SIEMENS

# IC for Inductive Proximity Switches with Short-Circuit Protection

**TCA 505 BG**

**Pb-free lead plating; RoHS compliant**

**Bipolar IC**

## Features

- Wide supply voltage of 3.1 to 4.5 V and 4 to 40 V
- Low current consumption of less than 0.8 mA
- Integrated output stage for up to 60 mA output current
- Short-circuit and overload protection of output stages and external components
- Temperature response of the IC compensates that of the coil
- High noise immunity
- High switching frequencies up to 5 kHz
- Useful extra functions
- Suitable for two-wire AC proximity switches
- Temperature range – 40 to 110 ˚C



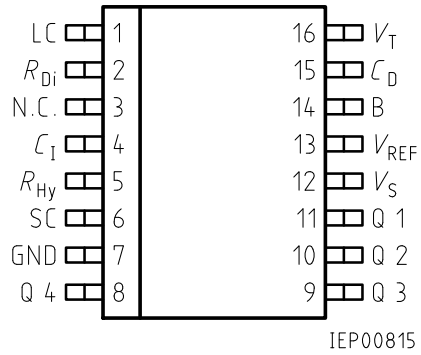
**PG-DSO-16-1**

| Type | Ordering Code | Package |
|---|---|---|
| TCA 505 BG | Q67000-A8341 | PG-DSO-16-1 (SMD) |
| TCA 505 B | Q67000-A8342 | Chip |

Besides its basic functions (oscillator, demodulator and threshold switch), the bipolar monolithic IC TCA 505 B includes a number of useful extra functions that enable high-grade, inductive proximity switches to be designed for an attractive price/performance ratio and with space savings.

Compared to earlier ICs for inductive proximity switches temperature drift, noise immunity and the switching frequency of the IC have been improved.

