achieve a better electrical performance and lower power dissipation than conventional transistors, dice can be build smaller to fit into smaller packages, or both of them.

Improved parameters are

- decreased power dissipation P_C,
- increased collector current I_C,
- increased peak collector current I_{CM},
- decreased collector-emitter saturation voltage V_{CEsat},
- increased current gain h_{FE} at high collector currents.

To show product performance improvements in detail the following explanations refer to the BC817-40, an industry standard 0.5 A-transistor in SOT23 package, and the BDP31, a 3 A-transistor in SOT223.

The SOT23 package was chosen because it is the most common SMD package for discrete semiconductor devices whereas the SOT223 package is a standard package of medium power transistors.

Table 4 and Table 5 on page 14 provide a quick comparison of parameters between these conventional and some of recently developed BISS transistors for a first orientation. The PBSS2540F[1] is one of the smallest transistors whereas the PBSS4350T handles the highest collector current in a SOT23 package. The PBSS4350Z is considered as a direct replacement for the BDP31 whereas the PBSS4540Z offers today's maximum continuous collector current ($I_{C\,max}$ = 5 A) in SOT223.

Replacing conventional by BISS transistors opens various opportunities for performance and efficiency improvements of the circuit design.

A BISS transistor die assembled in the same package as its conventional predecessor results in a product, which ***dissipates less heat*** ($T_j = T_a + R_{th} \times V_{CEsat} \times I_C$) during operation. For example, the actual power dissipation is reduced by 65 % comparing a conventional transistor with a BISS transistor at I_C = 3 A in a SOT223 package.

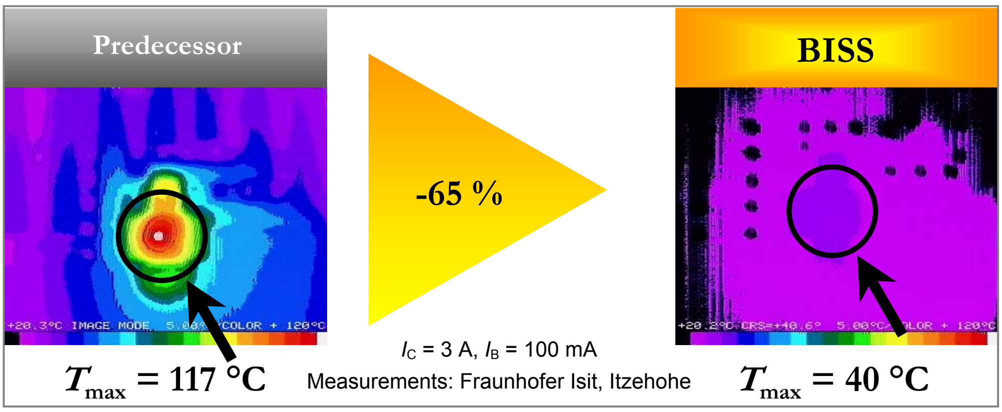


Figure 7: Junction temperature drops from 117 °C to 40 °C comparing SOT223 transistors

Thus, a BISS transistor can be selected to avoid hot spots on the printed circuit board. The circuit becomes more reliable and more efficient. In some cases a less expensive PCB can be used.

A ***higher permissible collector current*** I_C and furthermore I_{CM} is another great benefit due to the mesh-emitter design. The maximum continuous collector current for SOT23 transistors can now be specified up to 2 A (PBSS4350T), or 3 A using a SOT457 (SC-74) package, compared to 0.5 A of the BC817. Until now a continuous collector current of

[1] For product coding please refer to Annex B: Product coding

3 A was the domain of SOT223 transistors. The resulting reduction of board space of 38 mm² per package is significant[2].

SOT223 transistors are now available with a maximum continuous collector current of up to 5 A, a value which used to require a much larger and more expensive package. For small signal applications, a collector current of 0.5 A is now featured by the PBSS2540F; an ultra-small SOT490 (SC-89) packaged BISS transistor, which measures only 1.6 mm × 0.8 mm.

Table 1 provides an overview of already achieved maximum collector currents with regards to the package and a comparison to maximum collector currents of conventional transistors using the same package.

Table 1: Maximum continuous collector current for BISS transistors and comparison to conventional transistors

size code	package	$I_{C\,max}$	BISS transistor example	conventional transistor example	$I_{C\,max}$
1608	SOT490 (SC-89)	0.5 A	PBSS2540F	BC847BF	0.1 A
1612	SOT666	1 A	PBSS4140V	not available	
2012	SOT323 (SC-70)	1 A	PBSS4140U	BC817W	0.5 A
2012	SOT363 (SC-88)	2 A	PBSS4240Y	not available	
2913	SOT23	2 A	PBSS4240T	BC817	0.5 A
2915	SOT457 (SC-74)	3 A	PBSS4350D	not available	
6335	SOT223 (SC-73)	5 A	PBSS4540Z	BDP31	3 A

The main reason for the decrease in dissipated power is the ***decrease in collector-emitter saturation voltage V_{CEsat}***. Compared to a conventional 0.5 A transistor in SOT23 the collector-emitter saturation voltage today could be reduced by 73 %. Next generation BISS transistors will have even less saturation voltages.

Table 2: Collector-emitter saturation voltage is already reduced by 73 % today for SOT23 transistors

technology	type	V_{CEsat} at I_C = 0.5 A
conventional	BC817-40	220 mV typical
BISS, 1st generation	PBSS4140T	130 mV typical
BISS, 2nd generation	PBSS4350T	60 mV typical

Figure 8 compares typical collector-emitter saturation voltages of the conventional BC817-40 transistor in SOT23, the PBSS2540F in the ultra small SOT490 (SC-89) package and the PBSS4350T in SOT23. It shows that for the much smaller PBSS2540F the collector-emitter saturation voltage remains the same than for the BC817-40. The saturation voltage of the PBSS4350T is 60 - 70 % smaller than that for the BC817-40.

