# TPS312x Series Supervisory Circuits in Ultra-Low-Voltage Applications

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Power Management

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## IMPORTANT NOTICE

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# TPS312x Series Supervisory Circuits in Ultra-Low-Voltage Applications


**ABSTRACT**

Voltage-monitoring circuits are firmly established in microcomputer systems. These circuits perform system initialization, which includes circuit reset, and they monitor the supply voltage during operation. When combined with watchdog circuits, they monitor the proper functioning of a device in safety-relevant circuits. This report describes the new TPS312x series of voltage-monitoring integrated circuits that have a low supply voltage of 1.2 V and a low current consumption. These low-voltage monitoring circuits are intended primarily for use in battery-powered devices.


## 1 Introduction

Although the power supply for a computer is often the last component considered in the design process, two elements of this component perform crucial functions:

- The initialization circuit ensures the correct program start when the supply voltage is turned on.
- The voltage-monitoring circuit monitors the supply voltage of the system and prompts reinitialization of the processor when this voltage deviates abnormally from the setpoint value.

Because the requirements of the analog voltage-monitoring circuit differ significantly from those of the digital circuit, the early expectation that the functions of the voltage-monitoring circuit would be integrated on single silicon crystal have not yet been realized, but the importance of the functions has not diminished.

Texas Instruments has developed the TPS312x series integrated circuit (IC) in response to the demand for digital circuits with additional integrated functions and lower processor supply voltage. The TPS312x series IC has a nominal supply voltage of 1.2 V and higher, and is primarily intended for use in battery-powered devices.

# 2 Power Supply Circuitry

This section provides an overview of the initialization circuit, the watchdog circuit, and the voltage-monitoring circuit and their relationship to the power supply.

## 2.1 Initialization Circuit

In digital circuits, a defined initial status must be provided after the supply voltage has been turned on. Starting from this status a state-controlled machine switches from one state to the next in sequence. In a computer, the sequential execution of the program starts from the preset state of the program counter. Logic circuits such as flip-flops mostly have static set and reset inputs for this purpose. A high or low level on these inputs sets the circuit to the desired status.

Complex circuits such as microprocessors or microcomputers also have a reset input with a corresponding logic level at that input that brings the circuit to a defined initial status. Figure 1 illustrates the typical circuit for generating the reset signal when the supply voltage of a microprocessor is turned on.

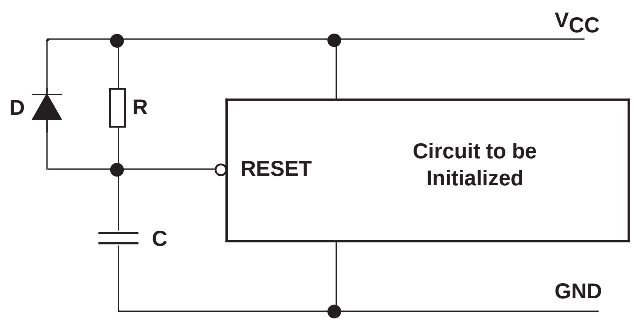


**Figure 1. Circuit for Generating Reset Signals**

After the supply voltage is turned on, a resistance-capacitance (R/C) element at the reset input ensures a delayed rise of the voltage at this input and thus generates the desired reset signal. The reset signal must be present at this input for a certain time, usually a few microseconds, until a microprogram in the processor has brought all the circuit components concerned to a defined initial state. To calculate the necessary time constants of the R/C element, you should know the rise time of the supply voltage, but frequently it is not known.

In initialization circuits, the diode D is usually parallel to the resistor R. If the supply voltage drops, this diode is supposed to discharge the capacitor C quickly and thus ensure reinitialization of the circuit. Assuming the threshold voltage of the reset input is about 1.4 V, for reinitialization to occur, the supply voltage must fall below 0.7 V. The diode has no effect on low voltage drops that may affect the functioning of the system.

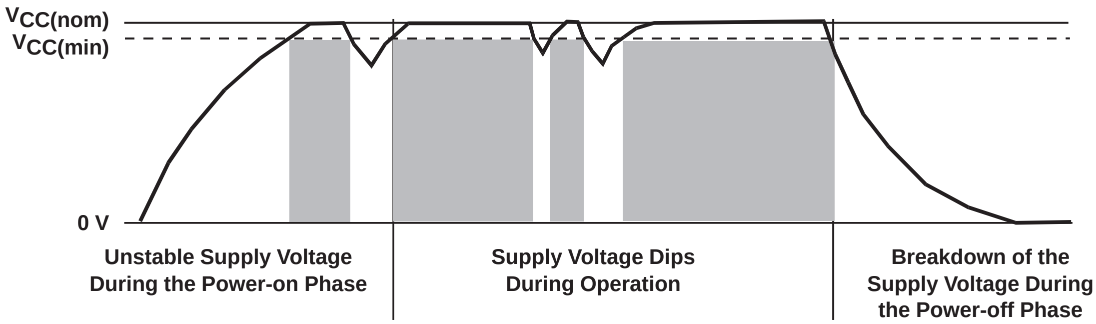


**Figure 2. Supply Voltage Characteristics**

Figure 2 describes the characteristics of the supply voltage of a system. After the main voltage or the battery is turned on, the supply voltage rises. The internal resistance of the transformer and rectifier and any current-limiting elements in the voltage regulator determine the rate of this rise. During the initial stage, short-term voltage drops may occur after nominal voltage has been reached because the charge in the filter capacitor upstream of the regulator is still too low. The connected system cannot function reliably in this phase.

A voltage-monitoring circuit must prevent start-up of the processor during this period. When the supply voltage reaches its stable setpoint value, the system can begin work, although short-term drops in the supply voltage are to be expected in the subsequent period because of interference on the main cable. The monitoring circuit must detect these drops with certainty. The supply voltage fails when the main voltage or the battery is turned off. The processor should stop working immediately in this phase to prevent unmonitored reactions of the circuit when the supply voltage is too low.

Careful monitoring of the supply voltage is necessary for the reliable operation of a system. You can assume that the connected circuit functions properly only during the periods shaded in Figure 2. The length of time the reset signal generates the monitoring circuit must also be determined. When the main voltage is turned on, the processor does not begin work until the supply voltage is stable. This phase may last for 10 ms or more, depending on the design of the main section.

For the processor to execute a microprogram sequentially during the reset phase, its oscillator must generate a signal of a certain frequency and amplitude. Microprocessors typically use crystal oscillators, which are very high quality components ($Q > 10^4$), as the frequency-determining element. The transient time of a crystal oscillator is correspondingly long, especially if the design of the circuit component takes high-frequency stability into consideration. The typical build-up time of crystal oscillators in the frequency range above 1 MHz is approximately 10 ms. At lower frequencies, the build-up time is significantly longer. Likewise, the length of the reset signal specified in the data sheet of the microprocessor or microcomputer must be considered. This time is typically a few microseconds. Adding together the times described here results in a proper reset signal length of approximately 100 ms.

## 2.2 Watchdog Circuit

Many microcomputer applications require safety functions to detect malfunctions caused by the defective execution of a program. Such programs contain a routine for this purpose which, at regular intervals, triggers a retriggerable monostable flip-flop called the watchdog circuit, shown in Figure 3. If this trigger fails to occur for a specific period of time, the toggle back of the flip-flop in the computer triggers an interrupt or a reinitialization.

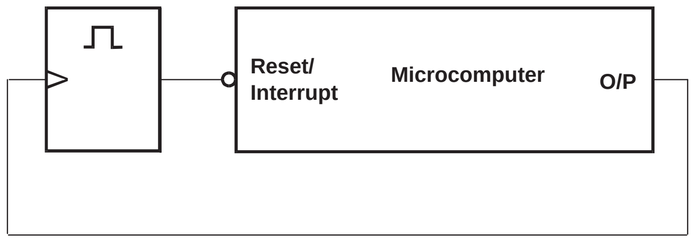


**Figure 3. Watchdog Circuit**

Interference voltages at the supply voltage connection or at any input or output terminal of the IC may produce uncontrolled currents that flow into the component and cause faulty program execution. These currents may change parts of the circuit to an unwanted state. When the program is unable to detect these unwanted operating states, corrective measures are taken and the watchdog circuit intervenes. The trigger of the monostable flip-flop fails as a result of the faulty functioning of the program, and the program run is interrupted after a specific period of time.

