

## ADVANCED INFORMATION

## BATTERY VOLTAGE MONITOR

### FEATURES

- Very Low Quiescent Current ( 5  $\mu$ A)
- Dual Comparator Outputs
- Single Monitor Input
- Miniature Package (SOT-23-5)

### APPLICATIONS

- Battery Powered Systems
- Cellular Telephones
- Pagers
- Personal Communications Equipment

### DESCRIPTION

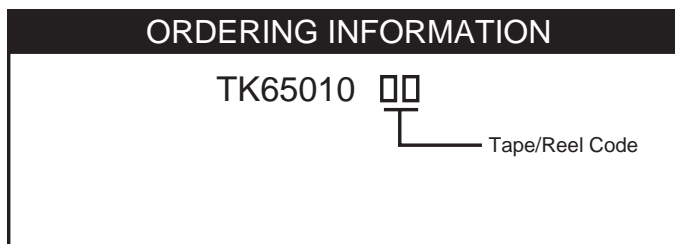
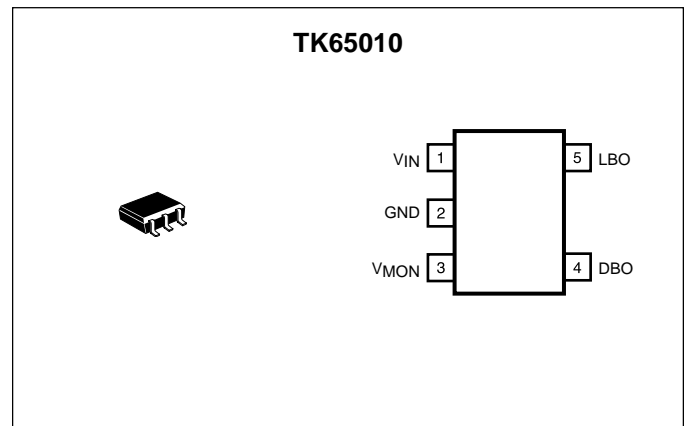
The TK65010 battery voltage monitor is designed for portable battery powered systems where board space and cost are important design considerations. The proprietary monitoring architecture of the TK65010 allows two separate warning thresholds to be set utilizing a single resistor divider and single input pin.

The first warning indicator, a Low Battery Output (LBO), is intended to warn the battery powered system of a low battery condition. In such a condition, the LBO may be used to alert the system to illuminate a low battery indicator and to take appropriate action preparing for battery failure.

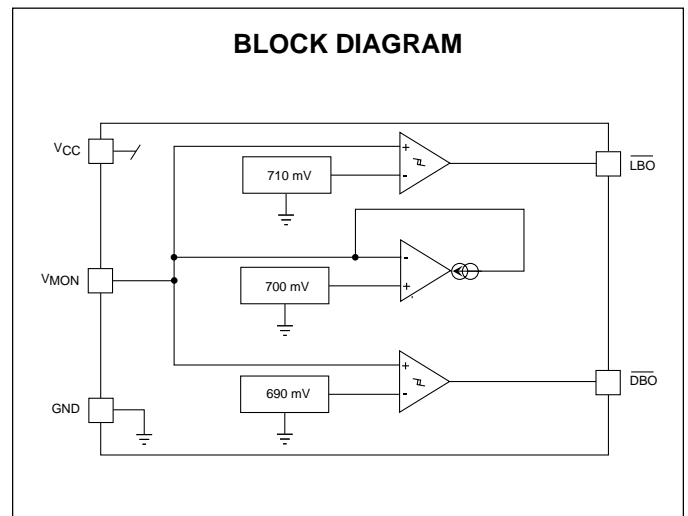
The second warning indicator, a Dead Battery Output (DBO), is intended to be used by the system for shutdown purposes. The availability of the DBO allows the system to shut down in order to minimize deep discharge of the battery.

The two warning indicators can be implemented utilizing the TK65010 and only two external components.

The TK65010 is available in a miniature 5-pin SOT-23-5 surface mount package.