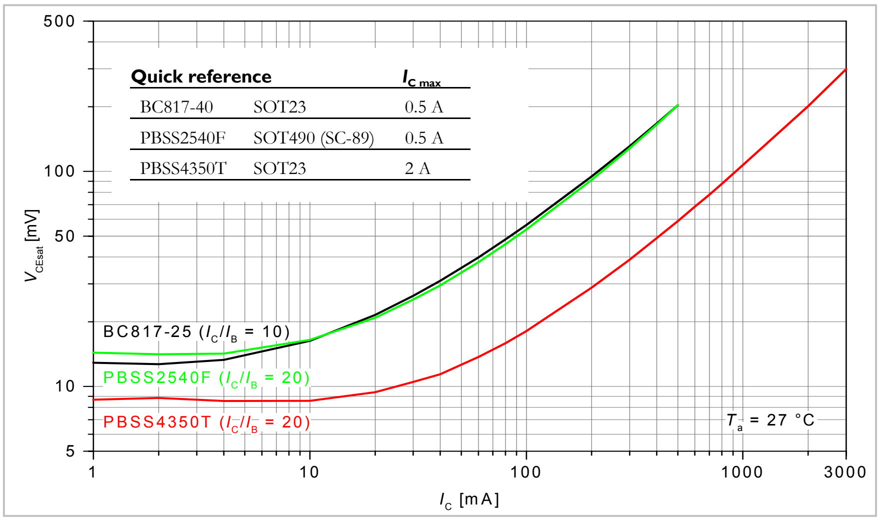


Figure 8: Typical collector-emitter saturation voltage of small signal transistors

[2] Reference: Philips Data Handbook SC 18: Discrete semiconductor packages 1999, chapter 4: Soldering guidelines and SMD footprint design, SOT23 and SOT223, reflow soldering

Figure 9 provides a further comparison of the medium power bipolar transistors BDP31, PBSS4350Z and PBSS4540Z, all SOT223 transistors. The saturation voltage of the PBSS4350Z is about 60 % and of the PBSS4540Z about 30 % of the values of the conventional BDP31.

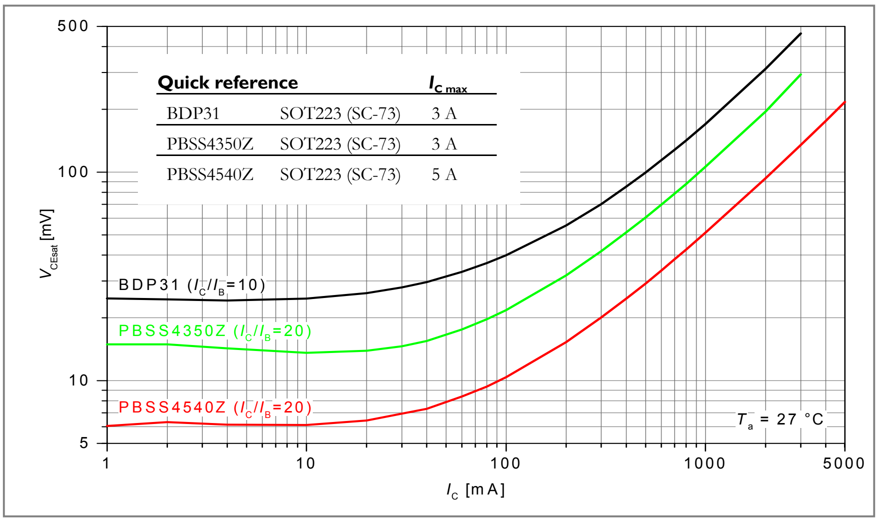


Figure 9: Typical collector-emitter saturation voltage of medium power transistors

The user has several opportunities to profit from the BISS transistor performance by selecting

- an ultra small SOT490 (SC-89) transistor with the V_{CEsat} performance of a SOT23 general purpose transistor,
- a SOT23 transistor with a much lower V_{CEsat} to reduce power dissipation or to avoid a hot spot,
- a SOT23 transistor to be used at I_C = 2 A with a smaller V_{CEsat} than a larger SOT223 (general purpose) medium power transistor. Thus, a larger medium power transistor can be replaced,
- a SOT223 transistor with a much lower V_{CEsat} to reduce power dissipation or to avoid a hot spot,
- a SOT223 transistor to be used at I_C = 5 A. Thus, a larger power transistor can be replaced.

The influence of different base currents is depicted in Figure 10 where the PBSS4540Z and the BDP31 are compared. It can be seen that for low collector currents only 10 % of the base current is required to achieve the same saturation voltage as for the BDP31. For high collector currents a still smaller base current is required.

In opposite, if the same base current is used the saturation voltage becomes about 10 % of the value of the BDP31 at low currents, and 25 % at 3 A.

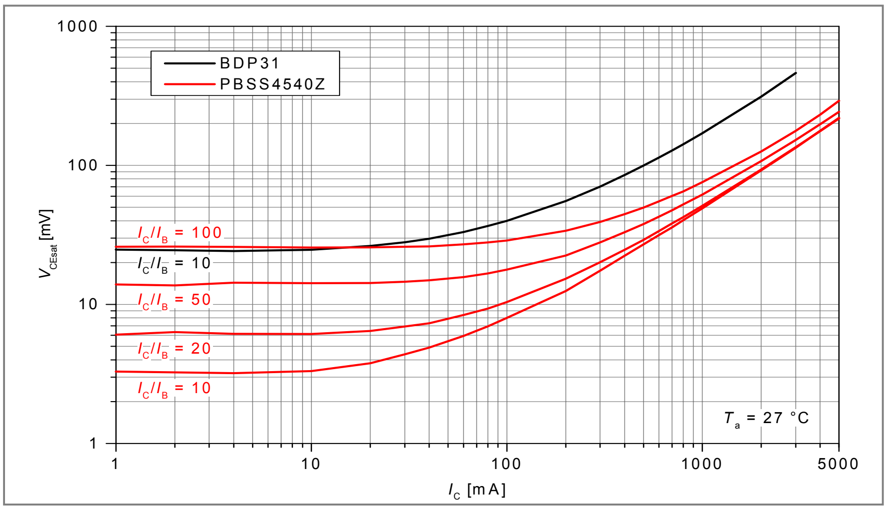


Figure 10: The saturation voltage strongly depends on the driving base current

To conclude, the smaller collector-emitter saturation voltage of low V_{CEsat} (BISS) transistors leads to less dissipated power ($P_C = V_{CEsat} \times I_C$), increases the load's operation voltage, particularly for low voltage applications and thus increases circuit efficiency.