In principle, a timer integrated into the microcomputer should perform this monitoring function; but, in practice, the error conditions described here often have detrimental side effects on the timer that prevent it from taking corrective action. As a safety measure, the watchdog function is placed in a circuit other than the one being monitored, such as the voltage-monitoring circuit. This circuit is the logical place for the watchdog function because circuit components required in the voltage-monitoring circuit can be used jointly and this joint design reduces the cost of components and the system.

## 2.3 Voltage-Monitoring Circuit

Since the late 1980s, the typical 5-V supply voltage of complex ICs has been steadily reduced as a result of the development of smaller circuit geometry and higher electrical field strengths at critical circuit components. Supply voltages of 3.3 V, 3.0 V, 2.5 V, 1.8 V, 1.5 V, and 1.2 V are now common and have made possible the development of battery-powered devices with ICs.

The supply voltage in battery-powered devices is determined by the voltage of commercially available batteries. Nickel-cadmium (NiCd) and nickel-metal-hydride (NiMH) batteries provide a supply voltage of 1.2 V; a series connection of several batteries increases this value. Lithium (Li) batteries supply a voltage from 3 to 3.6 V, the latter being achieved with three series-connected NiCd batteries.

# 3 TPS312x Series Circuits

Texas Instruments has developed the TPS312x series of voltage-monitoring circuits especially for battery-powered systems. These components are designed for applications in which the nominal supply voltage is between 1.2 V and 3.0 V. Four voltage options are offered, as described in Table 1.

**Table 1. Nominal Supply Voltages of TPS312x Series Monitoring Circuits**

| Type Designation | Nominal Supply Voltage |
|---|---|
| TPS312xx12 | 1.2 V |
| TPS312xx15 | 1.5 V |
| TPS312xx18 | 1.8 V |
| TPS312xx30 | 3.0 V |

The monitored voltage is measured in the IC at the supply voltage connection ($V_{DD}$) so that no additional sense input is required. In many applications, the inverse signal RESET is required in addition to the $\overline{\text{RESET}}$ output that becomes low when the supply voltage falls below a specified value. In many cases, it is necessary to activate the outputs under consideration via the manual reset ($\overline{\text{MR}}$) input by an external signal.

These components comprise the watchdog circuit and the voltage-monitoring function used to monitor the proper operation of systems. The watchdog function requires a trigger input (WDI) for the watchdog circuit. The components described here are installed in the SOT23-5 package, which has been effective in many applications because it is small. The limited number of pins in this package means that the watchdog circuit is combined with either the RESET or the $\overline{\text{RESET}}$ output. Although the 5-pin package does not implement all inputs and outputs described above, three different versions of the circuit are available in which the functions are combined (see Figure 4).

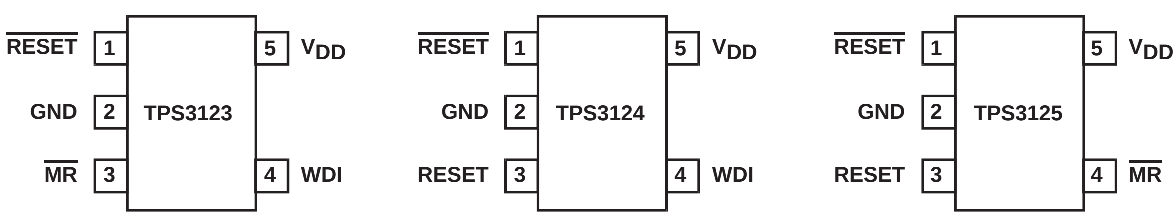


**Figure 4. Terminal Assignments of TPS312x Series Circuits**

Table 2 summarizes the functions that are combined in the monitoring circuits of the TPS312x series.

**Table 2. TPS312x Series Circuit Functions**

| Type | Function | | Inputs | | Outputs | |
|---|---|---|---|---|---|---|
| | Voltage Monitoring | Watchdog Circuit | $\overline{\text{MR}}$ | WDI | RESET | $\overline{\text{RESET}}$ |
| TPS3123 | ✓ | ✓ | ✓ | ✓ | | ✓ |
| TPS3124 | ✓ | ✓ | | ✓ | ✓ | ✓ |
| TPS3125 | ✓ | | ✓ | | ✓ | ✓ |

The main application for the TPS312x series circuits is battery-powered devices. During the development of these circuits, low current consumption was a prime consideration so that the batteries would not have an unreasonable load. The BiCMOS process (compared to bipolar technology) used in the production of these circuits allows you to significantly reduce the supply current ($I_{DD}$) of the devices to a maximum consumption range of 25–30 μA.

# 4 TPS312x Supply Voltage Supervisor

The TPS3125 component comprises the voltage-monitoring function of the TPS312x series. The functional description of the TPS3125 IC applies to all the options available in the TPS312x series.

## 4.1 Functional Description

Figure 5 shows a block diagram of the TPS3125 voltage-monitoring circuit. A highly accurate, temperature-compensated reference voltage source forms the core of the circuit. The comparator compares its voltage with the supply voltage ($V_{DD}$) distributed via the voltage dividers $R_2$ and $R_3$. If this is less than the reference voltage, the comparator's output becomes low. This prompts the reset logic to switch the $\overline{\text{RESET}}$ output to low and the RESET output to high. The same result delivers a low level at the $\overline{\text{MR}}$ input. This is a logic input. A pushbutton that initializes the circuit can also be connected here. The pullup resistor $R_1$ integrated at this input provides a high level at this connection in the event of unused input. When the signal at the $\overline{\text{MR}}$ input and at the comparator's output switches to high, this activates the timer in the reset logic, which keeps both outputs in the active state for an additional time delay ($t_d$ = 180 ms).

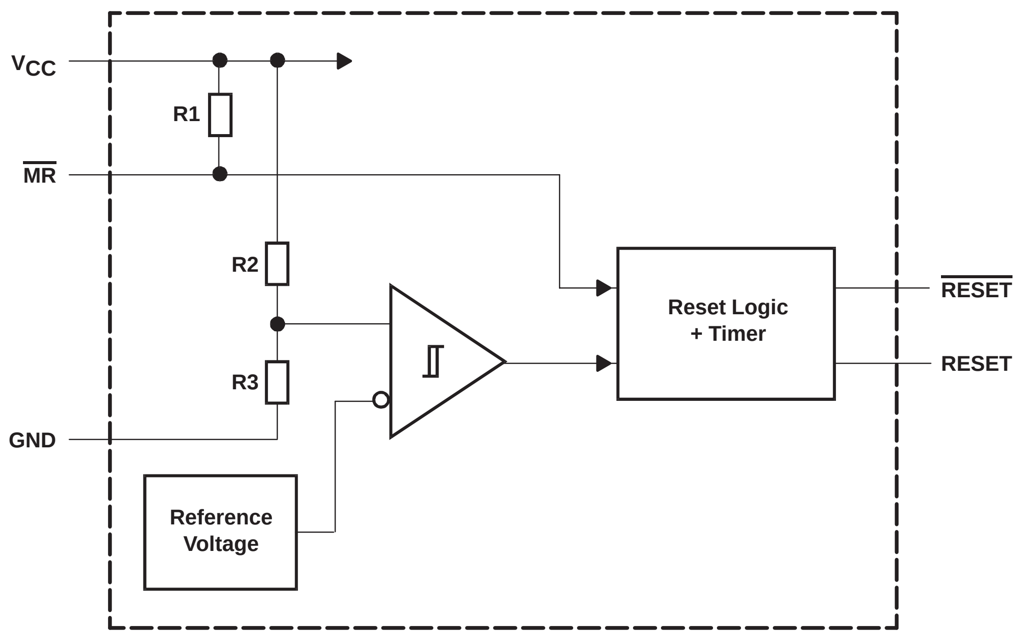


**Figure 5. TPS3125 Supply Voltage Supervisor**

Figure 6 illustrates the time correlations, and as this figure shows, the supply voltage ($V_{DD}$) rises slowly from 0 V. When the supply voltage reaches 0.85 V (at time A in Figure 6), the circuit becomes active and switches the $\overline{\text{RESET}}$ output to a defined low level. It is assumed that the voltage at the $\overline{\text{MR}}$ input closely follows the supply voltage. The supply voltage reaches the value $V_{IT+}$ at time B. When the internally distributed voltage exceeds the comparator's threshold value, the time delay of 180 ms begins, and the $\overline{\text{RESET}}$ output becomes high again after the time delay ends.

At time C, an external signal source switches the $\overline{MR}$ input to low, and the $\overline{RESET}$ output also becomes low. When the signal at this input becomes high again, the time delay ($t_d$) begins, and when the time delay ends, the $\overline{RESET}$ output becomes high again.

