Important notice

Dear Customer,

On 7 February 2017 the former NXP Standard Product business became a new company with the tradename **Nexperia**. Nexperia is an industry leading supplier of Discrete, Logic and PowerMOS semiconductors with its focus on the automotive, industrial, computing, consumer and wearable application markets

In data sheets and application notes which still contain NXP or Philips Semiconductors references, use the references to Nexperia, as shown below.

Instead of http://www.nxp.com, http://www.philips.com/ or http://www.semiconductors.philips.com/, use **http://www.nexperia.com**

Instead of sales.addresses@www.nxp.com or sales.addresses@www.semiconductors.philips.com, use **salesaddresses@nexperia.com** (email)

Replace the copyright notice at the bottom of each page or elsewhere in the document, depending on the version, as shown below:
- © NXP N.V. (year). All rights reserved or © Koninklijke Philips Electronics N.V. (year). All rights reserved
Should be replaced with:
- **© Nexperia B.V. (year). All rights reserved**.

If you have any questions related to the data sheet, please contact our nearest sales office via e-mail or telephone (details via **salesaddresses@nexperia.com**). Thank you for your cooperation and understanding,

Kind regards,

Team Nexperia

AN10361

Philips BISS loadswitch solutions and the SOT666 BISS loadswitch demo board

Rev. 01.00 — 20 June 2005 Application note

Document information

Info	Content
Keywords	BISS, loadswitch, high side switch, supply line switch, SOT666, low V_{CEsat}, RET
Abstract	This application note describes the Philips BISS loadswitch solutions using improved bipolar technology and the SOT666 BISS loadswitch demo board, complemented by selected measurement results.

PHILIPS

Revision history

Rev	Date	Description
<01>	<20050620>	Initial document

Contact information

For additional information, please visit: http://www.semiconductors.philips.com

For sales office addresses, please send an email to: sales.addresses@www.semiconductors.philips.com

1. Introduction

After the introduction into different loadswitch solutions the demo board will be described and measurement results will be provided to allow the designer a more detailed view to the loadswitch performance.

The SOT666 BISS loadswitch demo board is intended to be used for evaluation purpose of the PBLS1501V – PBLS1503V and PBLS4001V – PBLS4003V BISS Loadswitches in the SOT666 package.

Evaluation results can also be used for the PBLS1501Y – PBLS1503Y and PBLS4001Y – PBLS4003Y BISS loadswitches in SOT363 (SC-88) due to the same electrical and thermal specification and internal die construction.

2. The loadswitch circuit

A loadswitch – also referred to as high side switch or supply line switch – switches a supply voltage to a load or a supply line. It is used to drive fans, relays or motors, to switch sub-circuits like a mobile phone camera module or to build a voltage sequencing circuit. A digital signal switches the load switch ON or OFF.

There are four alternatives to realize a loadswitch circuit as Fig 1 – Fig 4 show.