TAPE/REEL CODE  
TL: Tape Left



# TK65010

## ABSOLUTE MAXIMUM RATINGS

All Pins Except GND ..... 6 V      Operating Temperature Range ..... -20 to +80 °C  
 Power Dissipation (Note 1) ..... TBD      Junction Temperature ..... 150 °C  
 Storage Temperature Range ..... -55 to +150 °C

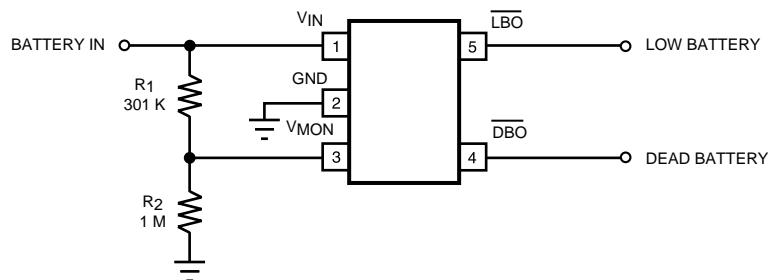
## TK65010 ELECTRICAL CHARACTERISTICS

$V_{IN} = 5\text{ V}$ ,  $T_A = T_j =$  Full Operating Temperature Range, unless otherwise specified.

SYMBOL	PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNITS
$V_{IN}$	Input Supply Range		0.9		6	V
$V_{TH, LBO}$	LBO Comparator Threshold			710		mV
$V_{ref, OA}$	OP-Amp Reference			700		mV
$V_{TH, DBO}$	DBO Comparator Threshold			690		mV
$V_{TH, LBO, HYST}$	LBO Comparator Hysteresis			TBD		mV
$V_{TH, DBO, HYST}$	DBO Comparator Hysteresis			TBD		mV
$I_{FB}$	Peak Feedback Current	$V_{MON} = V_{TH, LBO}$		-580		nA
$I_Q$	Quiescent Current			5		$\mu\text{A}$
$V_{LBO}$	Low Battery Threshold	(Note 2)		1.1		V
$V_{DBO}$	Dead Battery Threshold	(Note 2)		0.9		V

Note 1: Power dissipation is 400 mW when mounted as recommended (200 mW In Free Air). Derate at 1.6 mW/°C for operation above 25 °C.  
 Note 2: When using test circuit below.

### TEST CIRCUIT



## THEORY OF OPERATION

The circuit in Figure 1 illustrates a typical application utilizing the TK65010. The TK65010 differs from most voltage monitors due to the fact that two separate comparator thresholds can be set utilizing a single resistive divider and a single input pin. One comparator output is used as an early “low battery” warning. The second comparator can be used as a later “dead battery” warning.

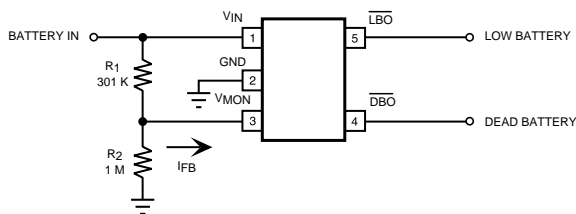


FIGURE 1

In a typical voltage monitor, which uses an external resistive divider for setting the voltage monitor threshold, the input bias current to the monitor pin is essentially zero. In this type of scenario, the voltage on the monitor input would be a resistively divided version of the battery voltage. The TK65010 introduces a small feedback current ( $I_{FB}$ ) which introduces a “plateau” into the transfer characteristics between the battery voltage and the voltage monitoring pin. The width of this plateau is dependent upon the current range of the feedback current ( $I_{FB}$ ) and the values of the external resistor network. Figure 2 illustrates the typical relationship between the battery voltage ( $V_{IN}$ ), the feedback current ( $I_{FB}$ ) and the voltage on the monitoring pin ( $V_{MON}$ ).

In selecting a resistor divider network, there are typically two degrees of freedom when selecting values. The first criteria in selecting the divider is the ratio of the two resistors. Selecting the ratio defines the lower threshold of the voltage monitor (DBO). The second degree of freedom when selecting the resistor divider is the absolute resistance values. This second degree of freedom can be utilized to set a secondary monitoring threshold (LBO) greater than the first.