The supply voltage ($V_{DD}$) drops shortly before time D because of an abnormal load change or a main voltage drop and falls below the threshold voltage ($V_{IT-}$) at the time already mentioned. At the same time, the $\overline{RESET}$ output becomes active low. The supply voltage then recovers and at time E again exceeds the threshold voltage ($V_{IT+}$). The $\overline{RESET}$ output, delayed by the time delay ($t_d$), becomes high again.

At time F, the device is switched off, the supply voltage drops, and the voltage-monitoring circuit responds. The $\overline{RESET}$ output remains active until the supply voltage ($V_{DD}$) falls below 0.85 V. The circuit stops functioning below this voltage, and the output level becomes undefined.

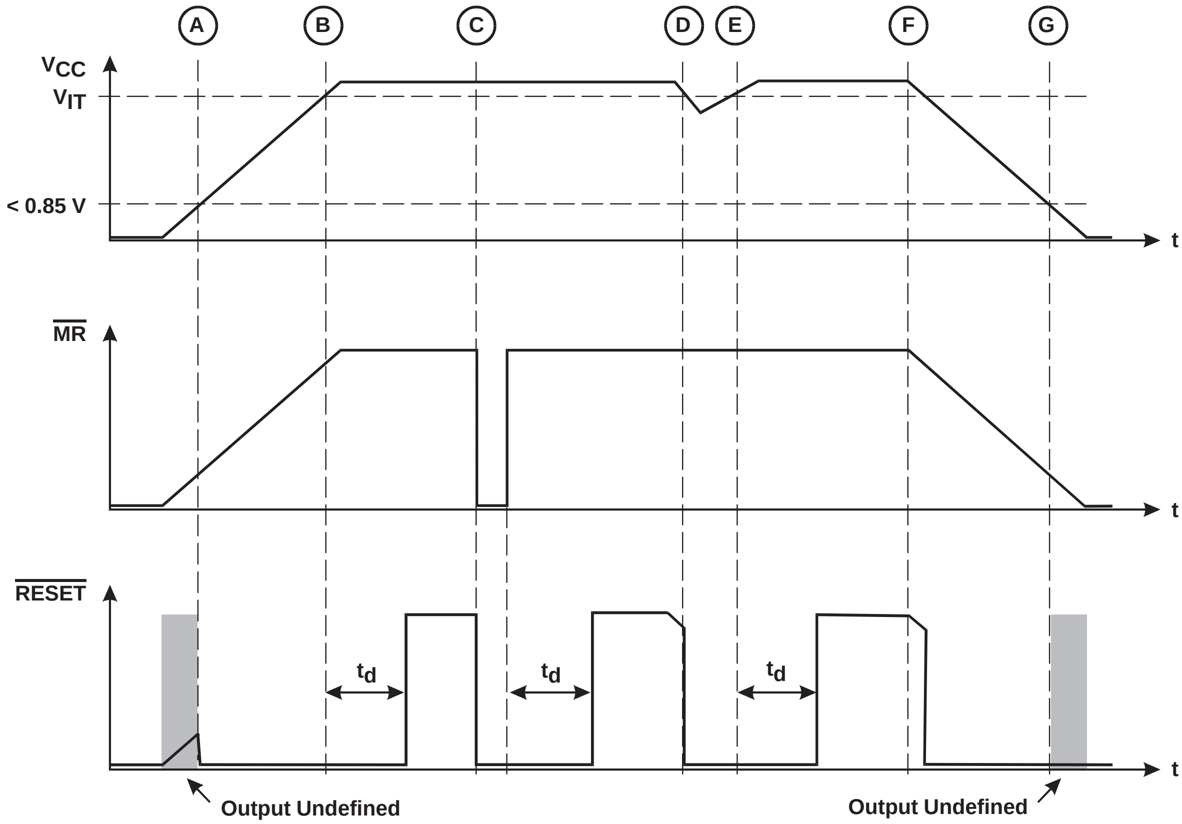


**Figure 6. TPS3125 Circuit Timing Output Characteristics**

Figure 7 and Figure 8 show the signal forms measured on the TPS3125L30 and TPS3125J12 ICs. In these examples, the supply voltage ($V_{DD}$) rises from 0 V to its nominal value of 3.0 V, or 1.2 V in approximately 150 ms. The voltage at the $\overline{RESET}$ output follows the voltage ($V_{DD}$) in the first moment, but as soon as this voltage reaches a value of 0.4 V, the output assumes a defined status. When the supply voltage reaches the threshold voltage value ($V_{IT+}$), the time delay ($t_d$) begins. The $\overline{RESET}$ output switches to high after the time delay ends, approximately 180 ms later.

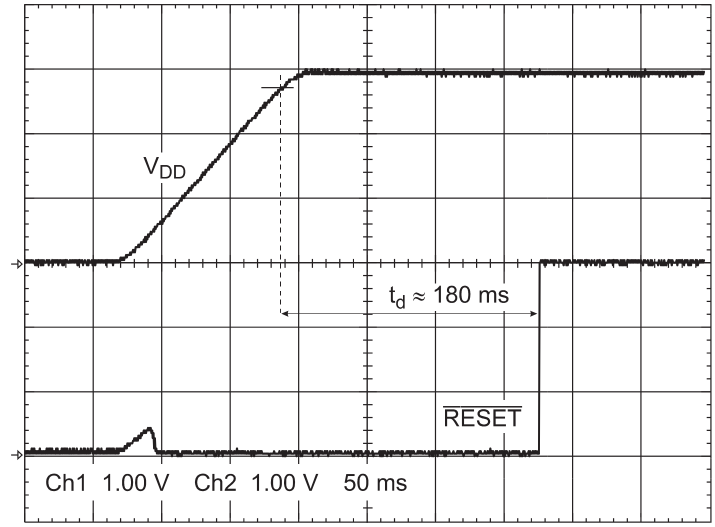


**Figure 7. TPS3125L30 Signal Form**

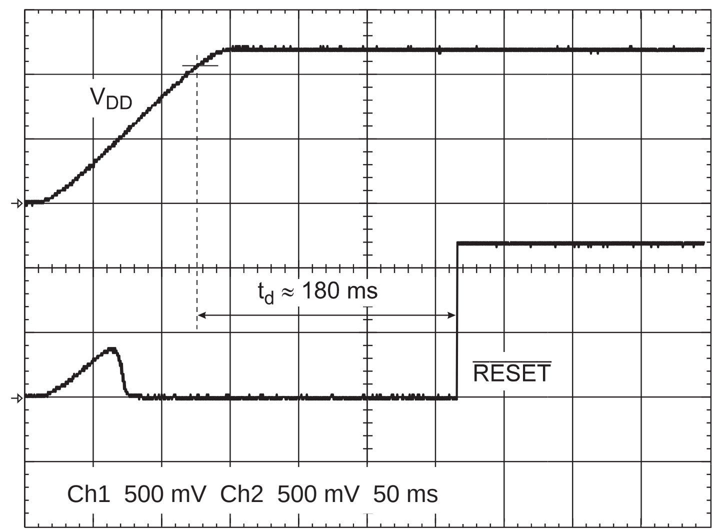


**Figure 8. TPS3125J12 Signal Form**

## 4.2 Threshold Voltage ($V_{IT}$)

Another important parameter for the selection of a suitable voltage-monitoring circuit is the threshold voltage ($V_{IT}$). The RESET output of the circuit must become active if the supply voltage falls below this value. In the past, this voltage value was usually selected so that it was approximately 10% below the nominal supply voltage of the circuit. In most cases, this calculation produced a value that was correct, though the data sheets of many complex ICs ensure safe operation at a supply voltage that is only 5% below the nominal value.

The minimum supply voltage indicated in IC data sheets represents the limits of the operating range under the given conditions (clock pulse frequency and ambient temperature). Often, however, not all operating parameters are at the most unfavorable end, so this limiting value may indicate too great a restriction. Battery-powered devices are designed to use a supply voltage as low as possible to make maximum use of the energy stored in the battery; consequently, these devices achieve the maximum operating time with one charge of the battery. Many applications do not require operation over the full range of temperatures given in the data sheets, which, under certain circumstances, extends the supply voltage range. Conversely, applications that require a wide range of operating temperatures typically restrict the supply voltage range.

The behavior of the ring oscillator, shown in Figure 9 , demonstrates the effect of the most important operating parameters—supply voltage ($V_{DD}$) and ambient temperature ($T_A$). In this circuit, the time delay of the five series-connected inverters primarily determines the output frequency. In addition to the process parameters of the semiconductor process used to produce the circuit, the ambient temperature and the supply voltage significantly influence this time delay. The diagram shows the dependence of the output frequency as a function of the $V_{DD}$ and $T_A$.