Further on, BISS transistors offer less drop in ***DC current gain h_{FE}*** at high collector currents. Figure 11 shows a normalised comparison of typical DC current gain values of the BC817-40 and the PBSS4350T.

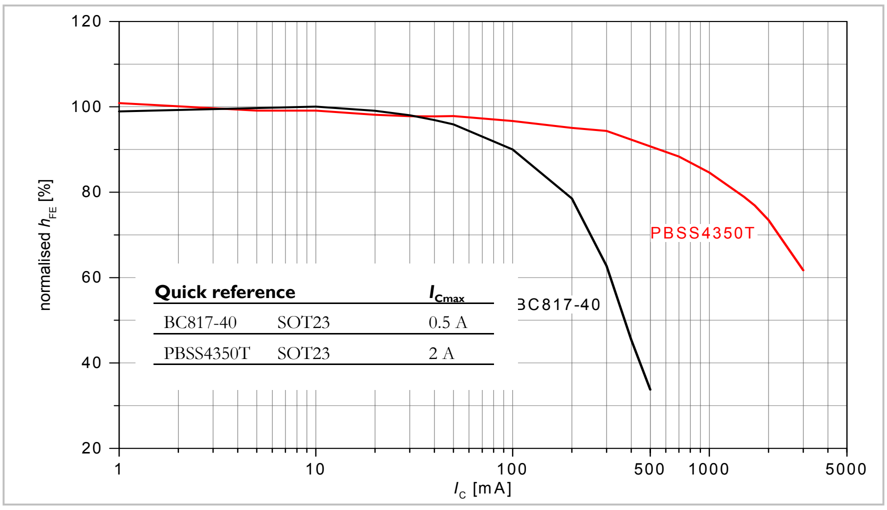


Figure 11: Typical DC current gain of small signal transistors

It can be seen that the current gain of the BC817-40 drops by about 65 % of it's original value at the maximum collector current of 500 mA, while the h_{FE} of the PBSS4350T is only reduced by 10 %. Consequently, the required base current for the conventional transistor has to be much higher than for the BISS transistor.

The smaller required base current of low V_{CEsat} (BISS) transistors takes off some load from the driving (digital) circuit and further reduces the power dissipation of the transistor itself ($P_B = V_{BE} \times I_B$), particularly at high collector currents. Hence, circuit efficiency is further increased.

2.3 Tips for BISS transistor selection

Today (April 2002) 35 BISS transistor devices are released and the portfolio is continuously enlarged further. An overview of these types provides Annex A: Quick selection guide. Even more types will be developed in the future. Please look at our transistor part of our website[3] or contact your next sales representative for updated information.

For many package families there are products in 3-pin packages available. If more power dissipation is required than the 3-pin package can provide one could select a single transistor in a 6-pin package before choosing the next larger package. Table 3 provides an overview of achievable power dissipation depending on package and collector mounting pad.

Table 3: Power dissipation depending on package and collector mounting pad

size code	package	P_{tot} footprint*)	P_{tot} 1 cm²*)	P_{tot} 6 cm²*)	BISS transistor example
1608	SOT490 (SC-89)	250			PBSS2540F
1612	SOT666	250	300		PBSS4140V
2012	SOT323 (SC-70)	250	350		PBSS4140U
2012	SOT363 (SC-88)	270	430		PBSS4240Y
2913	SOT23	250	480		PBSS4240T
2915	SOT457 (SC-74)		600	750	PBSS4350D
6335	SOT223 (SC-73)		1350	2000	PBSS4540Z
leaded	SOT54 (TO-92)	830	n.a.	n.a.	PBSS4350S

*) collector mounting pad

[3] http://www.semiconductors.philips.com/catalog/219/282/27046/30928/41781/index.html

Further on, to reduce power dissipation a transistor with a lower maximum collector-emitter voltage (15 V or 20 V types) can be selected if a high V_{CE0} of 40 to 50 V is not required. Low voltage transistors feature lower V_{CEsat} values than transistors with a higher V_{CE0}. The following diagram shows the V_{CEsat} reduction of the 15 V type PBSS2515F compared to the 40 V type PBSS2540F, to give just one example.

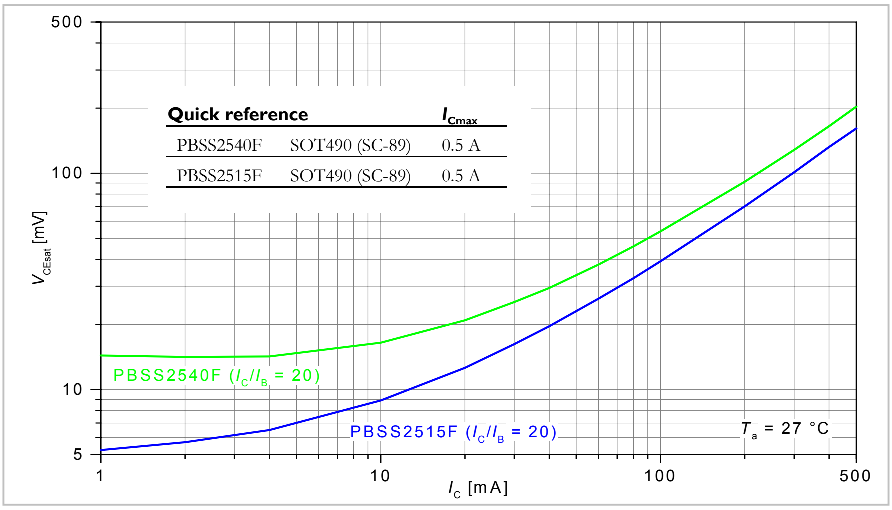


Figure 12: Further V_{CEsat} reduction for low voltage transistors

If the current gain at a given high collector current already started to drop for a selected transistor, a transistor with a higher maximum collector current capability can be selected. For example, the current gain at I_C = 3 A of the 5 A-transistor PBSS4540Z drops by 10 % from its original value whereas that of the 3 A-transistor PBSS4350Z already drops by 70 % (see Figure 13).