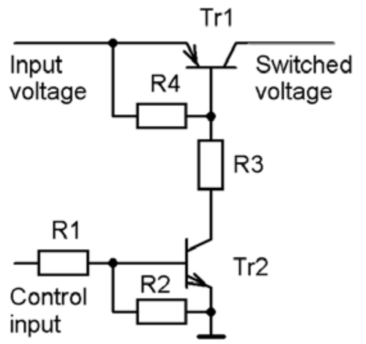


Fig 1. This loadswitch circuit uses bipolar transistors

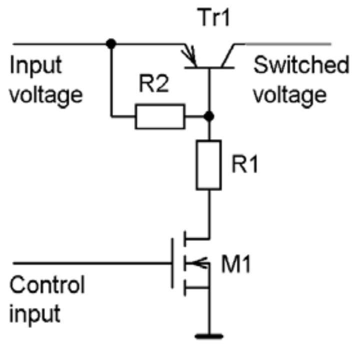


Fig 2. Alternative circuit with a control N-MOSFET

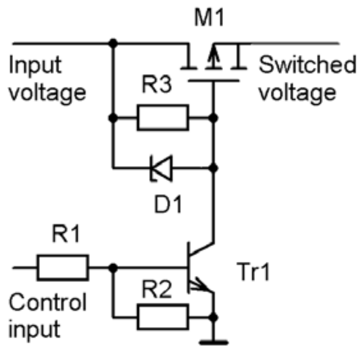


Fig 3. Alternative circuit with a pass P-MOSFET

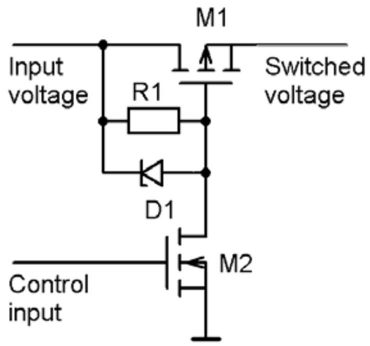


Fig 4. Alternative “pure” MOSFET solution

The loadswitch circuit in Fig 1 consists of six components and uses bipolar transistors. If a positive voltage is applied to the base of the control transistor Tr2 through R1, it switches the pass transistor Tr1. A small base current of about a Milliampere switches up to a few Amperes. The voltage drop across collector and emitter of the pass transistor can be influenced by its base resistor R3. The lower R3, the higher Tr1's base current and the lower the voltage drop, i.e. the saturation voltage. But, the higher the base current and the higher the input voltage the higher the power dissipation of this circuit, mostly through R3.

Fig 2 - Fig 4 show circuit alternatives using MOSFET(s). Depending on cost and performance requirements each alternative has its advantages and disadvantages as Table 1: explains. Compared to MOSFET pass transistor alternatives the major advantage of solutions with a bipolar pass transistor are the far lower costs, the major disadvantage the higher power dissipation particularly for input voltages above 5 V due to the required base current for Tr1 ($P_{tot} = P_C = P_{drive} = V_{CEsat} \times I_C + V_{in} \times I_B$). The P-MOSFET circuits are the most expensive ones and typically require an additional Zener diode for ESD protection.

Table 1: Cost and performance requirements determine the selection of loadswitch components

Pass transistor Control transistor	PNP bipolar NPN bipolar	PNP bipolar N-MOSFET	P-MOSFET NPN bipolar	P-MOSFET N-MOSFET
Reference figure	Fig 1	Fig 2	Fig 3	Fig 4
Cost	+ cheap pass transistor + cheap control transistor	+ cheap pass transistor - expensive control transistor	- expensive pass transistor + cheap control transistor	- expensive pass transistor - expensive control transistor
Power dissipation	- fair	- fair	+ low	+ low
Control input current	• low	+ no	• low	+ no
Threshold voltage	+ low	- high	+ low	- high
Reverse blocking	+ yes	+ yes	- no	- no
ESD sensitive	+ no	+ no	- yes	- yes

3. Bipolar transistor products for loadswitch applications

Philips offers a wide variety of product alternatives to realize a loadswitch allowing to build a discrete, a partly integrated or a fully integrated solution.

The widest flexibility and lowest voltage drop provides the discrete solution. The availability of various low V_{CEsat} (BISS) transistors[1] (PBSS-series) enables to select the best fitting transistor for the application. To limit the higher number of components the use of resistor-equipped transistors (RETs, PDTC-, PDTD-series) is recommended. These are standard transistors with built-in resistors making external resistors R1 and R2 obsolete.

If the current to be switched is less than 100 mA and if there are no tight voltage drop requirements the number of components can be reduced to one if a double NPN/PNP RETs (PIMD-, PUMD-, PEMD-series) is used. The circuit parameter can be set be selecting the most appropriate type out of 13 different combinations of resistance values.

1. see also AN10116 "Breakthrough In Small Signal - Low V_{CEsat} (BISS) Transistors and their Applications"

A partly integrated solution features a low voltage drop and a reduced number of components. The BISS loadswitch contains a PNP low V_{CEsat} (BISS) transistor as pass transistor and a NPN resistor-equipped transistor as control transistor in a 6pin package. The current portfolio (June 2005) includes 0.5 A and 1 A types with different breakdown voltages to meet different application requirements (e.g. V_{CEO} = 60 V for automotive applications) and different integrated resistors to set the control transistor's base current depending on the control input voltage. An external resistor (R3) is used to set the base current of the pass transistor. The voltage drop (= transistor's saturation voltage) decreases with increasing base current, whereas the power dissipation of the loadswitch circuit increases.