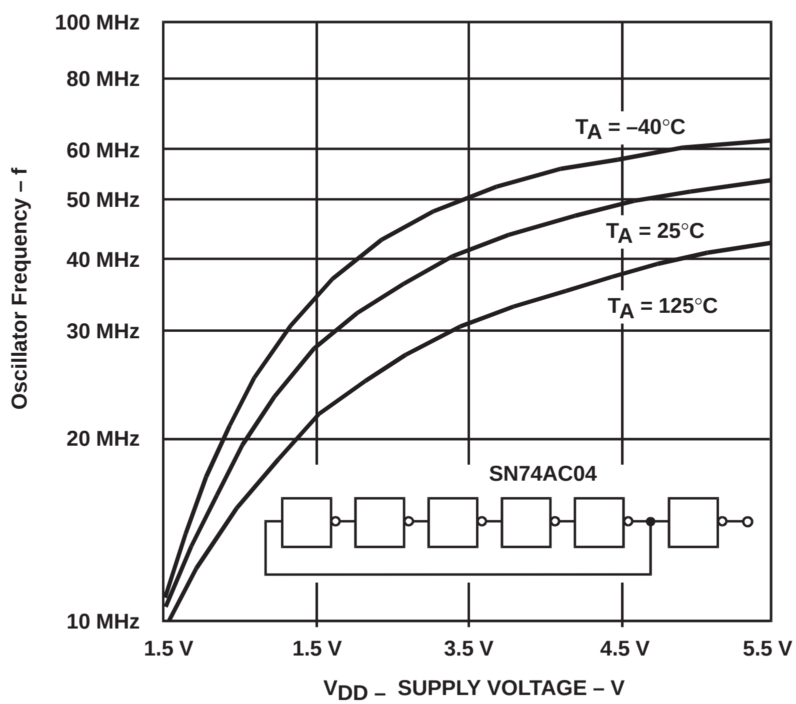


**Figure 9. Output Frequency of the Ring Oscillator**

Figure 9 demonstrates that you must consider the reliable supply voltage in each individual case. The operating point in voltage-monitoring circuits ($V_{IT-}$), which is typically 10% below the nominal supply voltage, may not be the optimal value in every case. Therefore, TI offers the TPS312x series voltage-monitoring circuits in the standard version with the threshold voltage that is 10% below the nominal supply voltage, and in versions with a threshold voltage that is 1% to 15% below the nominal supply voltage. These choices allow you to select the circuit most suitable for the application. Table 3 shows the available versions.

**Table 3. Threshold Voltages $V_{IT}$—TPS312x Series Circuits**

| | | **Nominal Supply Voltage/V** | | | |
|---|---|---|---|---|---|
| | | **1,20** | **1,50** | **1,80** | **3,00** |
| **$V_{IT-}$** | **Designation** | **Threshold Voltage $V_{IT-}$/V** | | | |
| $V_{nom}$ – 1 % | TPS312xA | 1,19 | 1,49 | 1,78 | 2,97 |
| $V_{nom}$ – 2 % | TPS312xB | 1,18 | 1,47 | 1,76 | 2,94 |
| $V_{nom}$ – 3 % | TPS312xC | 1,16 | 1,46 | 1,75 | 2,91 |
| $V_{nom}$ – 4 % | TPS312xD | 1,15 | 1,44 | 1,73 | 2,88 |
| $V_{nom}$ – 5 % | TPS312xE | 1,14 | 1,43 | 1,71 | 2,85 |
| $V_{nom}$ – 6 % | TPS312xF | 1,13 | 1,41 | 1,69 | 2,82 |
| $V_{nom}$ – 7 % | TPS312xG | 1,12 | 1,40 | 1,67 | 2,79 |
| $V_{nom}$ – 8 % | TPS312xH | 1,10 | 1,38 | 1,66 | 2,76 |
| $V_{nom}$ – 9 % | TPS312xI | 1,09 | 1,37 | 1,64 | 2,73 |
| **$V_{nom}$ – 10 %** | **TPS312xJ** | **1,08** | **1,35** | **1,62** | **2,70** |
| $V_{nom}$ – 11 % | TPS312xK | 1,07 | 1,34 | 1,60 | 2,67 |
| $V_{nom}$ – 12 % | TPS312xL | 1,06 | 1,32 | 1,58 | 2,64 |

To prevent continuous and repeated response by the monitoring circuit to slight periodic fluctuations of the supply voltage ($V_{DD}$), the comparator has a hysteresis of a few millivolts (see Table 4). In practice, under the circumstances described here, the low-pass characteristic produced by the delay circuit following the comparator usually prevents repeated response by the circuit. In this case, the output(s) are kept constantly active by the continual retriggering of the reset timer.

**Table 4. Threshold Voltage $V_{IT}$—Typical Hysteresis**

| **Nominal Threshold Voltage $V_{IT-}$** | **Typical Hysteresis** |
|---|---|
| 1.0 V < $V_{IT-}$ < 1.4 V | 15 mV |
| 1.4 V < $V_{IT-}$ < 2.0 V | 20 mV |
| 2.0 V < $V_{IT-}$ < 3.0 V | 30 mV |

## 4.3 Monitoring Circuit Sensitivity

The ICs described here should detect drops in supply voltage that might jeopardize the reliable operation of the circuit being monitored. To estimate the amplitude and duration of these drops as well as the effectiveness of the monitoring circuit, the causes of the drops must be analyzed. Supply voltage drops have two fundamental causes:

- Abnormal load changes that cannot be compensated for sufficiently quickly by the stabilization circuit or perhaps cannot be compensated for at all
- Voltage that is launched in the system by external interference sources

  This interference comes from electrostatic discharges, arcs, inductive loads, and lightning incidences during thunderstorms, which are characterized at times by extremely high power.

A rough estimate can be made of the size of voltage drops stemming from load changes. The circuit example shown in Figure 10 should be helpful in this respect. For example, assume that the current feeding the power supply rises by ΔI = 5 A as a result of a sudden current load change. Such load changes occur, for example, when modern microprocessors are switched from an idle state to active operation. Assume also that the regulated power supply is not immediately able to deliver this current; the current must first come from the capacitor (C).

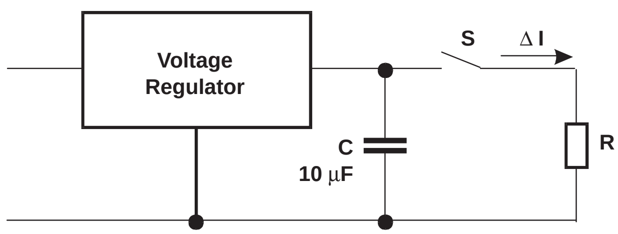


**Figure 10. Load Change in the Power Supply**

The voltage change ΔV at the capacitor C is calculated using the following formula:

$$\Delta V = \frac{1}{C} \times \Delta I \times t \qquad (1)$$

The following is obtained by conversion:

$$\frac{\Delta V}{t} = \frac{1}{C} \times \Delta I = \frac{1}{10\,\mu F} \times 5A = 0.5\ V/\mu s \qquad (2)$$

The voltage-monitoring circuit must detect voltage changes of the calculated size and trigger a signal when the voltage falls below the minimum reliable value. The reaction of the voltage-monitoring circuit to a supply voltage drop for a duration of $t_p$ was determined for this example. Figure 11 shows the result measured on the TPS3125J12 IC. The last two digits of the type number indicate that this component is designed for a nominal supply voltage $V_{DDnom}$ = 1.2 V. The letter J indicates that the operating point is $V_{IT-} = V_{DDnom}$ – 10 % = 1.08 V (see Table 3). The circuit responds if the voltage $V_{DD}$ drops to this value for a period $t_p$ > 1 µs. The circuit is less sensitive to a drop for $t_p$ < 1 µs; that is, for fairly short drops, a slightly larger amplitude of voltage drop is required for the comparator to respond. The circuit reaches its limit when the duration of the drop is less than 500 ns. The comparator can detect drops of this duration to a limited extent only. Such short voltage drops are not expected under the operating conditions described here.