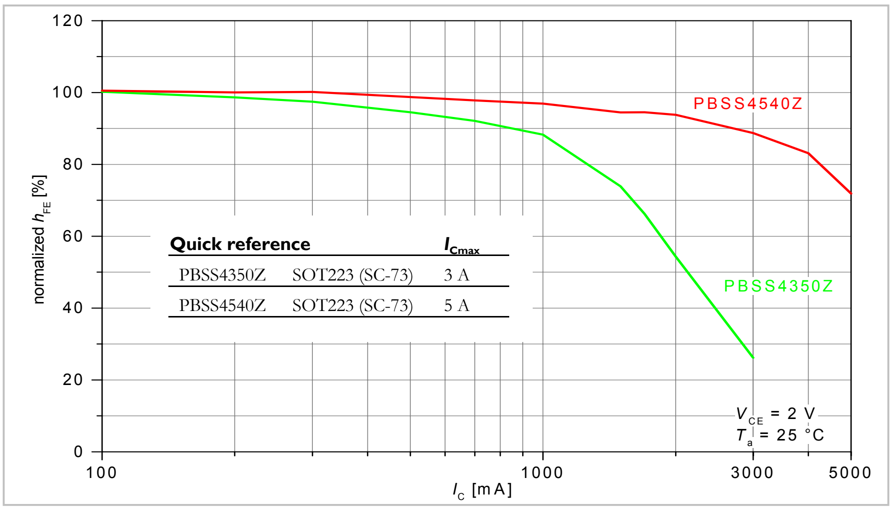


Figure 13: The 5 A-PBSS4540Z features higher current gain at I_C = 3 A than the 3 A-PBSS4350Z

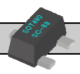
2.4 Conclusions

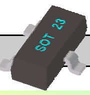
Key features of low V_{CEsat} (BISS) transistors are:

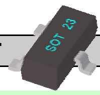
- Low collector-emitter saturation voltage and collector-emitter resistance
- Low power dissipation and consumption
- High collector current capability related to required board space
- High current gain at high collector currents

The following tables contain parameters to compare BISS and conventional transistors by figures. The middle column contains the general purpose transistor data for reference where the left and the right columns include the BISS transistor figures.

Table 4: BISS transistors allow to increase collector current in a given package or to reduce the package size



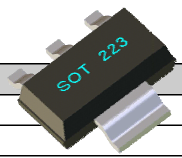




			PBSS2540F			BC817-40			PBSS4350T			
package				**SOT490 (SC-89)**			**SOT23**			**SOT23**		
body size				1.6 x 0.8			2.9 x 1.3			2.9 x 1.3		mm²
collector current (DC)		I_C		**0.5**			**0.5**			**3**		A
peak collector current		I_{CM}		1			1			5		A
collector-emitter voltage		V_{CE0}		40			45			50		V
total power dissipation		P_{tot}		250			250		300		480*)	mW
			min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	
DC current gain	I_C = 0.5 A	h_{FE}	50	130	–	40	130	600	300	580	–	
	I_C = 2 A		n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	200	360	–	
collector-emitter saturation voltage	I_C = 0.5 A	V_{CEsat}	–	200	250	–	200	700	–	60	80	mV
	I_C = 2 A		–	n.a.	n.a.	–	n.a.	n.a.	–	200	260	mV
equivalent on-resistance	I_C = 0.5 A	R_{CEsat}	–	400	500	–	400	1400	–	120	160	mΩ
	I_C = 2 A		–	n.a.	n.a.	–	n.a.	n.a.	–	100	130	mΩ

*) Device mounted on a printed-circuit board, single sided copper, tinplated, mounting pad for collector 1 cm²
n.a. – not applicable

Table 5: BISS transistors allow to increase the collector current or to avoid hot spots



			PBSS4350Z			BDP31			PBSS4540Z			
package				**SOT223**			**SOT223**			**SOT223**		
body size				6.5 x 3.5			6.5 x 3.5			6.5 x 3.5		mm²
collector current (DC)		I_C		**3**			**3**			**5**		A
peak collector current		I_{CM}		5			6			10		A
collector-emitter voltage		V_{CE0}		50			45			40		V
total power dissipation		P_{tot}	1.35*)		2**)		1.35*)		1.35*)		2**)	W
			Min.	typ.	max.	min.	typ.	max.	min.	typ.	max.	
DC current gain	I_C = 0.5 A	h_{FE}	200	335	–	40	75	–	300	500	–	
	I_C = 2 A		100	195	–	20	55	–	250	450	–	
	I_C = 5 A		n.a.	n.a.	–	n.a.	n.a.	–	100	350	–	
collector-emitter saturation voltage	I_C = 0.5 A	V_{CEsat}	–	60	90	–	100	300	–	30	90	mV
	I_C = 2 A		–	200	290	–	310	700	–	90	150	mV
	I_C = 5 A		–	n.a.	n.a.	–	n.a.	n.a.	–	210	355	mV
equivalent on-resistance	I_C = 0.5 A	R_{CEsat}	–	120	180	–	200	600	–	60	180	mΩ
	I_C = 2 A		–	100	145	–	155	350	–	45	75	mΩ
	I_C = 5 A		–	n.a.	n.a.	–	n.a.	n.a.	–	42	71	mΩ

*) Device mounted on a printed-circuit board, single sided copper, tinplated, mounting pad for collector 1 cm²
**) Device mounted on a printed-circuit board, single sided copper, tinplated, mounting pad for collector 6 cm² (approx. 1 inch × 1 inch)
n.a. – not applicable

3. APPLICATIONS

Many applications benefit from the improved performance of BISS transistors. The following examples are intended to provide some ideas for applying BISS transistors focussing on transistor related requirements.