Table 2: summarizes the three alternatives of realizing a bipolar loadswitch circuit.

Table 2: The partly integrated solution features a low voltage drop while the number of components could be reduced.

Solution	Discrete	Partly integrated	Fully integrated
Component count	4 – 6	2 – 3	1
Voltage drop	very low	low	higher
Flexibility	broadest portfolio	ability to balance low saturation voltage vs. low base current	large number of available types to meet application requirements
Collector current (I_C)	0.5 – 5 A	0.5 – 1 A	100 mA
Breakdown voltage (V_{CEO})	15 – 100 V	15 – 60 V	50 V
Types	PBSS-series (pass transistor) PDTC-, PDTD-series (control transistor)	PBLS-series	PIMD-, PUMD-, PEMD-series

4. The SOT666 BISS loadswitch demo board

The SOT666 BISS loadswitch demo board contains six loadswitch circuits as shown in Fig 5 – Fig 7. Each of the six circuits contains the BISS loadswitch Q – which includes the PNP pass transistor, the NPN control transistor and its two associated resistors – and two resistors R1 and R2 in size 0603. Additional space is given for optional 1206 sized input and output capacitors C1 and C2. The top row contains the 15 V types PBLS1501V through PBLS1503V whereas the bottom row is assembled with the 40 V types PBLS4001V through PBLS4003V. The difference between PBLSxx01V – PBLSxx03V types is the value of the internal resistors of the control transistor.

Table 3: contains the bill of material for the full board.

The connection of the demo board is done by soldering wires from the related pad to the application circuit or test setup.

Grooves allow to break the circuit into single loadswitch circuits which simplifies their use in the final application.