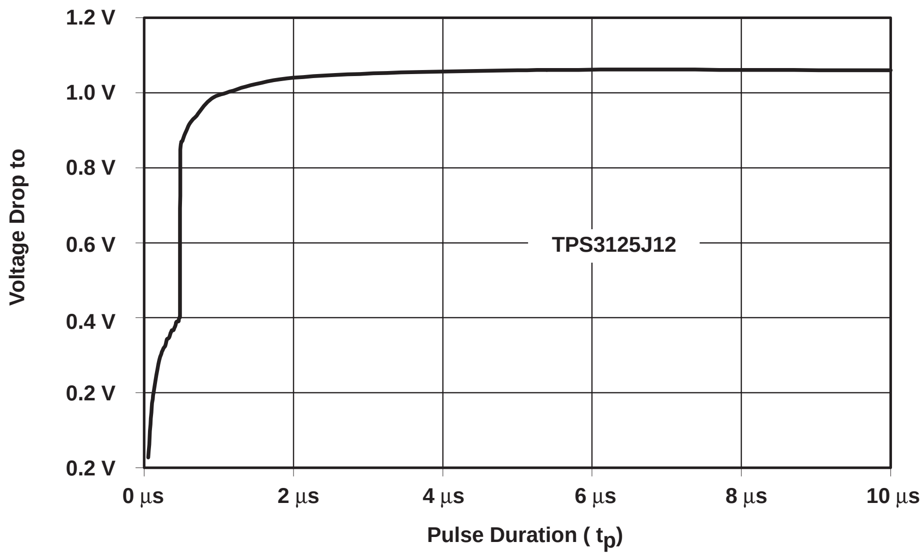


**Figure 11. TPS3125J12—Reaction fo Voltage Drops**

Figure 12 shows similar behavior with a TPS3125L30 monitoring circuit. Because of the high supply voltage $V_{DD}$, the comparator is still able to detect voltage drops of a lower amplitude with a drop duration of approximately 250 ns.

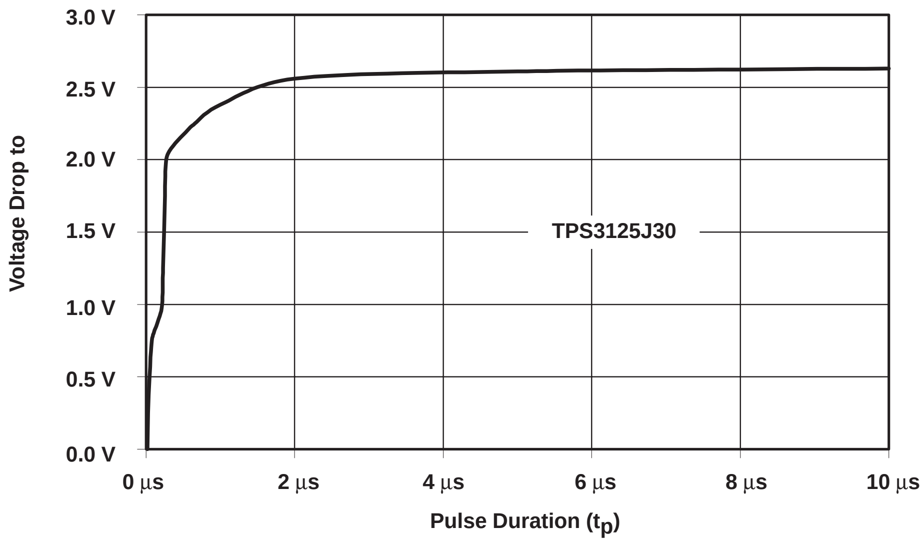


**Figure 12. TPS3125J30—Reaction fo Voltage Drops**

# 5 TPS3123 and TPS3124 Watchdog Circuits

Faulty operation of a system may result from supply voltage drops, interference from external sources, and program errors. Watchdog circuits monitor the functioning of a system to detect and correct problems. For this reason, the TPS3123 and TPS3124 supply voltage supervisor circuits combine the following functions:

- Voltage-monitoring function that monitors the presence of the correct supply voltage and provides a defined initialization of the system after it has been switched on or restored
- Watchdog function that takes corrective action in instances in which the functioning of the system is seriously disturbed for other reasons

Figure 13 shows the simplified block diagram of the TPS3123 and TPS3124 circuits. As described in Section 4.1, *Functional Description*, the voltage-monitoring circuit comprising the reference voltage source and the comparator form the core. When the supply voltage $V_{DD}$ distributed via the voltage dividers $R_2$ and $R_3$ is less than the reference voltage (see Table 3), the $\overline{RESET}$ output becomes low or the RESET output becomes high. When the supply voltage exceeds this threshold value, the timer in the reset logic keeps the outputs in active status for another $t_d$ = 180 ms before they switch back to inactive status. Because the SOT–23 housing in which these integrated circuits are assembled has only five pins, not all the inputs and outputs shown in Figure 13 can be provided simultaneously. Table 2 on page 5 gives an overview of the terminal configurations available.

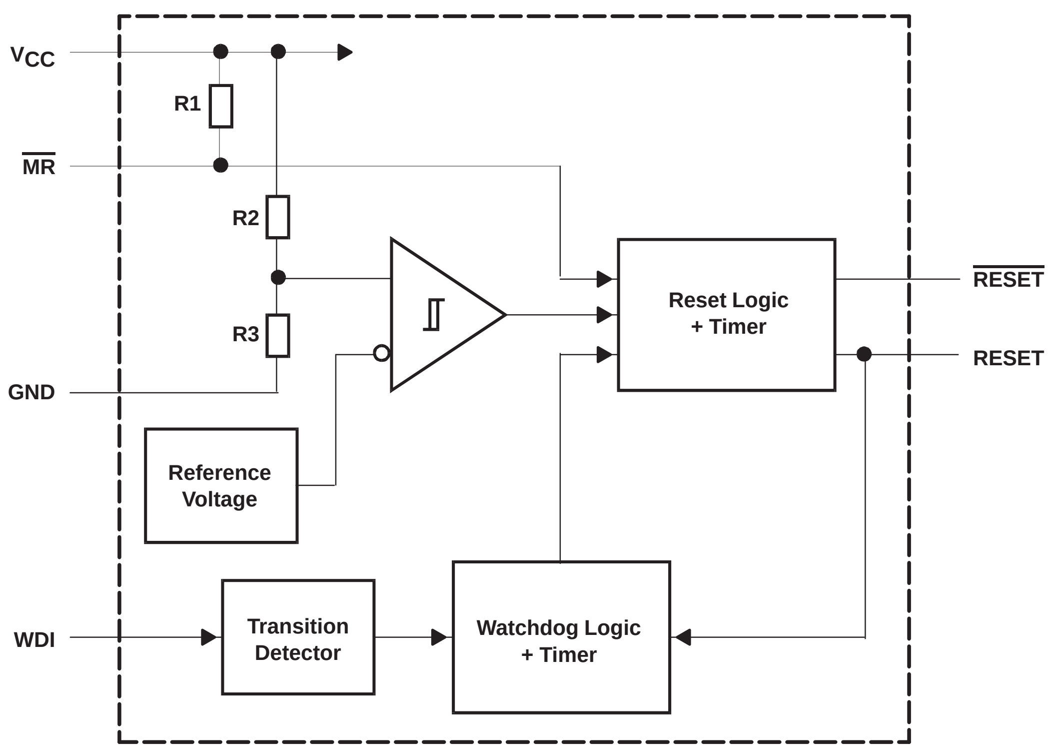


**Figure 13. TPS3123 and TPS3124 Circuits**

The TPS3213 and TPS3124 integrated circuits also contain the watchdog circuit. The Watchdog Logic + Timer functional block forms the core. This block is a retriggerable monostable flip-flop. The transition detector detects positive or negative edges at the watchdog input (WDI), and triggers the watchdog timer. The later has a time constant $t_{tout}$ = 1.4 s. When this time expires, the timer triggers the $t_d$ = 180-ms reset cycle. The active RESET output resets the watchdog logic, and a negative edge at this output (end of the RESET signal) retriggers the watchdog timer. The WDI is disabled during the reset cycle. Figure 14 illustrates this behavior.