Typically, when the battery voltage is relatively high, the voltage on the  $V_{MON}$  pin of the TK65010 will be a resistively divided version of the battery voltage minus the offset. The magnitude of the offset voltage will be dependent upon the resistor values comprising the external divider and the magnitude of the feedback current flowing into the  $I_{FB}$  pin.

Under these conditions, current will be flowing into the  $V_{MON}$  pin and will be limited to approximately 580 nA. As the battery voltage drops, the voltage on the  $V_{MON}$  pin will drop proportionately. When the voltage on the  $V_{MON}$  pin passes through approximately 710 mV, the output of the first comparator (LBO) will transition from a high to a low state. Shortly after the LBO output has been asserted, as the input voltage continues to drop, the magnitude of the current into the  $V_{MON}$  pin will begin to proportionately decrease as the input voltage decreases. An op-amp feedback loop internal to the TK65010 will attempt to maintain the voltage on the  $V_{MON}$  pin at a constant value of approximately 700 mV (thus, the plateau). As the battery voltage continues to drop, there comes a point where the feedback current decreases to approximately zero. At this point, the voltage on the  $V_{MON}$  pin will resume a proportional drop with the input voltage. As the voltage on the  $V_{MON}$  pin passes through approximately 690 mV, the second comparator output (DBO) will be asserted.

For details on how to properly select the resistor divider, refer to the “Design Considerations” section.

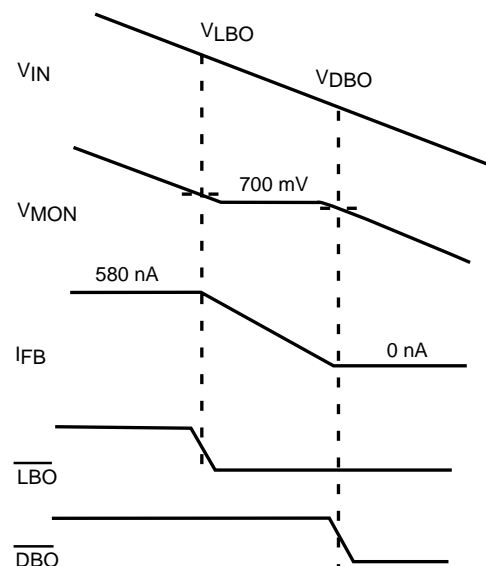


FIGURE 2

## PIN DESCRIPTION

### SUPPLY VOLTAGE PIN ( $V_{IN}$ )

This pin is the positive power supply for the TK65010. Current draw from the positive supply is typically 5  $\mu$ A.

### GND PIN (GND)

The pin provides the ground connection for the IC.

### VOLTAGE MONITORING PIN ( $V_{MON}$ )

This pin is the voltage monitoring pin of the TK65010. When the voltage on this pin is less than approximately 710 mV, the LBO signal will be asserted. When the voltage on this pin is less than approximately 690 mV, the DBO pin will be asserted. This pin is also connected to the negative input of a high-gain op-amp. The op-amp will attempt to maintain the voltage on this pin at 700 mV. However, the current-sink capability of this pin is limited to the range of 0 to 580 nA.

### LOW BATTERY OUTPUT PIN (LBO)

This active-low pin will be asserted when the voltage on the  $V_{MON}$  pin is less than approximately 710 mV; otherwise the LBO pin will not be asserted.

### DEAD BATTERY OUTPUT PIN (DBO)

This active-low output will be asserted when the voltage in the  $V_{MON}$  pin is less than approximately 690 mV; otherwise the DBO pin will not be asserted.

## DESIGN CONSIDERATIONS

In order to design a voltage monitor utilizing the TK65010, the two external resistors comprising the resistor divider must be properly selected. Selecting the ratio of the resistors will establish the lower monitoring threshold (DBO). Selecting the value of the  $R_1$  will establish the upper monitoring threshold (LBO) relative to the lower (DBO) threshold. The value of  $R_2$  will be dictated by the ratio  $R_1/R_2$  and the value of  $R_1$ . For the following explanations, please refer to the circuit diagram of Figure 3.