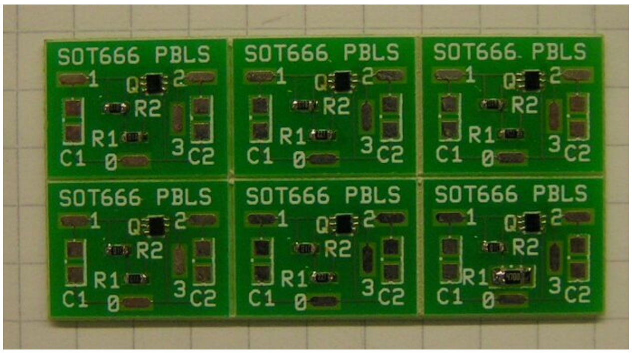


Fig 5. The SOT666 BISS loadswitch demo board

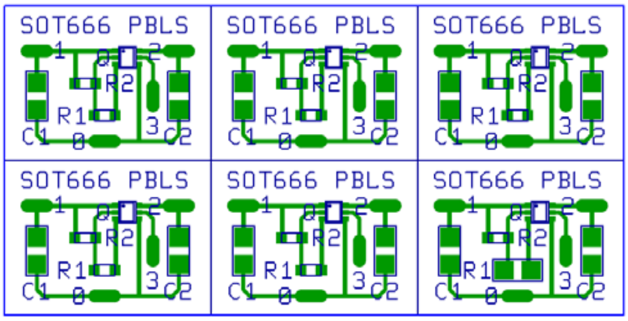


Fig 6. Demo board layout

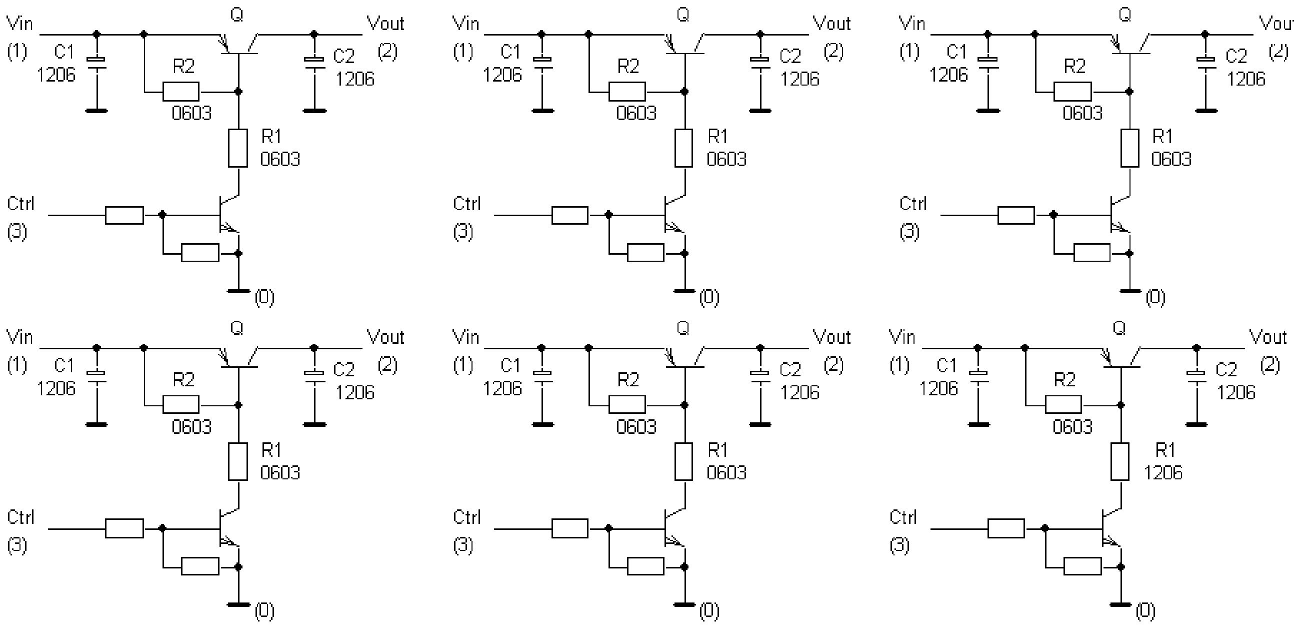


Fig 7. Demo board circuit

Table 3: Bill of materials

Part reference	Qty	Type, Value	Package	Vendor	Remark
Q	1	PBLS1501V (2k2 / 2k2)	SOT666	Philips	Counted from the top left to the bottom right
	1	PBLS1502V (4k7 / 4k7)			
	1	PBLS1503V (10k / 10k)			
	1	PBLS4001V (2k2 / 2k2)			
	1	PBLS4002V (4k7 / 4k7)			
	1	PBLS4003V (10k / 10k)			
R1	1	220R	0603[1]		
R2	1	10k	0603		
C1, C2			1206		not mounted

[1] Note: R1 of the bottom right loadswitch circuit is 1206 sized to improve power dissipation capability

5. Measurement results

This chapter discusses selected test results. Measurements were done for the 40 V-type PBLS4001V and the 15 V-type PBLS1501V. The internal resistance values are 2.2 kΩ for both types. Opposed to the demo board configuration described above, R1 was set to 100 Ω, 220 Ω and 470 Ω, respectively. R2 was kept open. Table 4: through Table 6: contain the measured values. The following paragraphs reflect the outcome.

BISS loadswitches with a lower breakdown voltage (V_{CEO}) feature a lower voltage drop and power dissipation. Comparing the 40 V PBLS4001V and the 15 V PBLS1501V (Table 4: and Table 6:) results in V_{CEsat} = 214 mV, P_C = 88 mW compared to V_{CEsat} = 127 mV, P_C = 52 mW of the latter one. As a guidance the user should select the lowest possible V_{CEO} value.

The lower the forced current gain I_C/I_B the lower the voltage drop V_{CEsat}. Table 5: exemplarily shows that V_{CEsat} decreases from 159 mV to 127 mV if I_C/I_B decreases from 46 to 10. In turn, the circuit needs more drive power ($P_{drive} = V_{in} \times I_B$) which reduces the efficiency. As a consequence the user needs to balance voltage drop and acceptable power dissipation by selecting R1. If the V_{drop} requirement can not be met by using a 500 mA BISS loadswitch the 1 A versions in SOT457 (SC-74) with lower saturation voltage values might be an alternative (see Table 7: below).