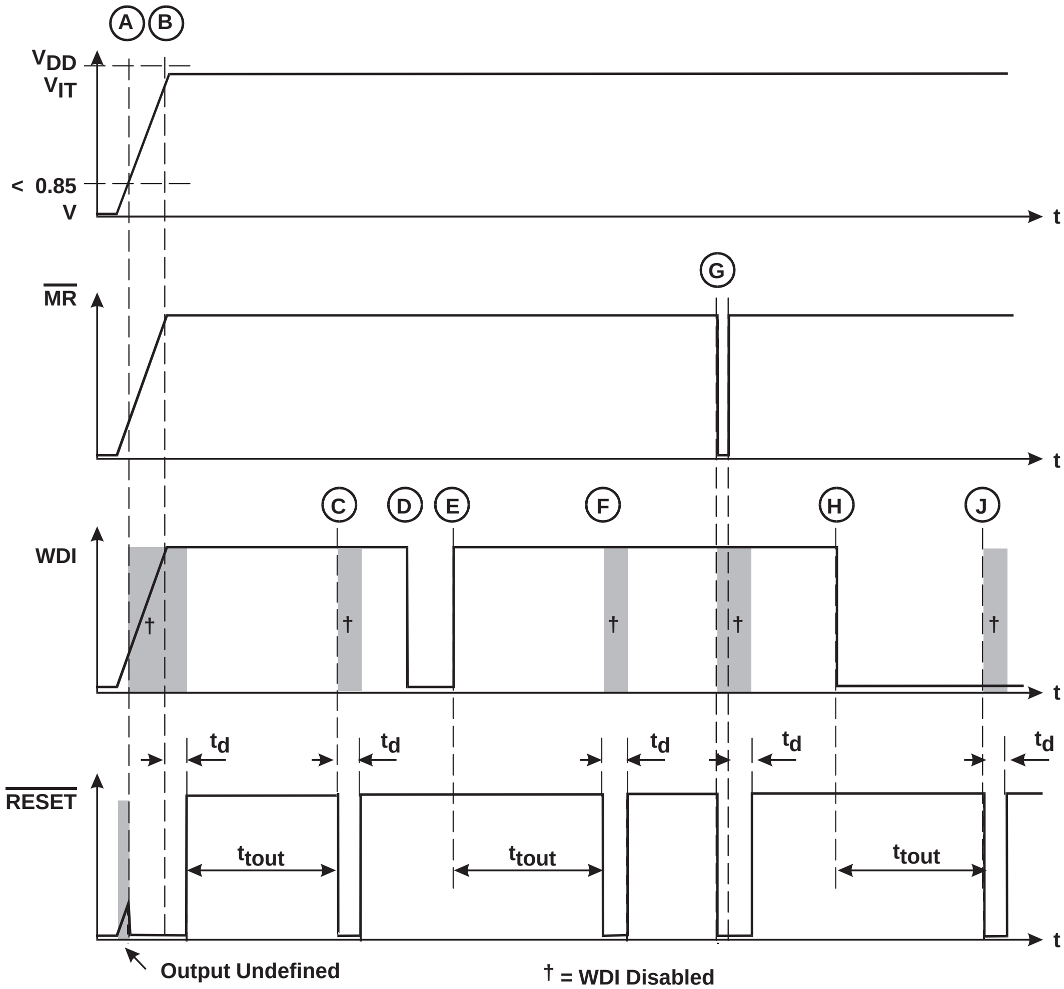


**Figure 14. Watchdog Circuit Timing**

When the supply voltage ($V_{DD}$) has risen to a value of $V_{DD}$ > 0.85 V after switch-on, the $\overline{RESET}$ output becomes active (low) (time A). After this voltage reaches a value of $V_{DD} > V_{IT+}$, the reset cycle begins (time B). The output continues to remain low for the duration of the time delay ($t_d$), or 180 ms. The WDI input is disabled until the end of this time as in all other shaded areas of the diagram. During the following transition time ($t_{tout}$) of 1.4 s, no change of level occurs at the WDI input; therefore, the watchdog timer retriggers a reset cycle at time C. A change of level from high to low or the reverse at the WDI input at time D and E resets the watchdog timer. After this, no retriggering of the timer occurs for the transition time ($t_{tout}$), so the $\overline{RESET}$ output becomes active again at time F for the time delay ($t_d$) of 180 ms. Before the transition time ($t_{tout}$) expires again, at time G, the $\overline{MR}$ input switches to low. The $\overline{RESET}$ output remains low for the length of the signal at this input plus the following 180 ms. Retriggering of the watchdog timer occurs at time H. At time J, the transition time ($t_{tout}$) measured from time H elapses again without the retriggering of the watchdog timer. Therefore, this timer retriggers a reset cycle. Figure 15 shows the signal form at the $\overline{RESET}$ output of a TPS3123x12 monitoring circuit ($V_{DD}$ = 1.2 V) when no change of level at the WDI input resets the watchdog timer.

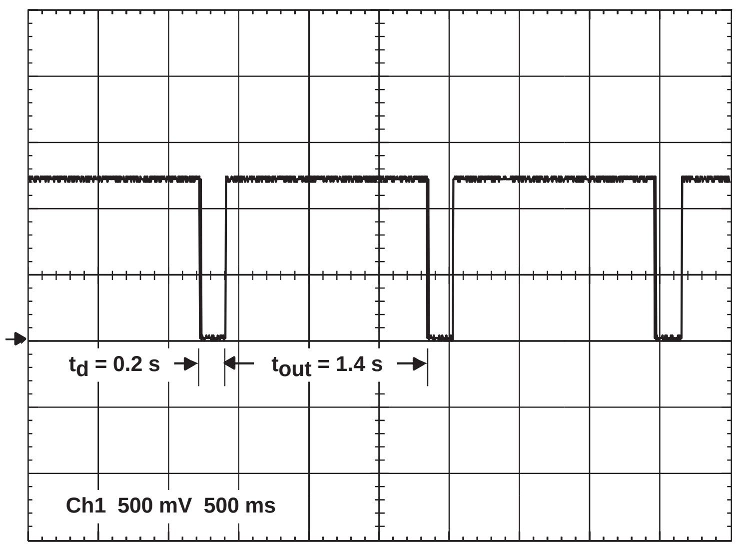


**Figure 15. Signal Form at the RESET Output**

# 6 Application Examples

This section describes application examples.

## 6.1 DSP With One Supply Voltage

The monitoring circuit application described here is extremely simple. Figure 16 shows the use of this circuit in conjunction with the TMS320UVC5402 digital signal processor (DSP). This integrated circuit can operate with different supply voltages or voltage combinations. Therefore, adaptation to the respective application condition is possible. The processor has two supply voltage connections. The $CV_{DD}$ connection supplies the processor core; this circuit's interface to the outside world (such as the address and data bus and the accompanying control signals) is supplied by the $DV_{DD}$ connection. The processor core requires a nominal supply voltage ($CV_{DD}$) of 1.2 V. The interface is designed for an extended nominal supply voltage range ($DV_{DD}$) of 1.2 to 2.5 V to facilitate easy adaptation to the surrounding circuit.

In the simplest case, only one voltage source supplies the signal processor. Then the $CV_{DD}$ and $DV_{DD}$ pins are connected in parallel. The nominal supply voltage is 1.2 V. A watchdog circuit monitors the system. The voltage-monitoring and watchdog functions are combined in the TPS3123 IC. With a minimum required signal processor supply voltage ($CV_{DDmin}$) of 1.14 V ($V_{DDnom}$ – 5 %) in this case, as shown in Table 3, the E version of the TPS3123 IC is selected. In this example, the full type designation of the monitoring circuit is TPS3123E12. Figure 16 shows the circuit schematic.

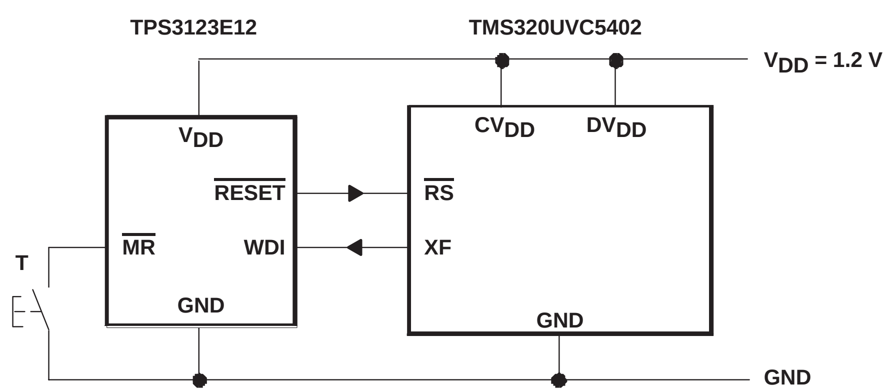


**Figure 16. Monitoring Circuit for the TMS320UVC5402**

The $\overline{\text{RESET}}$ output of the TPS3123 voltage-monitoring circuit triggers the reset input $\overline{\text{RS}}$ of the digital signal processor TMS320UV5402 and thus provides correct initialization of the computer. The watchdog circuit monitors the correct operation of the system. For this purpose, the program running in the signal processor must change the state of the XF output at regular intervals; that is, by switching from high to low or the reverse. Changing the output level via the WDI input resets the watchdog timer connected to this output (see Section 5, *TPS3123 and TPS3124 Watchdog Circuits*). If the resetting of this timer fails to occur for an interval longer than $t_{tout}$ = 1.4 s, the $\overline{\text{RESET}}$ output becomes low and reinitializes the processor. The initialization of the processor can also be triggered via the pushbutton T connected at the $\overline{\text{MR}}$ input. A pullup resistor is not necessary at this location because it is already integrated in the TPS3123 as $R_1$ shown in Figure 13.