**TCA 505 BG**

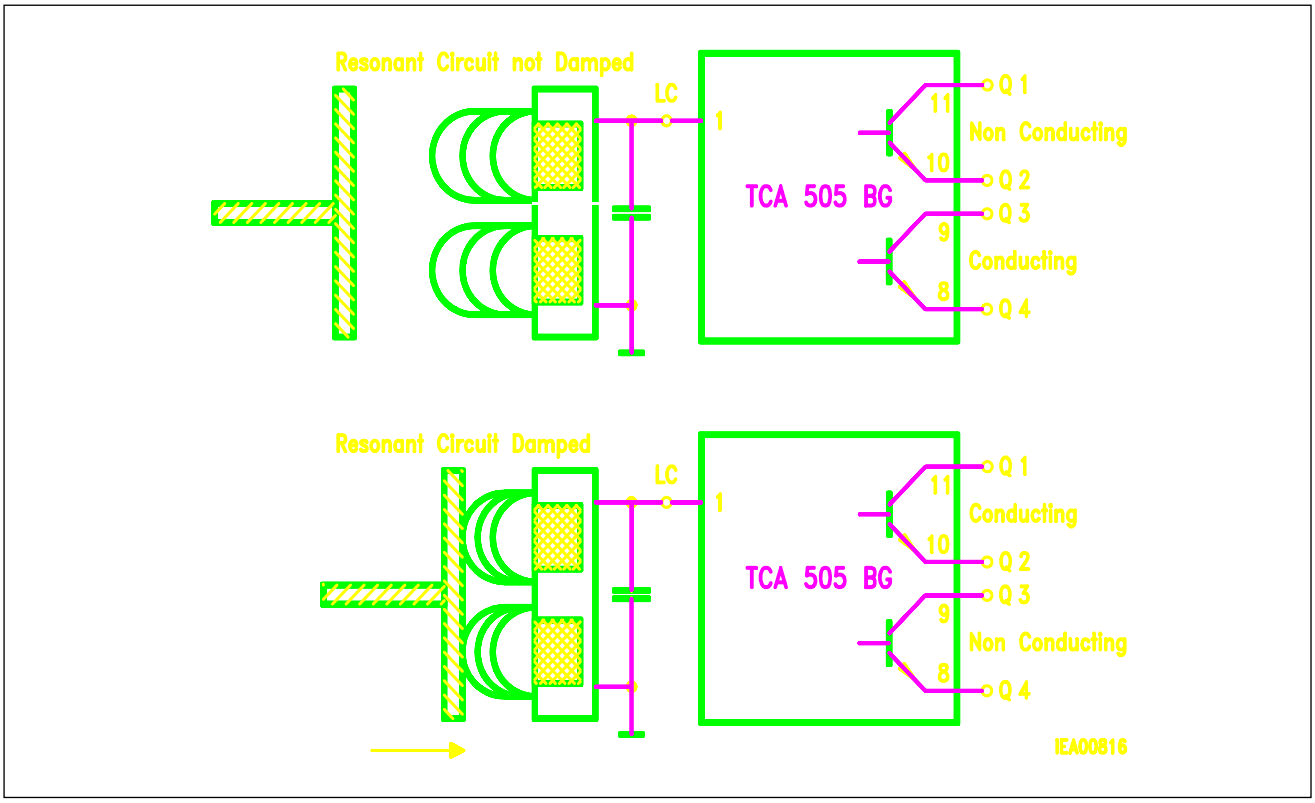



**Pin Configurations**
(top view)

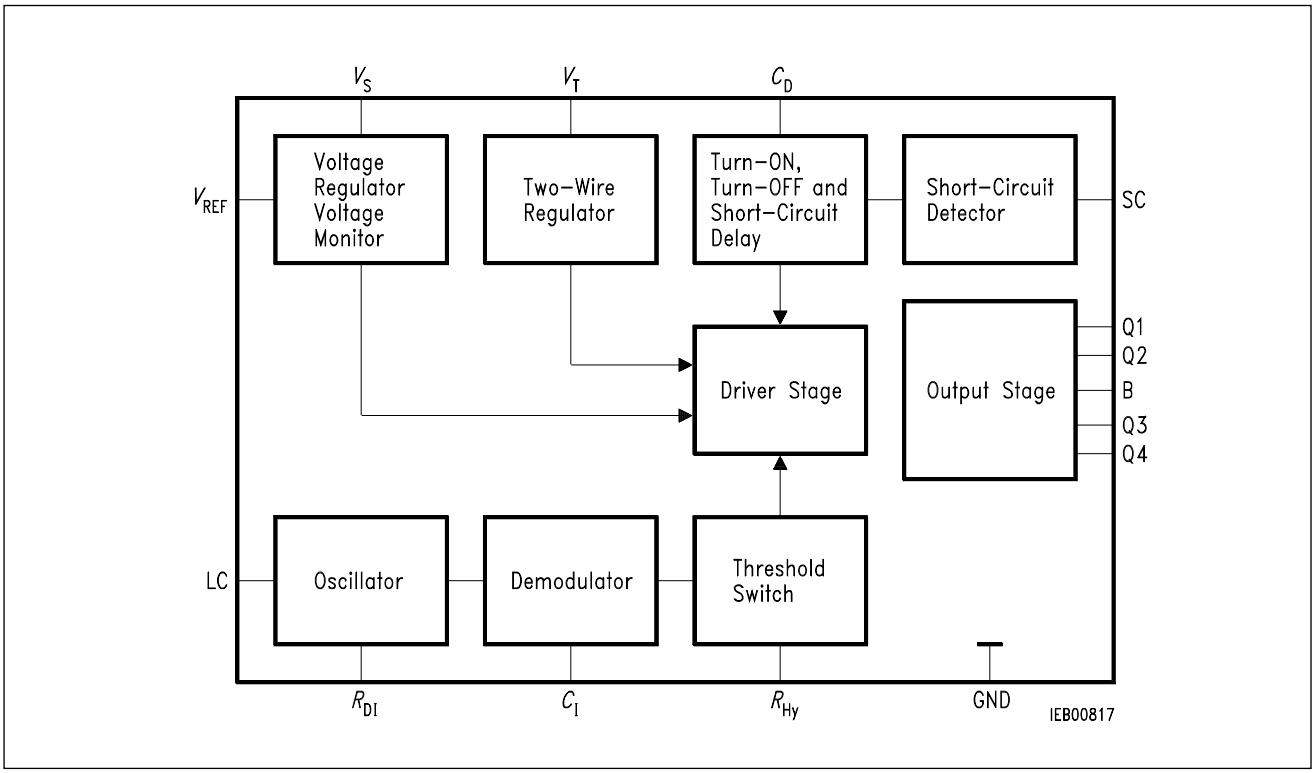
**Pin Definitions and Functions**

| Pin | Symbol | Function |
|---|---|---|
| 1 | LC | Oscillator |
| 2 | $R_{Di}$ | Distance |
| 3 | N.C. | Not connected |
| 4 | $C_I$ | Integrating capacitance |
| 5 | $R_{Hy}$ | Hysteresis |
| 6 | SC | Short-circuit detector |
| 7 | GND | Ground |
| 8 | Q4 | Output |
| 9 | Q3 | Output |
| 10 | Q2 | Output |
| 11 | Q1 | Output |
| 12 | $V_S$ | Supply voltage |
| 13 | $V_{REF}$ | Reference voltage |
| 14 | B | Base Output Transistors |
| 15 | $C_D$ | Turn-ON delay / Short-circuit delay |
| 16 | $V_T$ | Two-wire regulator |

## Functional Description and Application




**Operation Schematic**




**Block Diagram**

## Functional Description

This circuit is used to design inductive proximity switches. The resonant circuit of the LC oscillator is implemented with an open half-pot ferrite and a capacitor in parallel (pin LC). If a metallic target is moved closer to the open side of the half-pot ferrite, energy is drawn from the resonant circuit and the amplitude of the oscillation is reduced accordingly. This change in amplitude is transmitted to a threshold switch by means of a demodulator and triggers the outputs (**see operation schematic**).

By means of an external distance resistor on the oscillator (pin $R_{Di}$) it is possible to set the switching distance within wide limits, the optimal distances being 0.1 to 0.6 of the diameter of the half-pot ferrite, although both of these parameters can be exceeded. The circuit also enables the setting of a path hysteresis by switching of the external distance resistor via pin $R_{Hy}$ (**see application circuit 1**).

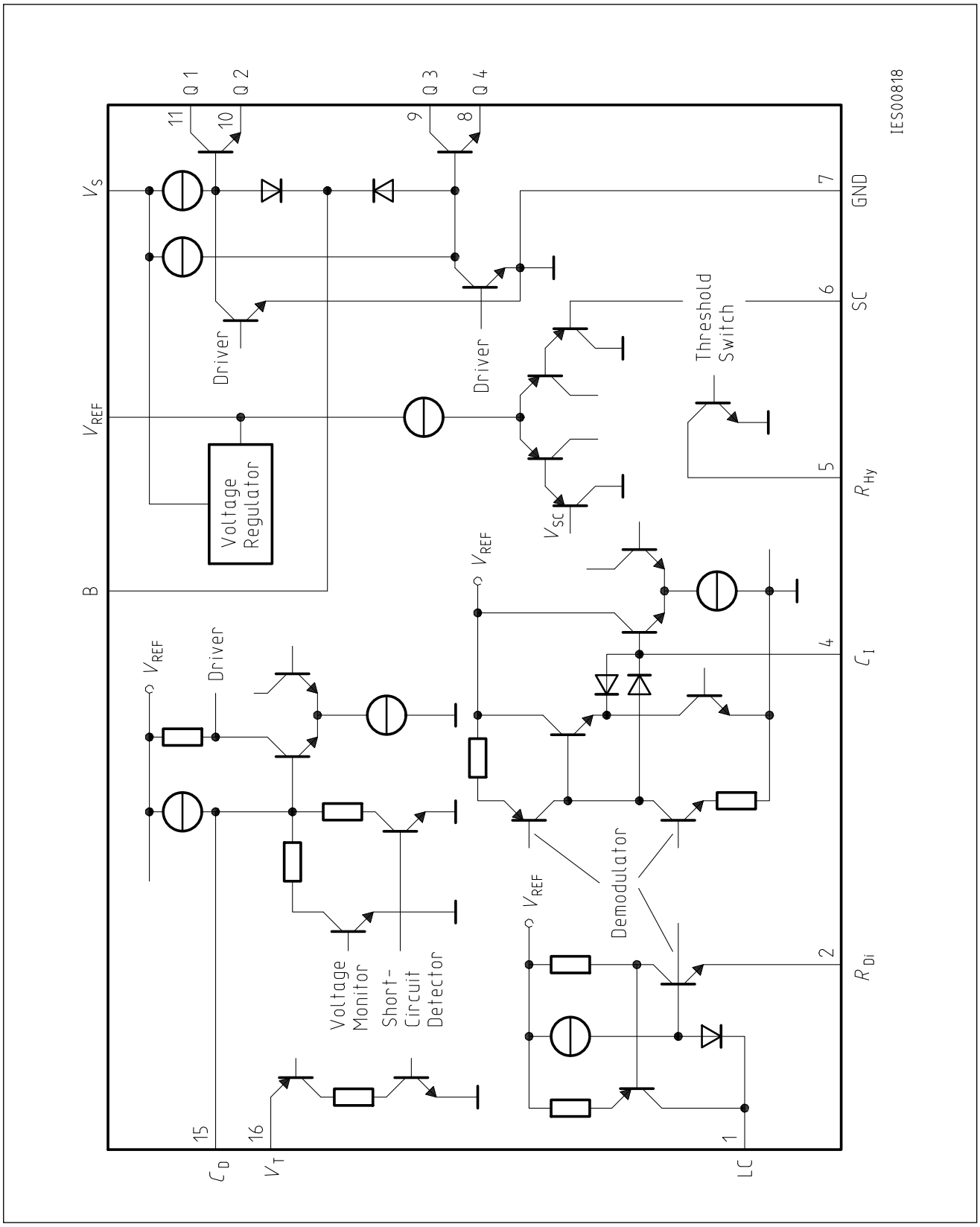
There are two antiphase output stages (Q1 / Q2 and Q3 / Q4) for max. 50 mA. The output transistors are driven in a floating state thus providing the user with optimal flexibility for evaluation of the output signals. It is therefore possible to use the output transistors either as emitter follower, open-collector, as a current source or in push-pull operation. When pin B is connected to $V_{REF}$, Q2 and Q4 can be used between 0 V and $V_{REF}$. The maximum base voltage of the output transistors can be set on pin B. If B is connected to $V_{REF}$, any constant current up to 50 mA can be set on the outputs by means of resistors on Q2 or Q4 (**see application circuits 2 and 3**).

Q1 through Q4 and also additional external output transistors can be protected against destruction by short-circuit or overload. This is the purpose of pin SC which turns off the output transistors periodically in the presence of overload.

By means of a capacitor on $C_D$ it is possible to set the response delay and the turn-OFF time of short-circuit protection. The same capacitor also defines the turn-ON delay of the output stages when the supply voltage is applied, whereby the output stages are inhibited during buildup of the oscillator. Finally $C_D$ produces a turn-OFF delay of the output stages to prevent the turn-ON delay from running its full length at brief voltage dips on $V_S$.

A switching regulator is incorporated for the voltage supply of the circuit when it is used as a two-wire AC proximity switch, and this is activated when pin $V_T$ is connected to $V_S$. The circuit has a stabilized voltage of approx. 2.9 V that is brought out on pin $V_{REF}$.

Supply-voltage range: The operating range in normal operation is between 4 and 40 V. If pin $V_{REF}$ is connected to $V_S$, the circuit is operating between 3.1 and 4.5 V. In this case, however, $V_{REF}$ is no longer internally stabilized, i.e. the analog IC functions depend on the operating voltage.