3.1 Inverter and Emitter Follower

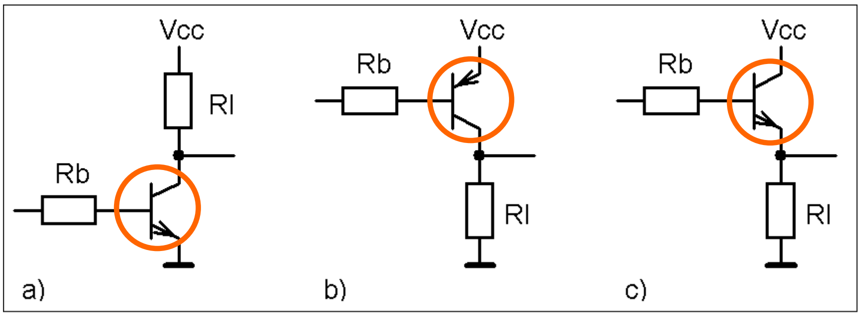


Figure 14: Inverter and emitter follower

Two basic transistor circuits are shown in Figure 14, the inverter in a) and b), and the emitter follower in c), also known as common emitter circuit, and common collector circuit, respectively. Due to the fact that all applications below basically are one of these configurations the following statements are of general nature.

In inverter configuration the transistor operates in normal, or in saturation mode. In normal mode the collector-emitter voltage decreases with increasing input voltage, or base current, respectively. In saturation mode the collector-emitter voltage remains nearly constant even if the input voltage is further increased. The collector-emitter voltage is now called collector-emitter saturation voltage. Inverter circuits which use BISS transistors instead of conventional ones benefit from all the performance improvements described in chapter 2.2.

In emitter follower configuration the output voltage (= emitter voltage) follows the base voltage. The transistor thus always operates in normal mode. Since the voltage gain (V_{out}/V_{in}) is approximately one the circuit's gain depends on the current gain only. Thus, an emitter follower profits from the high current gain and the high collector current capability of BISS transistors but not from the low saturation voltage.

3.2 Power management

DC/DC-converter

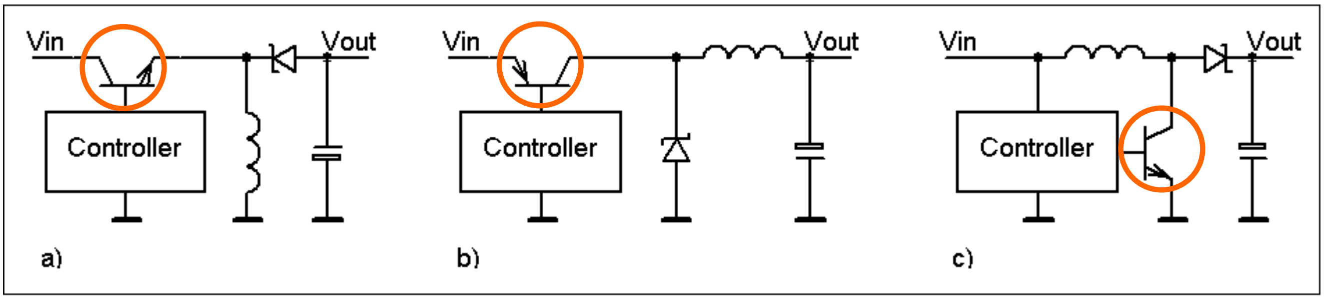


Figure 15: DC/DC-converter topology examples

DC/DC-converter circuits are increasingly used in nearly all electronic devices. The vast variety includes mains driven 3 kW converters as well as very small sized battery driven converters for handheld devices such as PDAs and mobile phones. To reduce heat generation, to increase battery's lifetime and to protect the environment a high efficiency of DC/DC-converters is mandatory.

Due to their excellent performance (see 2.2, again) BISS transistors perfectly fit into DC/DC-converter applications as pass transistors. Figure 15 provides three typical DC/DC-converter topology examples, the step-up/down (buck-boost) converter (a)), the step-down (buck) converter (b)), and the step-up (boost) converter (c)). The transistors operate in emitter follower (a), or in inverter (b), c)) configuration with it's behaviour as described in 3.1 above.

Further, BISS transistors are also applicable to low voltage fly-back and push-pull converters.

Complementary driver

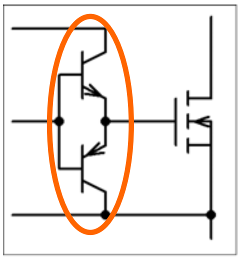


Figure 16: Complementary driver

Table 6: Recommended types for complementary driver application

type	package	description
PBSS4140T / PBSS5140T	SOT23	single, 1 A
PBSS4140DPN	SOT457 (SC-74)	double, 1 A
PBSS2515YPN	SOT363 (SC-88)	double, 0.5 A
PBSS2515VPN	SOT666	double, 0.5 A
PBSS4140S / PBSS5140S	SOT54 (TO-92)	single, 1 A
PMBT2222A / PMBT2907A*)	SOT23	single, 0.6 A

*) no BISS transistors, but reference

The complementary driver is an emitter follower application used in DC/DC-converters and still camera strobes to drive MOSFET switches. The main task is to load and unload the gate capacitance as fast as possible to minimise switching losses. Further, the driver takes off some load from the controller circuit. Thus, a high DC-current gain even at maximum collector current, and a high (peak) collector current capability are important criteria for transistor selection making BISS transistors attractive for this application.

In case cross-conduction is a problem a low-ohmic resistor between the emitter of the NPN-transistor and the gate of the MOSFET can be added. This doesn't affect the turn-off behaviour while delaying turn-on.