## 6.2 DSP With Two Supply Voltages

The integrated circuits connected to the signal processors such as memory often require a higher supply voltage than 1.2 V. For this reason, this signal processor interface is designed so that it can be operated with a supply voltage $DV_{DD}$ of up to 2.64 V. In this case, both $CV_{DD}$ and $DV_{DD}$ must be monitored. Figure 17 shows two monitoring circuits used for this purpose.

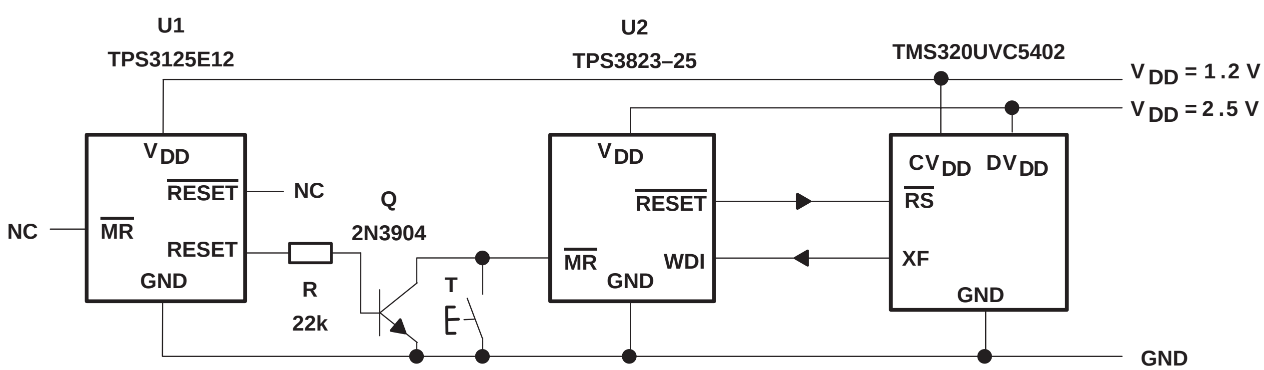


**Figure 17. Monitoring Circuit for a Processor With Two Supply Voltages**

The circuit $U_1$ (TPS3125E12) monitors the supply voltage of the processor core $CV_{DD}$ (nominal 1.2 V). Due to its supply voltage, the outputs of the circuit supply a high level $V_{OH}$ < 1.2 V only. This level is not adequate to trigger the $\overline{\text{MR}}$ input of the circuit $U_2$ (TPS3125). In this instance, adaptation of the level takes place via the transistor Q (2N3904). The pullup resistor integrated at the $\overline{\text{MR}}$ input of circuit $U_2$ then makes provision for an adequate high level. Parallel to this transistor is the pushbutton T, which can also be used to trigger system initialization. The monitoring circuit $U_2$ TPS3823-25 then triggers the reset input $\overline{\text{RS}}$ of the signal processor. Circuit $U_2$ also contains the watchdog function. The XF output of the signal processor retriggers the trigger input WDI of the watchdog timer.

## 6.3 Microcomputers With Active-High RESET Input

Most microprocessors, microcomputers, and logic circuits require a reset signal that is active when low, as shown in Figure 16 and Figure 17. With some circuits, however, a high level must be present at the reset input to execute the reset function. In addition to the various CMOS logic circuits of the CD4000 series, 80xx series microcomputers are also available from various manufacturers. Figure 18 shows the TPS3125 voltage-monitoring circuit application with an 80xx microcomputer.

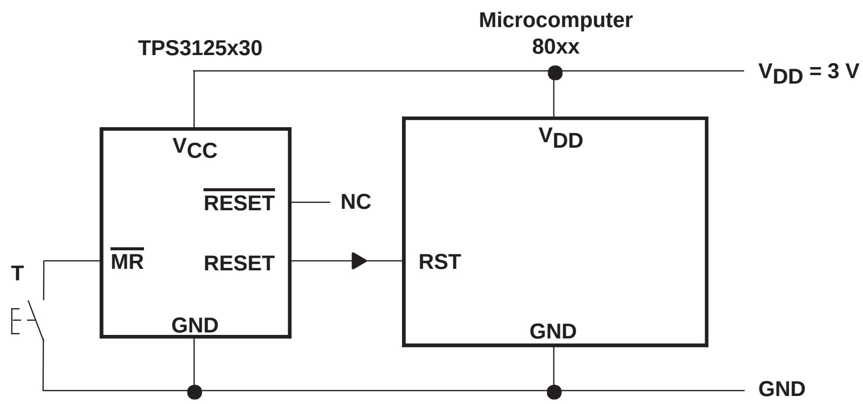


**Figure 18. Initialization Circuit of a Microcomputer With Active-High Reset Input**

## 6.4 Monitoring Positive and Negative Supply Voltages

A range of analog circuits requires a positive and a negative supply voltage, for example, +3 V and –3 V. If both supply voltages are provided, often operational amplifiers can handle dc voltages of both polarities. In such cases, the monitoring circuit must then monitor both voltages; this is possible with an appropriate circuit configuration, as shown in Figure 19.

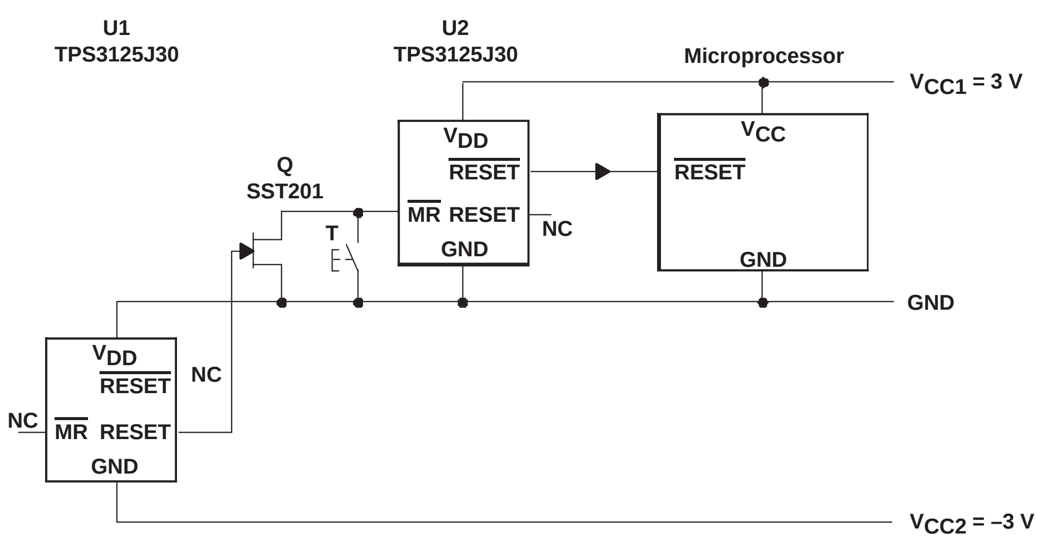


**Figure 19. Monitoring of a Positive and Negative Supply Voltage**

Figure 19 shows a suggested circuit for monitoring two voltages, $V_{CC1}$ = 3 V and $V_{CC2}$ = –3 V. The circuit $U_2$ (TPS3125) monitors the positive supply voltage $V_{CC1}$, while circuit $U_1$ of the same type monitors the negative voltage $V_{CC2}$. The field-effect transistor (FET) Q (SST201, manufacturer Temic Semiconductors™) takes over the change of the level relating to –3 V of the latter circuit to a level relating to 0 V. With an inadequate $V_{CC2}$, the RESET output of the lower circuit is high (= 0 V). As a result, the gate source voltage of the transistor Q $V_{gs}$ = 0 V. Consequently, the transistor conducts and switches the $\overline{\text{MR}}$ input of the monitoring circuit $U_2$ to the low level. The $\overline{\text{RESET}}$ output of the latter circuit also becomes low, just as it would if the positive voltage $V_{CC1}$ were not at the required level. The use of the N channel FET Q also allows an appropriate signal to be emitted by the monitoring circuit in the event of total failure of voltage $V_{CC2}$.