**Circuit Diagram** (simplified)

## Pin Functions

### Pin 1; LC

The resonant circuit of the proximity switch is connected between LC and ground.

### Pin 2; $R_{Di}$

A resistor between this pin and ground sets the current in the oscillator circuit. The greater the value of the resistor, the smaller is the current feed from the oscillator into the resonant circuit and the greater therefore is the switching distance. The greater the Q of the resonant circuit, the greater is the value of the distance resistor necessary for setting a certain switching distance.

### Pin 4; $C_I$

$C_I$ can remain open; if high noise immunity is to be achieved however, this pin should be provided with a series RC element ($R_I$, $C_I$). If pin $C_D$ is not used, a correctly dimensioned RC element on this pin will also prevent any erroneous pulses on the output when the supply voltage is turned on (**see application circuit 1**).

### Pin 5; $R_{Hy}$

Depending on the status of the circuit, $R_{Hy}$ will be high-impedance or low-impedance to ground (open collector). If the distance resistance (see $R_{Di}$) is split into two resistors $R_{Di}$ and $R_{Hy}$, a distance hysteresis can be set by means of $R_{Hy}$. If series hysteresis is applied, $R_{Hy}$ is connected in series with $R_{Di}$ or shorted. If parallel hysteresis is applied, $R_{Hy}$ is connected in parallel with $R_{Di}$ or made high-impedance (**see application circuit 1**).

### Pin 6; SC

SC serves for short-circuit sensing in the output circuit that is to be protected. The current can be sensed referred to ground or $V_S$. The current sensing is made by a dedicated resistor in the output circuit. For a voltage drop $\geq$ 0.3 V across $V_S$ and SC or across ground and SC, all outputs are turned off after the turn-OFF delay (brief glitches on the outputs or the charging of line capacitances therefore do not trigger the short-circuit protection). After a pause about 200 times the turn-off delay, the outputs turn-ON again. If the short-circuit is still present, the turn-OFF cycle will start up anew.

Both the internal output stages and externally connected output stages can be protected against sustained short-circuits or overload.

A limiting of the output current is an externally connected output stage during the turn-off delay must be ensured. Normally the current limiting by the $\beta$ of the output transistor is sufficient, meaning that no further circuit devices are called for (**see application circuits**). The outputs Q1 to Q4 are already internally protected against overcurrent so that, in the case of a short-circuit, the current will not exceed 250 mA.

In order to prevent thermal overloads, the current-conducting output is to be connected to pin SC (**see application circuit 4**).

**Pins 8, 9, 10, 11; Outputs Q1, Q2, Q3, Q4**

Q1 is the open collector, Q2 the open emitter of one output transistor, Q3 the open collector and Q4 the open emitter of the second output transistor in antiphase with the first output transistor (**see operation schematic**). Q1 and Q3 or Q2 and Q4 can be connected in parallel as required. The function of the outputs is ensured when the emitter potential of the output transistors (Q2, Q4) is between 0 V and the voltage on pin B. If B is not connected, the operating range of Q2 and Q4 extends to approx. $V_S$ – 2 V. For current setting on the outputs, **see pin B**.

**Pin 12; $V_S$**

Outputs Q1 through Q4 are inhibited as long as the voltage on $V_S$ is below approx. 3.6 V. They are enabled between approx. 3.6 and 4 V, the basic function of the circuit is then ensured. During the turn-ON and turn-OFF of $V_S$ there are consequently no undesirable static states. The operating data and characteristics apply upwards from 4 V. See pin $C_D$ for the avoidance of erroneous pulses during oscillator buildup.

**Pin 13; $V_{REF}$**

The internal stabilized voltage of the IC of approx. 2.9 V appears on this pin. A capacitor can be connected between $V_{REF}$ and ground to improve the noise immunity of the overall circuit function. If $V_{REF}$ is connected to $V_S$, it is possible to operate the circuit in a supply- voltage range of 3.1 through 4.5 V. In this case $V_{REF}$ is no longer stabilized. The analog functions of the circuit e.g. switching distance, however, are then dependent on the supply voltage.

**Pin 14; B**

This pin serves for limiting the base voltage of the internal output-stage transistors. If this pin is connected to $V_{REF}$ for example, it is possible to set a constant output current ($I_Q = V_{REF}$ / external resistor) that is independent of the supply voltage by means of an external resistor across Q2 (or Q4) and ground (watch out for power dissipation!).

**Pin 15; $C_D$**

A capacitor on this pin delays the activation of the outputs after the supply voltage is applied (turn-ON delay). In this way erroneous pulses are prevented on the output during buildup of the oscillator.

If $V_S$ falls to less than 3.6 to 4 V, the outputs are not inhibited until after a turn-OFF delay time, this also being determined by $C_D$. In this way the delayed turn-ON operation described above is suppressed if there are just short glitches (voltage dips) on $V_S$. This is of particular advantage for large core diameters, because in such cases a relativity long turn-ON delay has to be selected and the delayed twin-on operation would otherwise be activated each time there was a brief voltage dip.

The capacitor $C_D$ also sets the turn-off delay and the pause duration in short-circuit operation. The sample / pause ratio is approx. 1:200 (**see pin SC**).

If these functions can be dispensed with, $C_D$ can remain open.

**Pin 16; $V_T$**

If this pin is connected to + $V_S$, the supply voltage of the IC (when used as a two-wire proximity switch) can be generated by switching the outputs. The quiescent current can then be kept low. This mode is primarily suitable for AC switches with power supply by phase-control.

The switching of the outputs is made in a $V_S$ range of 6 to 8 V. At 8 V the outputs are turned on, until $V_S$ falls to 6 V. At 6 V the outputs are inhibited, until $V_S$ again reaches 8 V. In this mode $V_S$ should not exceed 14 V or fall below 4 V.

**Absolute Maximum Ratings**
$T_A$ = – 40 to 110 ˚C

| Parameter | Symbol | Limit Values | | Unit | Test Condition |
|---|---|---|---|---|---|
| | | min. | max. | | |
| Supply voltage | $V_S$ | – 0.3 | 42 | V | |
| Output voltages<br>B open<br>B connected | $V_{Q1}$; $V_{Q3}$<br>$V_{Q2}$; $V_{Q4}$<br>$V_{Q2}$; $V_{Q4}$ | – 1<br>– 1<br>– 1 | 41<br>$V_S$ + 1<br>$V_B$ | V<br>V<br>V | $V_{Q2}$; $V_{Q4} \leq V_S$<br>$V_{Q2}$; $V_{Q1}$; $V_{Q4}$<br>< $V_{Q3}$ |
| Output currents | $I_{Q1}$; $I_{Q3}$<br>– $I_{Q2}$; – $I_{Q4}$ | 0<br>0 | 60<br>60 | mA<br>mA | does not apply to shortcircuit |
| Voltage on $V_T$ | $V_T$ | – 0.3 | 14 | V | |
| Current on $V_{REF}$ | – $I_{REF}$ | 0 | 100 | µA | |
| Voltage on SC | $V_{SC}$ | 0 | $V_S$ | V | |
| Current from $R_{Di}$ | – $I_{RDi}$ | 0 | 2 | mA | |
| Current to $R_{Hys}$ | $I_{RHy}$ | 0 | 2 | mA | |
| Voltage on B | $V_{SB}$ | – 0.3 | $V_S$ | V | |
| Storage temperature | $T_{stg}$ | – 55 | 110 | ˚C | |
| Thermal resistance (system - air) | $R_{th\ SA}$ | | 110 | K/W | PG-DSO-16-1 |
| Junction temperature | $T_j$<br>$T_j$ | | 110<br>150 | ˚C<br>˚C | <br>max. 70.000 h |
| Capacitor | $C_V$ | | 50 | nF | applies to short-circuit at the TCA 505 B only |