### SETTING THE DBO THRESHOLD

As mentioned above, the ratio of  $R_1/R_2$  established the "dead battery" threshold. The dead battery comparator trips when the voltage on the  $V_{MON}$  pin passes through approximately 690 mV and the current into the  $V_{MON}$  pin is approximately zero. Given the required dead battery threshold, the ratio  $R_1/R_2$  can be selected utilizing the following equation:

$$\text{DBO Threshold} = 690 \text{ mV} \times (1 + R_1/R_2)$$

or

$$R_1/R_2 = (\text{DBO Threshold} - 690 \text{ mV}) / 690 \text{ mV}$$

### SETTING THE LBO THRESHOLD

The threshold of the LBO comparator will be at a value greater than the DBO threshold. The value of resistor value  $R_1$  dictates the difference between the LBO and DBO thresholds as follows:

$$\text{LBO Threshold} = \text{DBO Threshold} \times 1.029 + R_1 \times 580 \text{ nA}$$

or

$$R_1 = (\text{LBO Threshold} - \text{DBO Threshold} \times 1.029) / 580 \text{ nA}$$

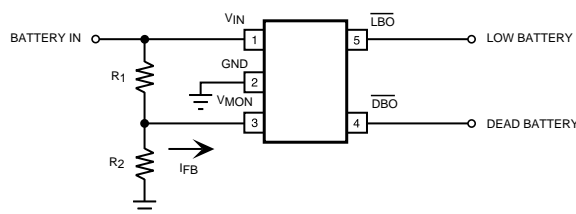


FIGURE 3

### RESISTOR TOLERANCE CONSIDERATIONS

The tolerance of the LBO and DBO thresholds will have a significant dependence upon the tolerance of the resistive components used in the resistor divider. When utilizing the previously described equations for setting the LBO and DBO thresholds, it is possible that optimal values of the resistive elements  $R_1$  and  $R_2$  may be relatively large. Since large resistive components are not always available with tight tolerances, an alternate method can be used for applications where tighter tolerances are required.

The purpose of the resistor divider connected between the Battery Input and the  $V_{MON}$  pin is twofold. The first purpose is to appropriately select the divider ratio such that the DBO threshold is set to the desired level. The second purpose is to select the absolute resistor values such that the LBO threshold is set to an appropriate level relative to the DBO threshold. Effectively, an attenuated voltage source with a relatively large output impedance is driving the  $V_{MON}$  pin. This scenario is illustrated in Figure 4.

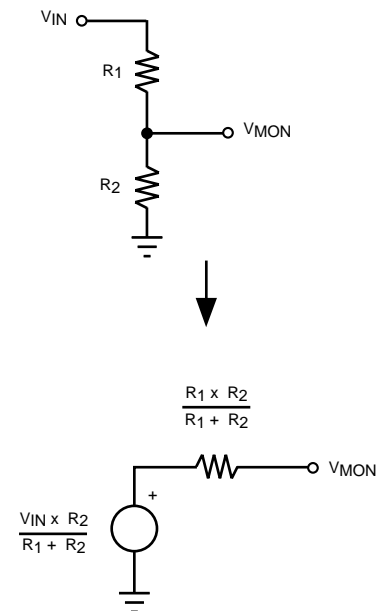
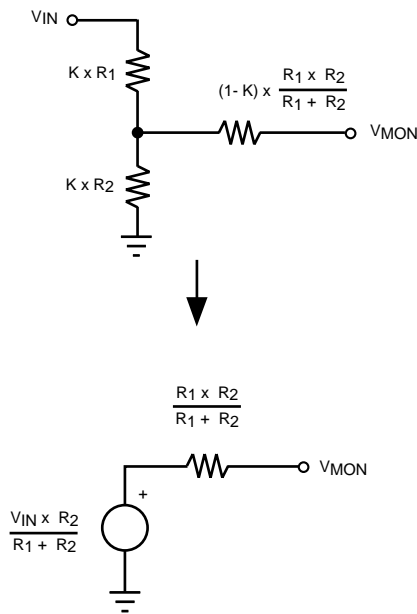