Supply line switch

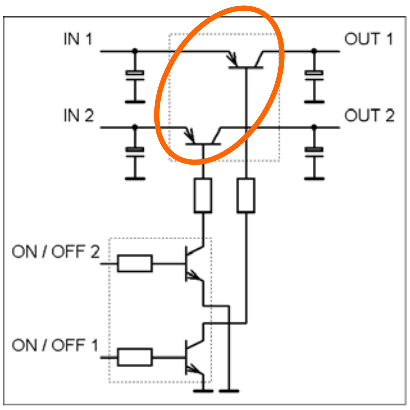


Figure 17: Dual supply line switch

Table 7: Recommended types for supply line switch

type	package	description
PBSS3515VS	SOT666	double, 0.5 A
PBSS5140V	SOT666	single, 1 A
PBSS5140T	SOT23	single, 1 A
PEMH-series	SOT666	double RET*)
PDTC-series	various	single RET*)

*) Resistor Equipped Transistor

Particularly in battery powered equipment (e.g. laptops) it is necessary to switch-off sections, which are actually not in use to extend battery's lifetime. To achieve low losses and to be compliant with the digital logic levels and power supply specifications it is essential that these switches have a low voltage drop, i.e. the saturation voltage of the transistor should be as low as possible. Figure 17 shows an example of a cost-efficient space saving solution by using a double 0.5 A BISS transistor PBSS3515VS along with a double resistor equipped transistor (RET) PEMHx which come both in a ultra-small SOT666 package.

Current extension and low dropout voltage capability for voltage regulator ICs

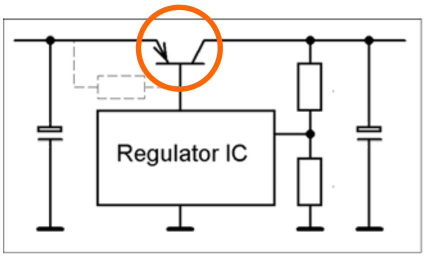


Figure 18: Linear voltage regulator extension (simplified schematic)

Table 8: Recommended types for low drop voltage regulator

type	package	description
PBSS5540Z	SOT223 (SC-73)	single, 5 A, 2 W
PBSS5350Z	SOT223 (SC-73)	single, 3 A, 2 W
PBSS5340D	SOT457 (SC-74)	single, 3 A, 0.75 W
PBSS5350S	SOT54 (TO-92)	leaded, 3 A, 0.83 W

Improved collector current capability, current gain, and saturation voltage of BISS transistors allow an efficient extension of the output current capability of integrated (low drop) voltage regulator ICs (e.g. MAX687, LT1123, ADM666A), at a significantly reduced voltage drop between in- and output.

The typical achievable dropout voltage becomes as low as -55 mV at 0.1 A, or -140 mV at 1 A output current. Due to the high current gain of the vertical transistor only a small base drive current is required, typically I_B = 3.45 mA for I_C = 1 A (figures applicable to PBSS5240T).

Thus, the efficiency can be increased from ≈80 % to >95 %, as the example calculation in Table 9 shows.

It should be noted that all low dropout voltage regulators are more load capacitance sensitive. This trade-off of the low dropout voltage is due to inverting operation of the PNP pass transistor.

To mention another alternative, an LDO-regulator can also be built by using the circuit shown in Figure 19 with the same PNP pass transistor related performance improvements as shown above. For recommended types refer to Table 8.

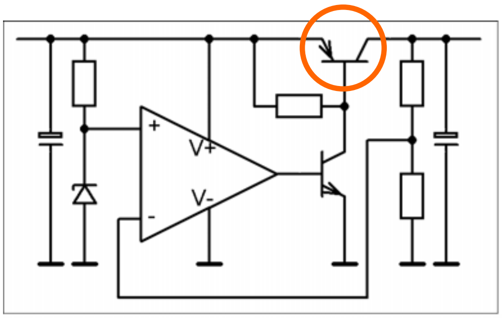


Figure 19: Building a low dropout voltage regulator using standard components

Table 9: Low dropout voltage improves efficiency

	Standard voltage regulator	Low dropout voltage regulator
V_{out}	3.3 V	
I_{out}	1.0 A	
$P_{out} = V_{out} \times I_{out}$	3.3 W	
V_{drop}	1.0 V	0.1 V
$P_{in} = P_{out} + I_{out} \times V_{drop}$	4.3 W	3.4 W
$\eta = P_{out} / P_{in} \times 100$ %	77 %	97 %

Battery charger

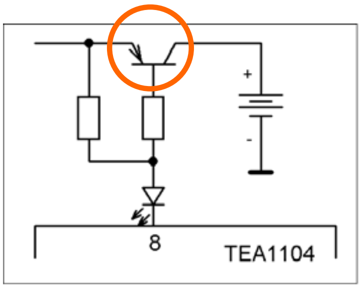


Figure 20: Typical output stage of a battery charger

Table 10: Recommended types for battery charger

type	package	description
PBSS5540Z	SOT223 (SC-73)	single, 5 A, 2 W
PBSS5350Z	SOT223 (SC-73)	single, 3 A, 2 W
PBSS5340D	SOT457 (SC-74)	single, 3 A, 0.75 W
PBSS5350S	SOT54 (TO-92)	leaded, 3 A, 0.83 W

Battery chargers today use intelligent charging methods to meet the requirements of batteries. Monitoring battery voltage, charge current and temperature is state-of-the-art and often done by integrated circuits. However, many ICs require an external discrete pass element. Low V_{CEsat} (BISS) transistors fit perfectly into this application due to their high gain and high current capability.

Table 11: Conventional vs. BISS transistors used in a battery charger

	Conventional	BISS transistor solution
Selected transistors	BD434 (TO-126)	PBSS5350S (TO-92)
Max. collector-emitter voltage	22 V	50 V
Max. collector current I_C	4 A	3 A
Min. current gain at 2 A	50	100
Max. saturation voltage at 2 A	0.5 V	0.3 V

The Philips TEA1104 battery monitor and fast charge IC for NiCd and NiMH batteries is only one example where a BISS transistor can be applied as Figure 20 shows. For example a PBSS5350S can be used as pass transistor instead of the much larger BD434 recommended in the TEA1104 data sheet.