**Operating Range**

| | | | | | |
|---|---|---|---|---|---|
| Supply voltage | $V_S$ | 4<br>3.1 | 40<br>4.5 | V<br>V | <br>$V_{REF}$ = $V_S$ |
| Ambient temperature | $T_A$ | – 40 | 110 | ˚C | |
| Distance and Hysteresis resistance<br>$R_{Di}$ and $R_{Hy}$ in series<br><br>$R_{Di}$ and $R_{Hy}$ parallel | <br>$R_{Di}$<br>$R_{Hy}$<br>$R_{Di}/R_{Hy}$ | <br>300<br>0<br>300 | | <br>Ω<br>Ω | |
| Output voltage on Q2, Q4<br>B open<br>B connected | <br>$V_{Q2}$; $V_{Q4}$<br>$V_{Q2}$; $V_{Q4}$ | <br>– 0.3<br>– 0.3 | <br>$V_S$ – 2<br>$V_B$ | <br>V<br>V | |

Only the circuitry provided for passive components may be connected to pins LC, $R_{Di}$, $C_I$, $C_D$

**Characteristics**
4 V ≤ $V_S$ ≤ 40 V; $T_A$ = – 40 to 110 °C

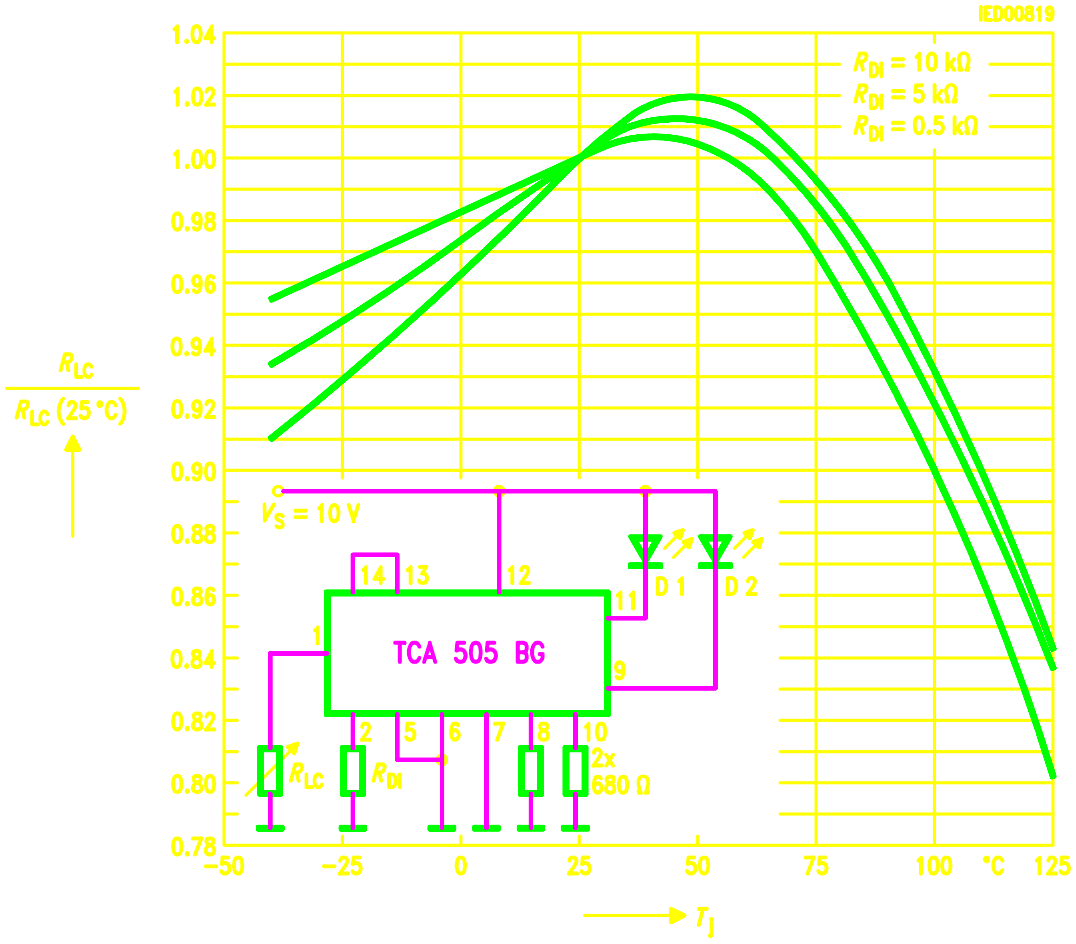
| Parameter | Symbol | Limit Values | | | Unit | Test Circuit |
|---|---|---|---|---|---|---|
| | | min. | typ. | max. | | |
| **Power Supply ($V_S$)** | | | | | | |
| Current consumption<br>Normal mode (S1 = S2 = OFF)<br>Two-wire operation<br>S1 = ON, S2 = OFF<br>4 V ≤ $V_S$ ≤ 12 V | <br>$I_S$<br>$I_S$ | | <br>550<br>625 | <br>740<br>840 | <br>µA<br>µA | <br>1<br>1 |
| Turn-ON threshold<br>(outputs active)<br>S1 = OFF | $V_{TON1}$ | | 3.64 | 4 | V | 1 |
| Turn-OFF threshold<br>(outputs disabled)<br>S1 = OFF | $V_{TOFF1}$ | 3.0 | 3.6 | | V | 1 |
| Hysteresis $V_{TON1} - V_{TOFF1}$<br>S1 = OFF | $\Delta V_{Hy1}$ | | 40 | | mV | 1 |
| **Oscillator (LC, $R_{Di}$)** | | | | | | |
| Oscillator frequency | $f_{OSC}$ | | | 3 | MHz | 1 |
| Oscillator amplitude | $A_{OSC}$ | | 0.8 | | $V_{pp}$ | 1 |
| **Demodulator, Threshold Switch ($C_I$, $R_{Hy}$)** | | | | | | |
| Threshold on $C_I$ | $V_{CI}$ | | 2 | | V | 1 |
| Hysteresis on $C_I$ | $V_{HyCI}$ | | 0.8 | | V | 1 |
| Current in $C_I$ | $I_{CI}$ | | 7 | | µA | 1 |
| Current from $C_I$ | $-I_{CI}$ | | 6 | | µA | 1 |
| Switching frequency<br>$C_I$ < 50 pF | $f_S$ | | 5 | | kHz | 1<br>(L = 70 µH) |
| **Reference Voltage ($V_{REF}$); Base Output Transistors** | | | | | | |
| Reference voltage<br>$I_{REF}$ = 0 to 100 µA | $V_{REF}$ | 2.65 | 2.9 | 3.10 | V | |
| Offset voltage $V_B = V_{Q2, 4}$<br>$V_B = V_{REF}$; $I_{Q2, 4}$ = 5 mA | $V_{OB}$ | | 110 | 155 | mV | 1 |