FIGURE 4

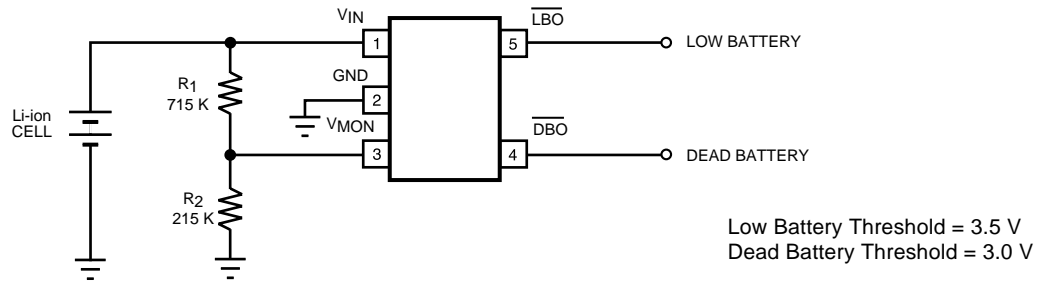
**DESIGN CONSIDERATIONS (CONT.)**

The resistor divider consisting of  $R_1/R_2$  can be scaled downward by a factor scale factor (K) to utilize smaller resistor values  $K \times R_1$  and  $K \times R_2$  ( $K < 1$ ). By adding an additional series resistor, which can be dependent upon the scale factor (K) and the resistor values comprising the divider, the  $V_{MON}$  pin will effectively see the same voltage source and drive impedance as illustrated in Figure 4. The three-resistor attenuator is illustrated below in Figure 5.