The collector-emitter saturation resistance depends on the collector current. Opposed to the $R_{DS(on)}$ of MOSFETs the R_{CEsat} of bipolar transistors depends on the collector current. This can be seen in Table 6: where R_{CEsat} decreases with increasing collector current operating with constant forced current gain I_C/I_B.

The total power dissipation sums up from drive and collector power dissipation. As Fig 9 shows the total power dissipation P_{tot} can be reduced by reducing the drive power dissipation P_{drive}, i.e. the PNP transistor's base current. However, the saturation voltage increase – indicated by the increasing collector power dissipation P_C – must be watched to meet the V_{drop} requirement. If the 500 mA PBLS-series is not sufficient, check the 1 A PBLS-series (see Table 7: below).

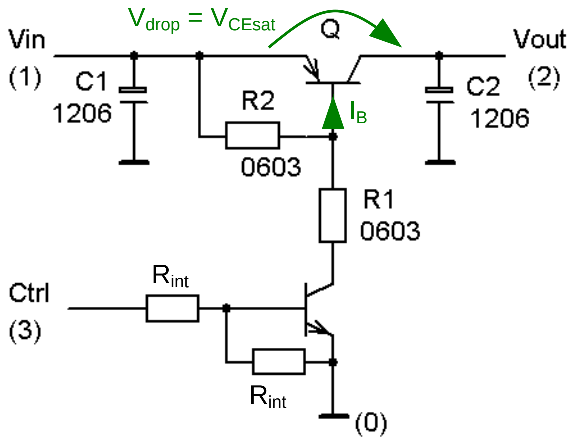


Fig 8. Parameter definition for chapter 5

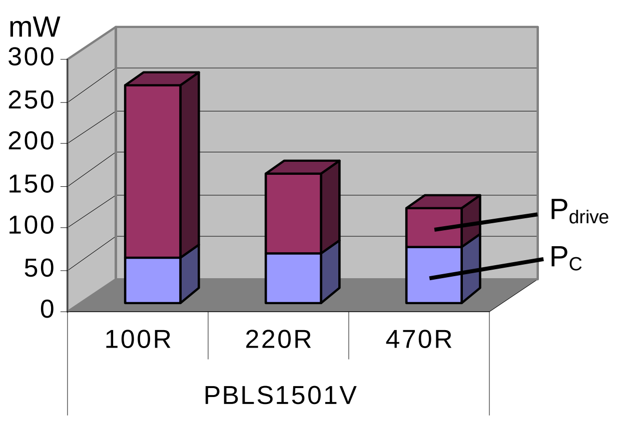


Fig 9. Total power dissipation as a result of drive power dissipation P_{drive} and collector power dissipation P_C

Table 4: PBLS4001V, I_C/I_B = constant

V_{CEO} = 40 V, R_{int} = 2.2 kΩ, R_2 = open

I_C	V_{CEsat}	R_{CEsat}	I_B	I_C/I_B	R_1	P_C	P_{tot}
412 mA	214 mV	519 Ω	41 mA	10	100 Ω	88 mW	293 mW
232 mA	133 mV	573 Ω	19 mA	12	220 Ω	31 mW	126 mW
105 mA	72 mV	686 Ω	9 mA	11	470 Ω	8 mW	53 mW

Table 5: PBLS1501V, I_C = constant

V_{CEO} = 15 V, R_{int} = 2.2 kΩ, R_2 = open

I_C	V_{CEsat}	R_{CEsat}	I_B	I_C/I_B	R_1	P_C	P_{tot}
412 mA	127 mV	308 Ω	41 mA	10	100 Ω	52 mW	257 mW
412 mA	140 mV	340 Ω	19 mA	22	220 Ω	58 mW	153 mW
412 mA	159 mV	386 Ω	9 mA	46	470 Ω	66 mW	111 mW

Table 6: PBLS1501V, I_C/I_B = constant

V_{CEO} = 15 V, R_{int} = 2.2 kΩ, R_2 = open

I_C	V_{CEsat}	R_{CEsat}	I_B	I_C/I_B	R_1	P_C	P_{tot}
412 mA	127 mV	308 Ω	41 mA	10	100 Ω	52 mW	257 mW
232 mA	77 mV	332 Ω	19 mA	12	220 Ω	18 mW	113 mW
105 mA	39 mV	371 Ω	9 mA	12	470 Ω	4 mW	49 mW

6. Calculating and selecting BISS loadswitches

Typically, there are three application based parameters: Maximum input voltage, switch current and maximum voltage drop. Further, there might be a limitation for Tr2's base current and for the maximum power dissipation of the loadswitch circuit (parameter definition refers to Fig 1).