**Characteristics** (cont'd)
4 V ≤ $V_S$ ≤ 40 V; $T_A$ = – 40 to 110 °C

| Parameter | Symbol | Limit Values | | | Unit | Test Circuit |
|---|---|---|---|---|---|---|
| | | min. | typ. | max. | | |
| **Two-Wire Regulator ($V_T$)** | | | | | | |
| Turn-ON threshold (outputs active) S1 = ON | $V_{TON2}$ | 6.7 | 8 | 9.3 | V | 1 |
| Turn-ON threshold (outputs disabled) S1 = ON | $V_{TOFF2}$ | 5.0 | 6 | 7.0 | V | 1 |
| Hysteresis $V_{TON2}$ – $V_{TOFF2}$, S1 = ON | $\Delta$Hy 2 | 1.6 | 2 | 2.4 | V | 1 |
| **Turn-ON, Turn-OFF and Short-Circuit Delay ($C_D$)** | | | | | | |
| Turn-ON delay S1 = OFF | $t_{DON}$ | 0.49 | 0.65 | 0.82 | ms/nF | 2 |
| Turn-OFF delay S1 = OFF; $V_S$ ≥ 3.6 V | $t_{VA}$ | 17.0 | 25 | 34.0 | µs/nF | 2 |
| Shortcircuit turn-off delay S1 = OFF | $t_{SC}$ | 1.70 | 2.5 | 3.40 | µs/nF | 2 |
| Shortcircuit pause S1 = OFF | $t_P$ | 0.36 | 0.5 | 0.65 | ms/nF | 2 |
| **Outputs (Q1, Q2, Q3, Q4)** | | | | | | |
| Residual voltage Q1-Q2, Q3-Q4 SQ2 0-1 = ON, SQ4 0-1 = ON S1 = OFF | $V_{QRes}$ | | | | | |
| $I_Q$ = 5 mA | $V_{QR}$ | | 0.10 | 0.14 | V | 1 |
| $I_Q$ = 60 mA | $V_{QR}$ | | 0.5 | 0.99 | V | 1 |
| $I_Q$ = 60 mA | $V_{QR}$ | $V_S$ – 2.2 | $V_S$ –1.8 | | V | 1 |
| Reverse current on Q1, 3 | $I_{QR}$ | | | 10 | µA | |
| Residual current on Q2, 4*) Q2, 4 conducting but Q1, 3 open | $I_{Qres}$ | | | 50 | µA | 1 |
| In case of short-circuit output current | $I_{QSC}$ | | 300 | 500 | mA | 1 |
| **Shortcircuit Detector (SC)** | | | | | | |
| Trigger level ref. to $V_S$, S1 = OFF | $V_{SCS}$ | 0.255 | 0.3 | 0.345 | V | 1 |
| Trigger current S1 = OFF | $I_{SCS}$ | | | 30 | µA | 1 |
| Trigger level ref. to ground S1 = OFF | $V_{SCO}$ | 0.255 | 0.3 | 0.345 | V | 1 |
| Trigger current S1 = OFF | – $I_{SCO}$ | | | 6 | µA | 1 |

## Diagrams

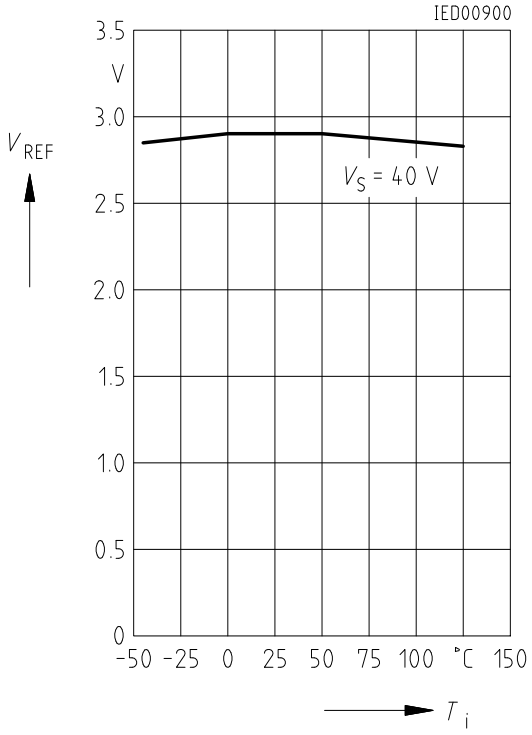
Temperature Response of Switching Point



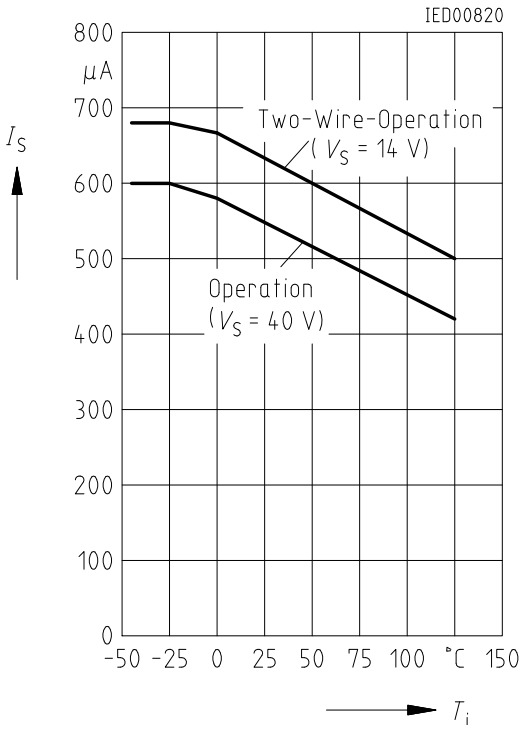

Resistor $R_{LC}$ is set in each case so that the TCA 505 B just switches from D2 to D1. In this way the TCA 505 B, together with a suitably dimensioned resonant circuit, can form a proximity switch that exhibits a very good temperature coefficient (± 2.5 %) over the entire temperature range and without any kind of extra external wiring.