CCFL power supply

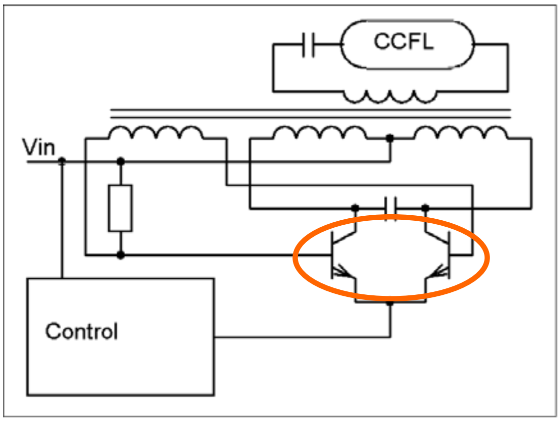


Figure 21: Resonant push-pull CCFL power supply (simplified schematic)

Table 12: Recommended types for CCFL power supply

type	package	description
PBSS4140U	SOT323	single, 1 A
PBSS4140T	SOT23	single, 1 A
PBSS4240T	SOT23	single, 2 A
PBSS4140S	SOT54 (TO-92)	leaded, 1 A

To power cold cathode fluorescent lamps (CCFLs) a high-voltage source is required. Beside the Philips UBA2070 CCFL ballast driver IC a push-pull converter (Royer circuit) shown in Figure 21 is an alternative solution.

The whole circuit consists of the control stage (e.g. UCC3973, LT1172, MAX1610), the resonant push-pull stage – where BISS transistors are recommended to use for efficient operation – and the high-voltage stage.

3.3 Peripheral driver

Simple load driver

Both, the inverter and the emitter follower configuration (see Figure 14) are used to switch heavier loads such as relays, lamps, and motors. The high collector current capability as well as the high current gain makes BISS transistors especially suitable for this kind of applications.

For low voltage applications the low collector-emitter saturation voltage of the inverter circuit supports a proper load operation. For example, load's voltage in a 3 V circuit is larger than 2.9 V (PBSS4350T et. al.) as opposed to 2.3 V using the BC817. The emitter follower circuit offers a low-ohmic output while the high-ohmic input is a negligible load to the source.

If an inductive load is driven the use of a free-wheeling diode is recommended to protect the transistor from voltages above their limits.

LED matrix driver

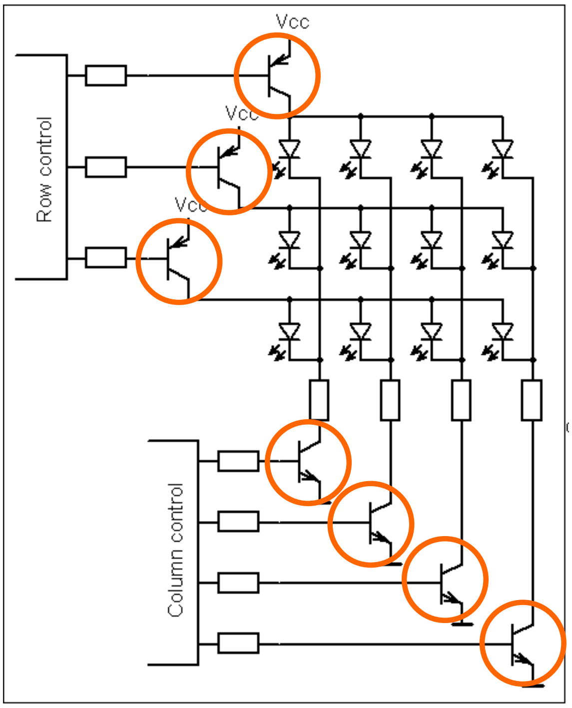


Figure 22: BISS transistors to drive a LED matrix

Figure 22 depicts a fraction of the output circuit of a LED display as it is used for larger graphic or moving message displays. The matrix may contain up to hundreds of LEDs, which would require a huge number of control ports if each LED would be separately driven. The more intelligent solution is to arrange the LEDs within a matrix, and thus to reduce the number of required drivers and wiring significantly.

The LEDs operate using a pulsed current. To obtain the same average current value than for continuous operation the pulse current becomes much higher: $I_{pulse} = I_{cont}$ / duty cyle. For example, if the continuous current in a 25 LED column should be 20 mA, the pulse current is as high as 500 mA for a duty cycle of 4 %.

Using the advantage of the matrix configuration requires transistors with high pulse current capability. Each column driver transistor must be capable to handle this 500 mA pulse current and each row driver must be capable to handle n × 500 mA pulse current where n is the number of rows.

Further, since the transistors are driven from standard logic circuits with limited current driving capability a high current gain is essential. A base current of 1.7 mA is sufficient to ensure saturation at I_C = 500 mA, selecting the PBSS4350T to give just one example.

Because the control logic is rarely capable to generate a 100 mA base drive current for the row driver an additional buffer using general purpose transistors, transistors pairs (e.g. BC847BS), resistor equipped transistors (RETs), or RET pairs is required under the given conditions.

In this particular application the saturation voltage is of a major concern for supply voltages ≤5 V. Two saturation voltages – the column and the row driver saturation voltages – sum up.

The following table summarises with a comparison of conventional vs. BISS transistors used for this particular application.

Table 13: Conventional vs. BISS transistors for driving a LED matrix

	Conventional transistor solution		**BISS transistor solution**	
Function	column driver	row driver	column driver	row driver
Selected transistors	BC817-40 (SOT23)	BDP32 (SOT223)	PBSS4350T (SOT23)	PBSS5540Z (SOT223)
Max. collector-emitter voltage	45 V	45 V	50 V	40 V
Actual pulsed collector current I_C	0.5 A	5 A	0,5 A	5 A
Min. current gain at I_C	40	20 (typ.)	300	50
⇨ required base current for saturation	<12.5 mA	250 mA	<1.7 mA	<100 mA
Max. saturation voltage at I_C	0.7 V +	>1 V	0.09 V +	0.375 V
⇨ resulting voltage drop	1.7 V		<0.435 V	