Selection criteria:

- $V_{CEO\,(Tr1)} \geq V_{in}$ — determining breakdown voltage (Tr1)
- $I_{C\,(Tr1)} \geq I$ — determining collector current (Tr1)
- $I_{B\,(Tr1)} = I_{C\,(Tr1)} / (I_C/I_B)_{(Tr1)}$ — setting base current (Tr1), I_C/I_B := 10 – 100
- $R_3 = (V_{in} - V_{BEsat\,(Tr1)} - V_{CEsat\,(Tr2)}) / I_B$ — calculating resulting resistance value (R3)
- $P_{R3} = I_B^2 \times R_3$ — calculating resistor's power dissipation (R3)
- $(I_C/I_B)_{(Tr2)} = I_{B\,(Tr1)} / I_{B\,(Tr2)}$ — $I_C/I_B \leq 100$, transistor saturated?
- $R_1 = (V_{ctrl} - V_{BEsat\,(Tr2)}) / I_{B\,(Tr2)}$ — calculating base resistor (R1)

The data sheet contains all relevant information like limiting values and V_{CEsat} curves.

Example:

V_{in} = 5 V; I = 200 mA; V_{ctrl} = 3,3 V; I_{ctrl} = 0,5 mA; V_{drop} = 100 mV typical

- $V_{CEO\,(Tr1)}$:= 15 V
- $I_{C\,(Tr1)}$:= 0.5 A ➔ PBLS15xxV
- $I_{B\,(Tr1)}$ = 200 mA / 20 = 10 mA ➔ I_C/I_B = 20 sufficient for V_{drop} requirement
- R_3 = (5 V – 1 V – 0.5 V) / 10 mA = 350 Ω
- P_{R3} = (10 mA)² x 330 Ω = 33 mW ➔ 330 Ω (next lower E24 value), size 0603
- $(I_C/I_B)_{(Tr2)}$ = 10 mA / 0.5 mA = 20
- R_1 = (3.3 V – 0.8 V) / 0.5 mA = 5 kΩ ➔ PBLS1502V (R1 = 4.7 kΩ)

This example is based on nominal values and yet disregards parameter spread of the resistance values and saturation voltage.

Table 7: gives an overview about the released BISS loadswitch types (June 2005).

Table 7: The BISS loadswitch portfolio contains 0,5 A and 1 A types

$I_{C\,Tr1}$	$V_{CEO\,Tr1}$	SOT457 (SC-74)	SOT363 (SC-88)	SOT666	V_{CEsat} @ I_C = 0,5 A
0.5 A	15 V		PBLS15xxY	PBLS15xxV	250 mV
	40 V		PBLS40xxY	PBLS40xxV	350 mV
1 A	20 V	PBLS20xxD			150 mV
	40 V	PBLS40xxD			170 mV
	60 V	PBLS60xxD			180 mV

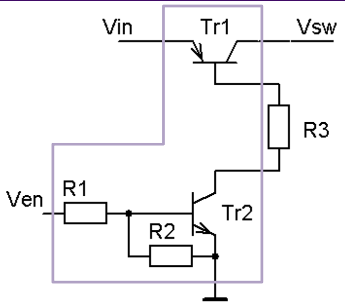
[2] Note: “xx” indicates a sequential number used to distinguish between different internal resistance values R1 and R2: 01 – 2.2 kΩ, 02 – 4.7 kΩ, 03 – 10 kΩ, 04 – 22 kΩ

7. Applications for BISS loadswitches

Beside standard applications like a supply line switch (e.g. camera module in a mobile phone) in Fig 10 or as high side switch (e.g. fan driver in a notebook) in Fig 11 the BISS loadswitches can be used to realize a voltage selector or a switchable constant current source.