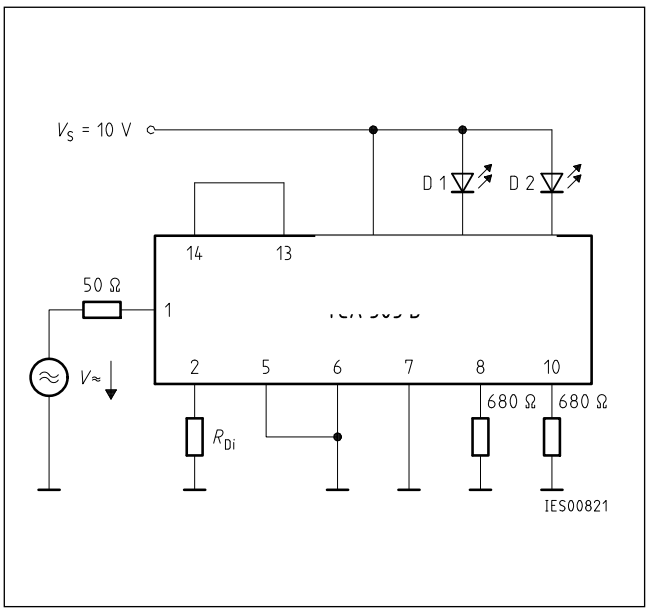
## Diagrams

### Reference Voltage versus Junction Temperature $T_j$

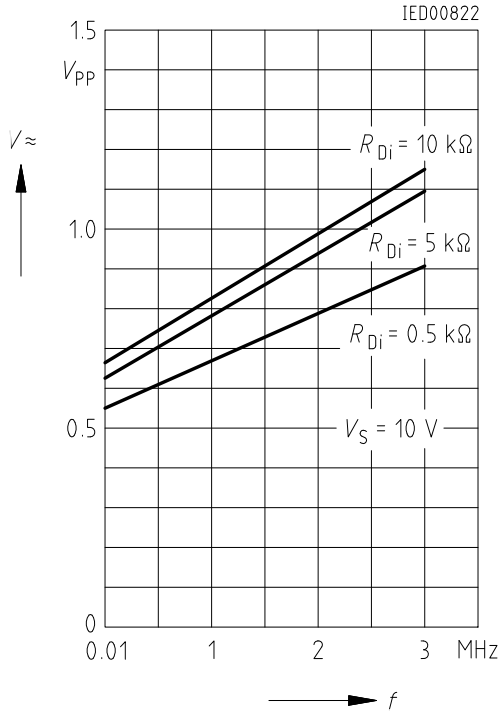


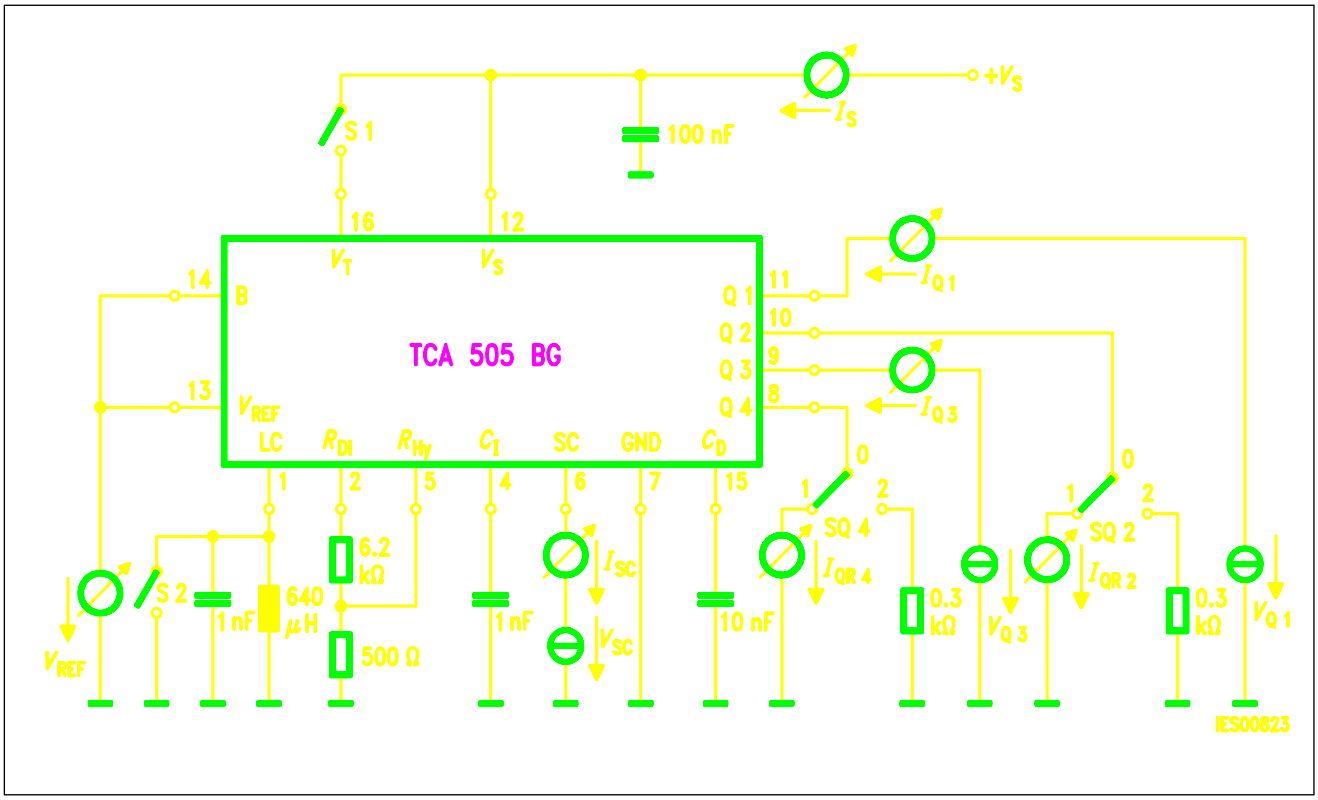

### Current Consumption versus Junction Temperature $T_j$



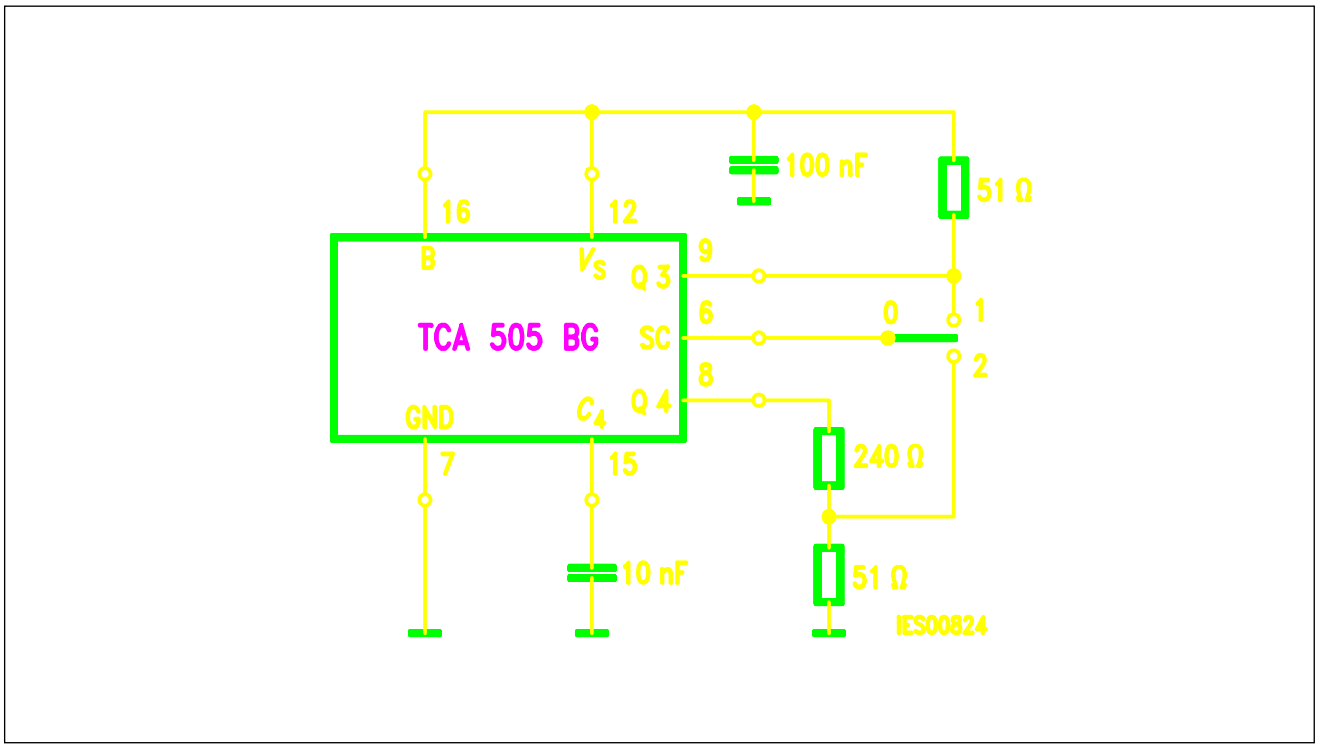




### Switching Amplitude versus Frequency $f$

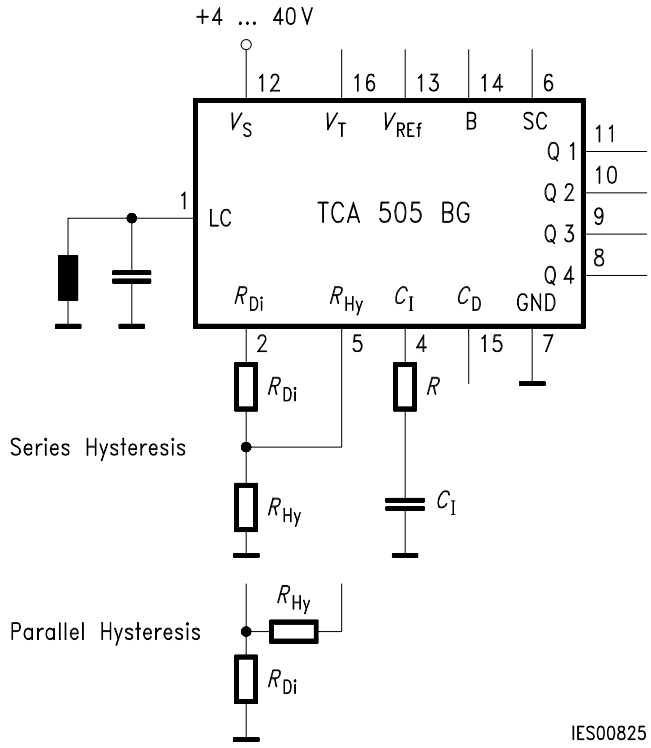





**Test Circuit 1**

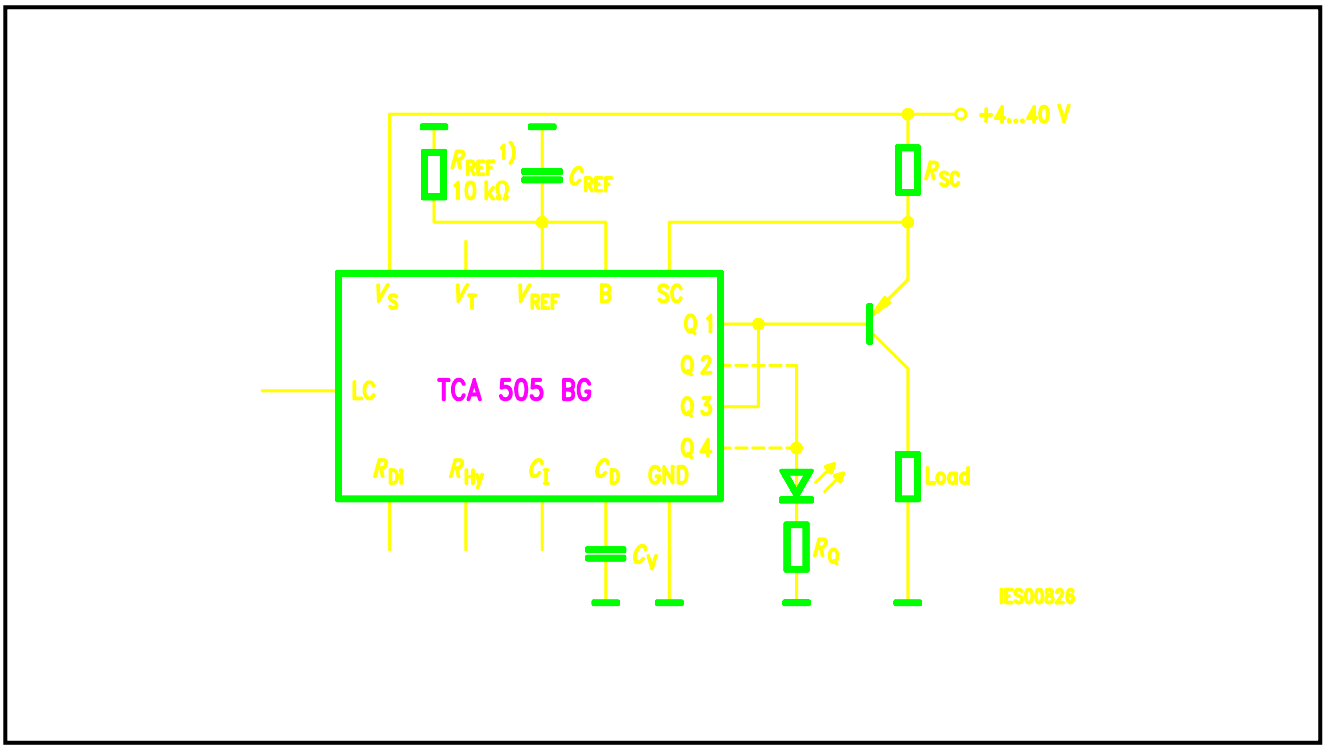



**Test Circuit 2**




For explanation see under "Pin Function"