Motor drivers

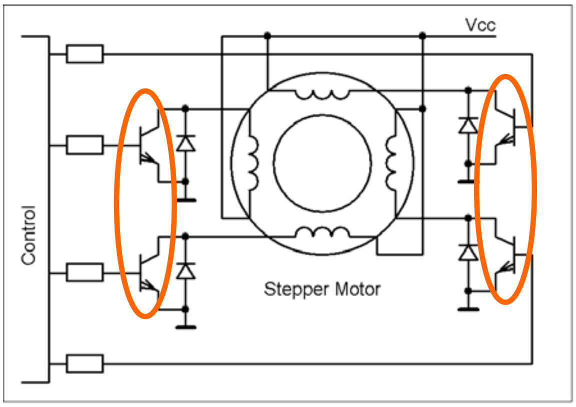


Figure 23: 4-phase stepper motor driver for printers and scanners

Table 14: Recommended types for motor drivers

type	package	description
PBSS2515VS	SOT666	double, 0.5 A
PBSS4350D / PBSS5350D	SOT457 (SC-74)	single, 3 A
PBSS4540Z / PBSS5540Z	SOT223 (SC-73)	single, 5 A
PBSS4140S / PBSS5140S	SOT54 (TO-92)	leaded, 1 A
PBSS4350S / PBSS5350S	SOT54 (TO-92)	leaded, 3 A

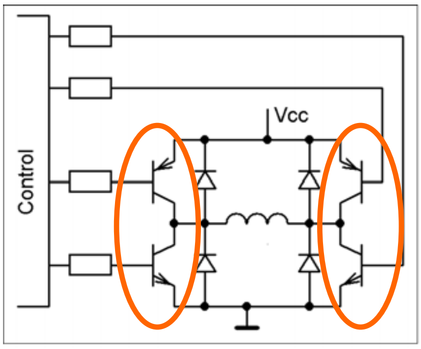


Figure 24: H-bridge motor driver

Figure 23 shows an interface, which drives a 4-phase stepper motor used for example in printers, scanners, copiers, and automotive applications. Figure 24 depicts a H- (full-) bridge to drive a motor in two directions. Discrete bipolar transistors allow an easy adoption of standard motor controller ICs or microcontrollers to different motors by simply selecting the appropriate transistors.

BISS transistors' low saturation voltages lead to an efficient operation even at low supply voltages. That's particularly important for low supply voltages because two saturation voltages sum-up as Table 15 explains.

Further, smaller and cheaper packages can be selected due to the lower power dissipation (e.g. SOT457 / SC-74 instead of SOT223 / SC-73).

Table 15: Conventional vs. BISS transistors used in a H-bridge circuit

	Conventional transistor solution		BISS transistor solution	
Polarity	NPN	PNP	NPN	PNP
Selected transistors	BC817-40 (SOT23)	BC807-25 (SOT23)	PBSS4350T (SOT23)	PBSS5350T (SOT23)
Max. collector-emitter voltage	45 V		50 V	
Actual pulsed collector current I_C	0.5 A		0.5 A	
Min. current gain at I_C	40	40	300	200
⇨ required base current for saturation	<12.5 mA	<12.5 mA	<1.7 mA	<2.5 mA
Max. saturation voltage at I_C	0.7 V +	0.7 V	0.09 V +	0.09 V
⇨ resulting voltage drop	<1.4 V		<0.18 V	

ANNEXES

Annex A: Quick selection guide

Size code	Package	I_C					V_{CE0}				Type, single		Type, double		
											NPN	PNP	2x NPN	2x PNP	NPN / PNP
		0.5 A	1 A	2 A	3 A	5 A	15 V	20 V	40 V	50 V	PBSS...	PBSS...	PBSS...	PBSS...	PBSS...
1608	SOT490 (SC-89)	x					x				...2515F	...3515F			
1612	SOT666	x					x						...2515VS	...3515VS	...2515VPN
1608	SOT490 (SC-89)	x							x		...2540F	...3540F			
1612	SOT666		x						x		...4140V	...5140V			
1612	SOT666			x					x		...4240V*)	...5240V*)			
2012	SOT363 (SC-88)	x					x								...2515YPN
2012	SOT323 (SC-70)		x						x		...4140U	...5140U			
2012	SOT363 (SC-88)			x					x		...4240Y	...5240Y			
2913	SOT23		x						x		...4140T	...5140T			
2915	SOT457 (SC-74)		x						x			...5140D			...4140DPN
2915	SOT457 (SC-74)			x				x							...4220DPN*)
2913	SOT23			x					x		...4240T	...5240T			
2913	SOT23				x			x			...4320T	...5320T			
2915	SOT457 (SC-74)				x			x				...5320D			
2913	SOT23				x					x	...4350T	...5350T			
2915	SOT457 (SC-74)				x					x	...4350D	...5350D			
6535	SOT223 (SC-73)				x					x	...4350Z	...5350Z			
6535	SOT223 (SC-73)					x			x		...4540Z	...5540Z			
leaded	SOT54 (TO-92)		x						x		...4140S	...5140S			
leaded	SOT54 (TO-92)				x					x	...4350S	...5350S			

*) under development

This portfolio overview is as of April 2002 and will be continuously extended.

Annex B: Product coding

PBSS 2 5 15 V S

Philips **B**reakthrough in **S**mall **S**ignal

Polarity
- 2 NPN (I_C < 1 A)
- 3 PNP (I_C < 1 A)
- 4 NPN (1 A ≤ I_C ≤ 10 A)
- 5 PNP (1 A ≤ I_C ≤ 10 A)
- 6 NPN (I_C > 10 A)
- 7 PNP (I_C > 10 A)
- 8 NPN (V_{CE0} > 100 V)
- 9 PNP (V_{CE0} > 100 V)

Max. collector current (I_C)
(actual value depends on polarity figure)

Configuration
- S Double transistor
- PN Complementary transistor pair

Package
- D SOT457 (SC-74)
- E SOT416 (SC-75)
- F SOT490 (SC-89)
- K SOT346 (SC-59)
- S SOT54 (TO-92)
- T SOT23
- U SOT323 (SC-70)
- V SOT666
- X SOT89
- Y SOT363 (SC-88)
- Z SOT223

Max. collector-emitter Voltage (V_{CE0})

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