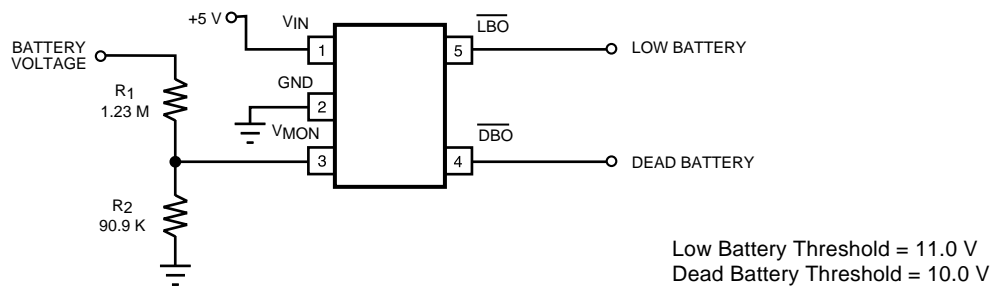


**FIGURE 5**

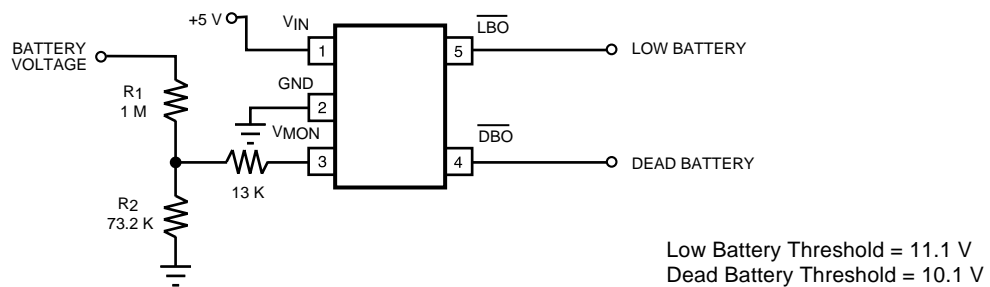
## APPLICATIONS INFORMATION



**FIGURE 6: BASIC BATTERY MONITOR**

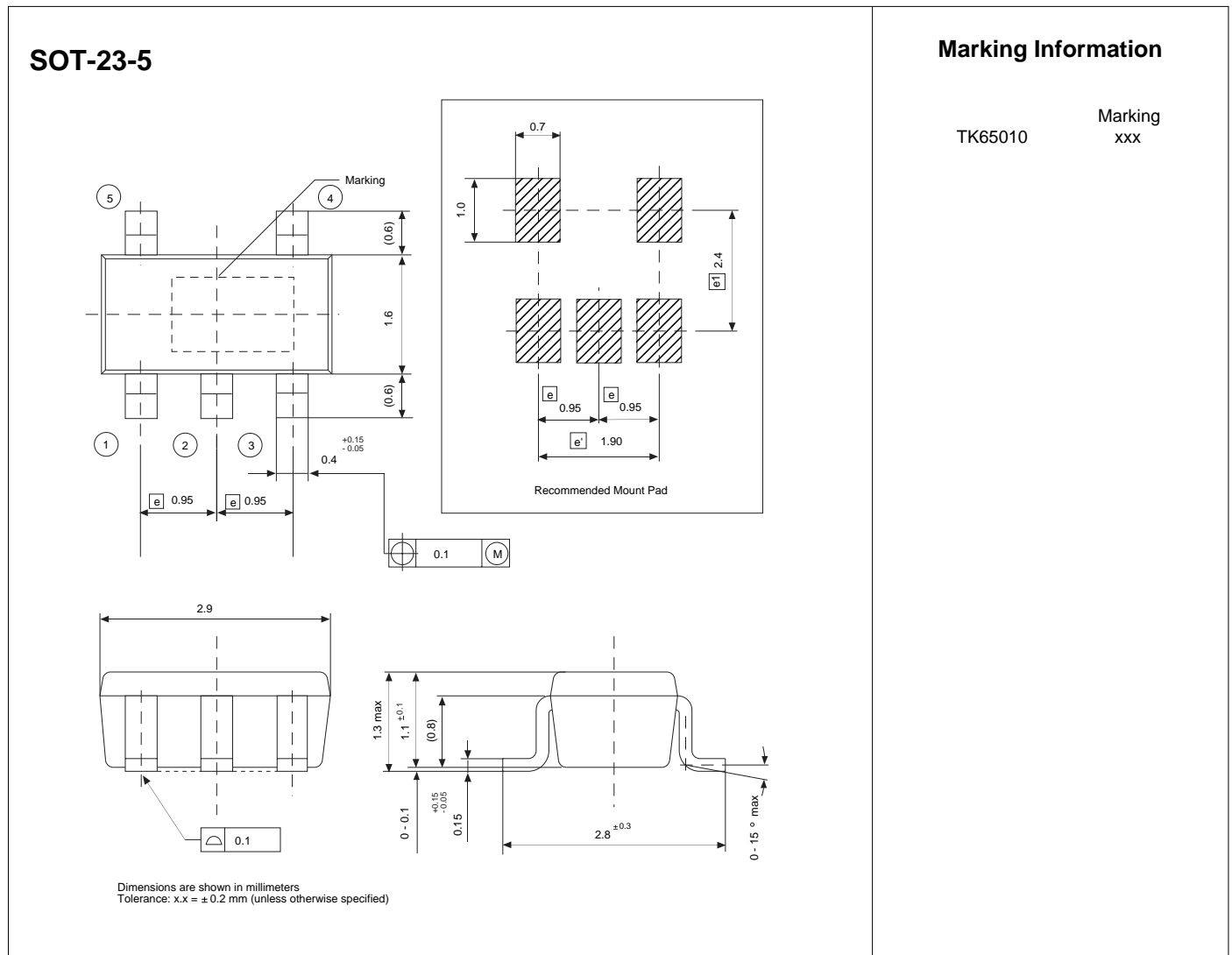


**FIGURE 7: HIGH VOLTAGE MONITOR**



**FIGURE 8: HIGH VOLTAGE MONITOR WITH 3-RESISTOR ATTENUATOR**

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