**Application Circuit 1**
**Input Circuitry** (Use of pins LC, $R_{Di}$, $R_{Hy}$, $C_I$)




**Application Circuit 2**
**Output Circuitry** (Use of pins $V_{REF}$, B, SC, Q1 through Q4, $C_D$)

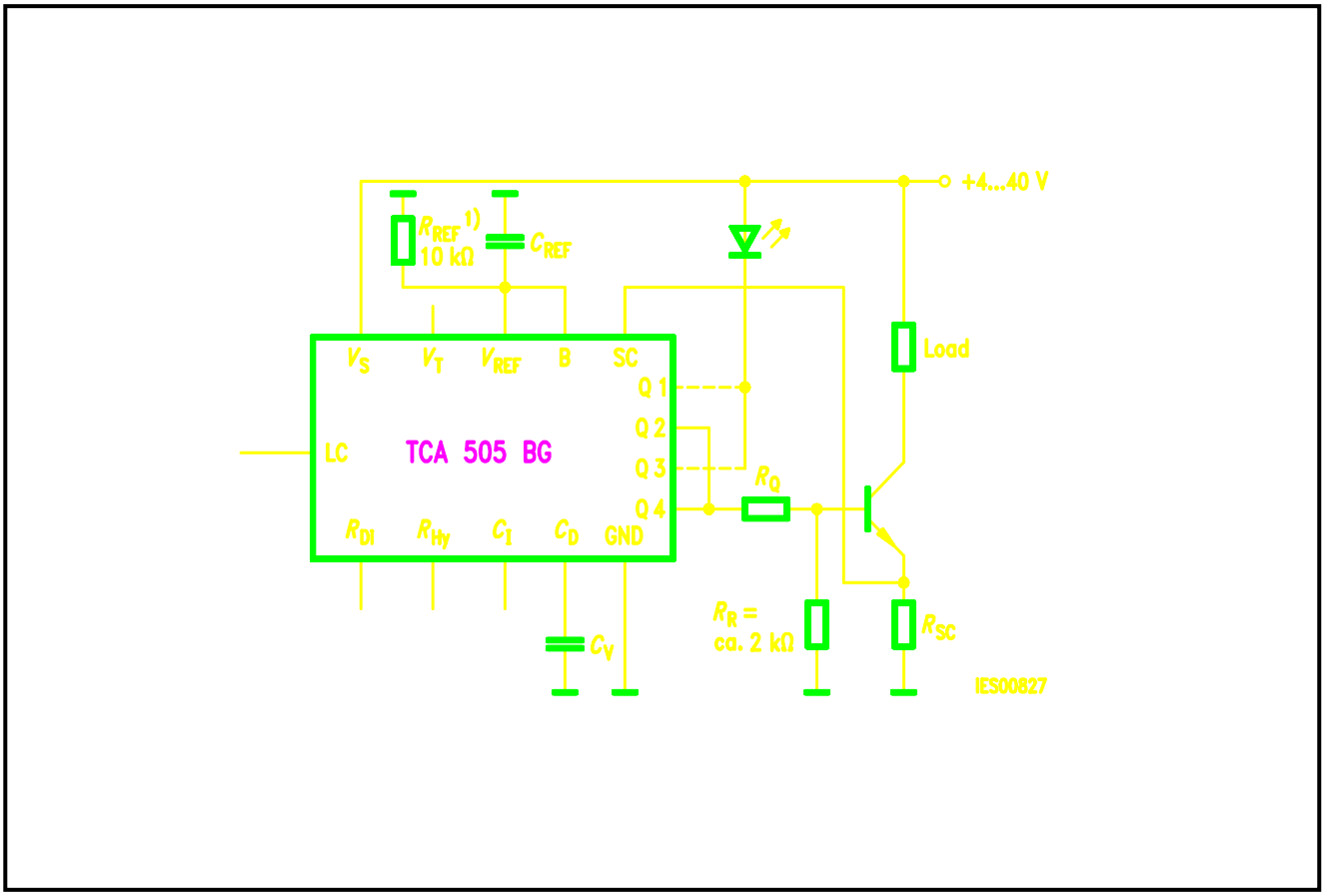
**P-switch, short-circuit-proof, LED indicator, configurable as normally closed or normally open**

Short-circuit-current sampling: $$R_{SC} = \frac{0.3\ \text{V}}{\text{max. load current}}$$

Constant base current: [1] $$R_Q = \frac{2.9\ \text{V} - V_{LED}}{\text{max. base current}}$$

For dimensioning of $C_D$ **see characteristics.** $C_D$ is usually between 1 and 10 nF. Filtering of $V_{REF}$ is for noise immunity. $C_{REF}$ can be 10 nF for example.