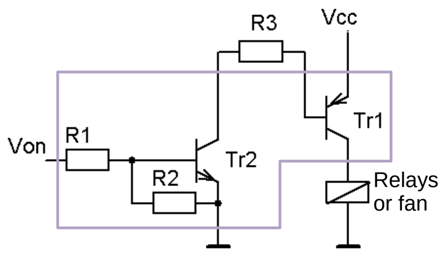
Fig 12 shows a voltage selector which switches either 3.3 V or 5 V to V_{out} depending on the logic signal at V_{sel} as it could be used to manage 3.3 V and 5 V SIM cards. The voltage drop of both input rails is minimized by applying a BISS loadswitch for the 5 V rail and a low V_F (MEGA) Schottky rectifier[2] or a low V_F small signal Schottky diode for the 3.3 V rail. If other voltages are used, please note that always the higher voltage needs to be connected to the Schottky diode.

A generic constant current source is given in Fig 13. R1 sets the current through D1 and D2, which must be much higher than the base current through Tr1 to achieve an unloaded voltage divider. R2 is used to set the output current I_{out}. The output current can be switched off by connecting V_{en} to ground.



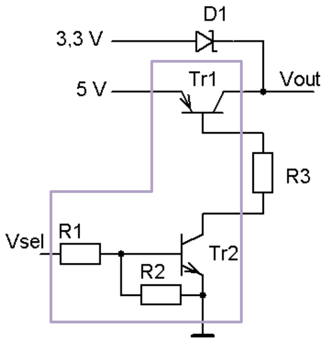
(1) Tr1, Tr2, Rint: 1x PBLS-series
R1: 1x standard resistor

Fig 10. Supply line switch uses only two components



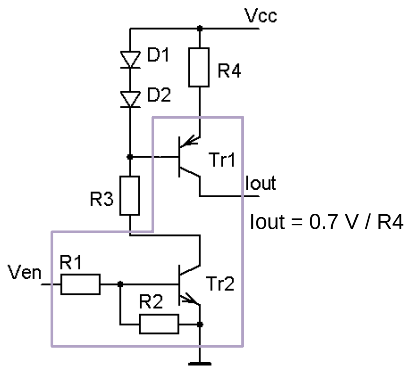
(2) Tr1, Tr2, Rint: 1x PBLS-series
R1: 1x standard resistor

Fig 11. Two component loadswitch



(3) Tr1, Tr2, Rint: 1x PBLS-series
D1: 1x PMEG-series or 1x BAT754
R1: 1x standard resistor

Fig 12. Voltage selector needs only three instead of six single components



(4) Tr1, Tr2, Rint: 1x PBLS-series
D1, D2: 1x BAV99W
R1, R2: 2x standard resistors

Fig 13. Switchable constant current source only requires four instead of eight single components

2. see also AN10230: "The PMEG1020EA and PMEG2010EA MEGA Schottky diodes – a pair designed for high efficiency rectification"

8. Disclaimers

Life support — These products are not designed for use in life support appliances, devices, or systems where malfunction of these products can reasonably be expected to result in personal injury. Philips Semiconductors customers using or selling these products for use in such applications do so at their own risk and agree to fully indemnify Philips Semiconductors for any damages resulting from such application.

Right to make changes — Philips Semiconductors reserves the right to make changes in the products - including circuits, standard cells, and/or software - described or contained herein in order to improve design and/or performance. When the product is in full production (status 'Production'), relevant changes will be communicated via a Customer Product/Process Change Notification (CPCN). Philips Semiconductors assumes no responsibility or liability for the use of any of these products, conveys no licence or title under any patent, copyright, or mask work right to these products, and makes no representations or warranties that these products are free from patent, copyright, or mask work right infringement, unless otherwise specified.

Application information — Applications that are described herein for any of these products are for illustrative purposes only. Philips Semiconductors make no representation or warranty that such applications will be suitable for the specified use without further testing or modification.

9. Contents

Date of release:20 June 2005

Document number: <12NC>

Published in Germany