1) When $I_Q$ > 10 mA, a resistor $R_{REF}$ on pin $V_{REF}$ will improve the constant current operation.




Application Circuit 3
**Output Circuitry** (Use of pins $V_{REF}$, B, SC, Q1 through Q4, $C_D$)

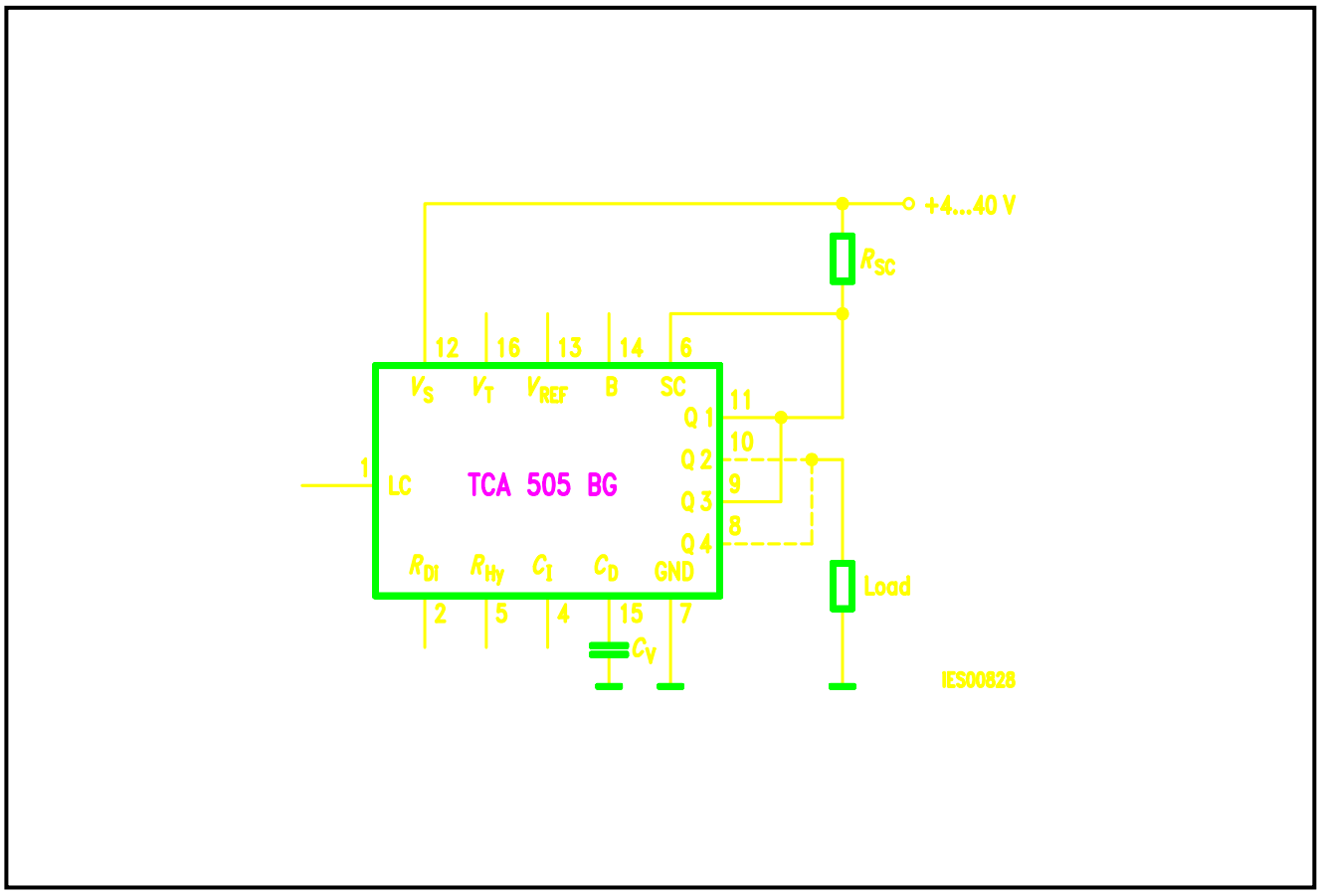
**N-switch, short-circuit-proof, LED indicator, configurable as normally closed or normally open**

Short-circuit-current sampling: $$R_{SC} = \frac{0.3\ V}{\text{max. load current}}$$

Constant base current: [1] $$R_Q = \frac{2\ V}{\text{max. base current} + I_{RR}}$$

For dimensioning of $C_D$ **see characteristics**. $C_D$ is usually between 1 and 10 nF. Filtering of $V_{REF}$ is for noise immunity. $C_{REF}$ can be 10 nF for example. $R_{REF}$ serves for discharging residual current of outputs Q2, 4.

1) When $I_Q$ > 10 mA, a resistor $R_{REF}$ on pin $V_{REF}$ will improve the constant current operation.




Application Circuit 4
**Output Circuitry** (Use of pins SC, Q1 to Q4, $C_D$)

**P-switch, short-circuit-proof, configurable as normally closed or normally open**

Short-circuit-current sampling: $$R_{SC} = \frac{0.3\ \text{V}}{\text{max. load current}}$$

During the sampling time, the short-circuit current within the IC is limited to a maximum of 250 mA. For dimensioning of $C_V$, **see characteristics**. $C_D$ is usually between 1 and 10 nF.

# OCEAN CHIPS
## Океан Электроники
## Поставка электронных компонентов

Компания «Океан Электроники» предлагает заключение долгосрочных отношений при поставках импортных электронных компонентов на взаимовыгодных условиях!

Наши преимущества:

- Поставка оригинальных импортных электронных компонентов напрямую с производств Америки, Европы и Азии, а так же с крупнейших складов мира;
- Широкая линейка поставок активных и пассивных импортных электронных компонентов (более 30 млн. наименований);
- Поставка сложных, дефицитных, либо снятых с производства позиций;
- Оперативные сроки поставки под заказ (от 5 рабочих дней);
- Экспресс доставка в любую точку России;
- Помощь Конструкторского Отдела и консультации квалифицированных инженеров;
- Техническая поддержка проекта, помощь в подборе аналогов, поставка прототипов;
- Поставка электронных компонентов под контролем ВП;
- Система менеджмента качества сертифицирована по Международному стандарту ISO 9001;
- При необходимости вся продукция военного и аэрокосмического назначения проходит испытания и сертификацию в лаборатории (по согласованию с заказчиком);
- Поставка специализированных компонентов военного и аэрокосмического уровня качества (Xilinx, Altera, Analog Devices, Intersil, Interpoint, Microsemi, Actel, Aeroflex, Peregrine, VPT, Syfer, Eurofarad, Texas Instruments, MS Kennedy, Miteq, Cobham, E2V, MA-COM, Hittite, Mini-Circuits, General Dynamics и др.);

Компания «Океан Электроники» является официальным дистрибьютором и эксклюзивным представителем в России одного из крупнейших производителей разъемов военного и аэрокосмического назначения «**JONHON**», а так же официальным дистрибьютором и эксклюзивным представителем в России производителя высокотехнологичных и надежных решений для передачи СВЧ сигналов «**FORSTAR**».

AVIC JONHON

**«JONHON»** (основан в 1970 г.)

Разъемы специального, военного и аэрокосмического назначения:

(Применяются в военной, авиационной, аэрокосмической, морской, железнодорожной, горно- и нефтедобывающей отраслях промышленности)

**«FORSTAR»** (основан в 1998 г.)

ВЧ соединители, коаксиальные кабели, кабельные сборки и микроволновые компоненты:

(Применяются в телекоммуникациях гражданского и специального назначения, в средствах связи, РЛС, а так же военной, авиационной и аэрокосмической отраслях промышленности).

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