## 6.5 Debounce of Switches

Voltage-monitoring circuits can be used in a variety of applications not described here. The debouncing of mechanical contacts is a recurring problem. If contact surfaces collide when a contact closes, they bounce back repeatedly. A similar effect can be observed later when the contact opens. This bounce time is in the range of 100 µs–10 ms, depending on the contact design. These are very long times compared to the reaction speed of digital circuits; therefore, the bouncing of the switch is typically interpreted as repeated actuation. Figure 20 shows a debouncing circuit.

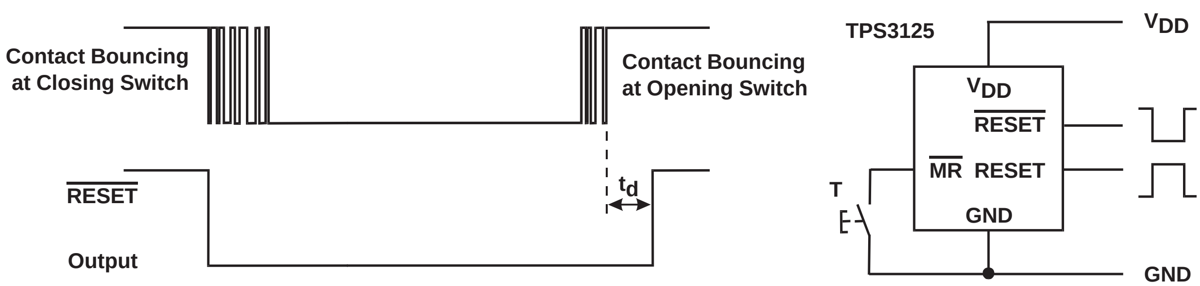


**Figure 20. Debouncing Circuit**

The low-pass with downstream Schmitt trigger circuit configuration is often used for switch debouncing. The monitoring circuits described here comprise these functions. On actuation of the pushbutton T the $\overline{\text{MR}}$ input becomes low. The RESET outputs follow this signal. The low level at the input simultaneously activates the reset timer (see Figure 20), which keeps the outputs in the active status for another 180 ms after a positive edge at the $\overline{\text{MR}}$ input. The low-pass characteristic, which deactivates the pulses caused by the contact bounce, is obtained in this way.

The same events occur when the contact opens. When the debouncing circuit is designed, a monitoring circuit is selected with the threshold voltage ($V_{IT}$) significantly below the threshold voltage of the actual voltage-monitoring circuit. This approach prevents drops on the supply voltage line that prompt the debouncing circuit to an unwanted reaction.

# 7 Application Considerations

As shown in Section 6, *Application Examples*, it is easy to structure the TPS312x series monitoring circuit in a variety of applications because there are so many versions of this circuit with active-high and active-low outputs (such as the additional reset input $\overline{MR}$ and the watchdog function). Even with this flexibility, however, you should adhere to some guidelines when using the circuit components to avoid undesirable results.

## 7.1 Printed Circuit Board Layout Consideration

While voltage-monitoring circuits for use in digital applications seem exactly like digital circuits, these components actually contain sensitive analog circuits—the reference voltage source and the comparator. These integrated circuits are selected according to their application so that the threshold voltage ($V_{IT}$) of the voltage-monitoring circuit element is only a few percent below the nominal supply voltage. The monitoring circuit must detect abnormal drops in the supply voltage, but short-term interference voltage that occurs during normal operation of the system must be prevented from activating a circuit response.

To prevent the voltage-monitoring circuit from responding to short-term interference voltages, observe the following rules when placing components on the printed circuit board (PCB):

- Place the monitoring circuit at points on the PCB where short-term interference either does not occur or occurs infrequently.
- Control the printed conductors on the PCB appropriately (see Figure 21).

  The blocking capacitor C is parallel to the supply voltage connections of the integrated circuits. Do not allow other system currents to flow on the connecting lines between the capacitor and the integrated circuits because they cause voltage drops on these lines that superimpose themselves on the voltage to be monitored and prompt an unwanted circuit response.

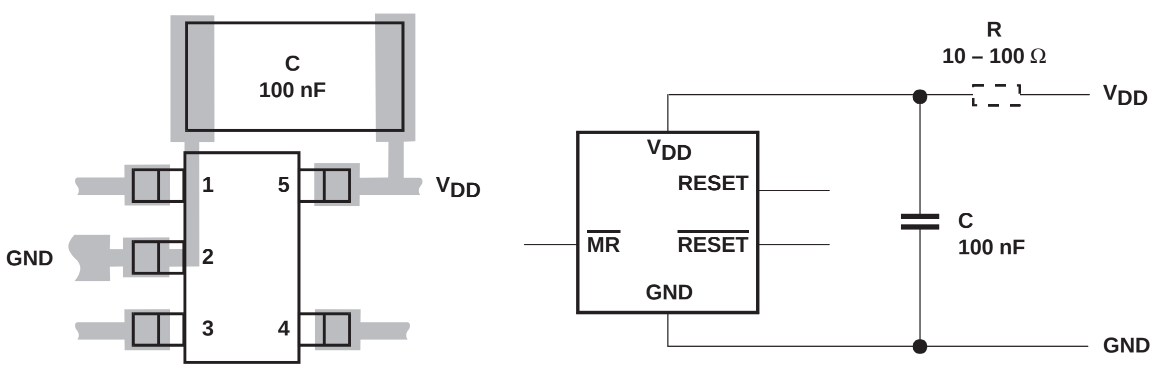


**Figure 21. Suggestion for Routing**

The capacitor C has various tasks. At high frequency, it provides a low impedance for the power supply to prevent unwanted feedback in the analog part of the monitoring circuit. This capacitor also supplies the current required during the output transitions for the current spikes in the output transistors, and for the charging of the load capacitance.

A resistor R in Figure 21 in the supply line may in some cases keep interference away from the circuit. When the monitoring circuit responds to interference voltages, you should try to identify the cause rather than simply filter out the interference. For example, the cause of such interference may be in the power supply. Capacitor C shown in Figure 10 on page 12 may be too small so that load changes cause supply voltage drops that are too large. The best solution is to increase the capacitance of this capacitor. In another instance, the voltage regulator may supply voltage that is too low and close to the threshold voltage $V_{IT}$. Adjusting the regulator's output voltage solves the problem.

## 7.2 External Noise

The considerations in Section 4.3, *Monitoring Circuit Sensitivity*, show that voltage drops in the power supply section (which can be attributed to the normal behavior of the connected circuit) are relatively slow. The monitoring circuits described can usually detect these events safely. Behavior is different with supply voltage interference that comes from outside the device. However, the ICs described here are voltage-monitoring circuits, not interference voltage detectors.

The amplitude and duration of external interference depend on its source. You can only predict the quality of external interference when you have precise knowledge of the interference source and of the coupling path, although you can make rough estimates on the coupling path (see Figure 22). Voltage $V_{noise}$ up to several 1000 V are to be expected there, depending on the nature of the interference source. The interference voltage reaches the potentially susceptible device with impedance ($Z_S$) via the coupling impedance ($Z_C$). The coupling impedance is $Z_C$ = 100 … 1000 Ω. The impedance of the potentially susceptible device (in this case, the impedance of the power supply system) is $Z_S$ < 1 Ω.

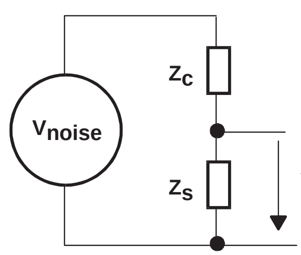


**Figure 22. Interference Path**

You should expect voltages ($V_S$) of several volts with a pulse duration from a few nanoseconds to 10 microseconds at the sink, depending on the interference source and the coupling impedance. Interference of this magnitude can create long-term problems with the system's functioning and may even destroy the circuit without a response from the monitoring circuit. Interference stemming from electrostatic discharges is often of short duration but high power.

Measuring interference voltages and distinguishing them from the normally superimposed voltages on the supply voltage is problematic. These voltages are measured with traditional oscillographs and the signal measured is tapped using standard probes (see Figure 23). This technique often fails when used to measure interference voltage stemming from external interference sources. Due to mechanical conditions, it is often difficult to apply the probe. This means that the measurement must be taken with the device open, and the shield effect of the housing is lost. This situation leads to unrealistic results.

Connecting the ground wire of the probe to the device under test is the main cause of incorrect measurements. The ground wire, several centimeters long, forms an antenna that picks up voltages and currents carried from the interference source by the air and superimposes on them the signal to be measured. No realistic results are obtained under these conditions.

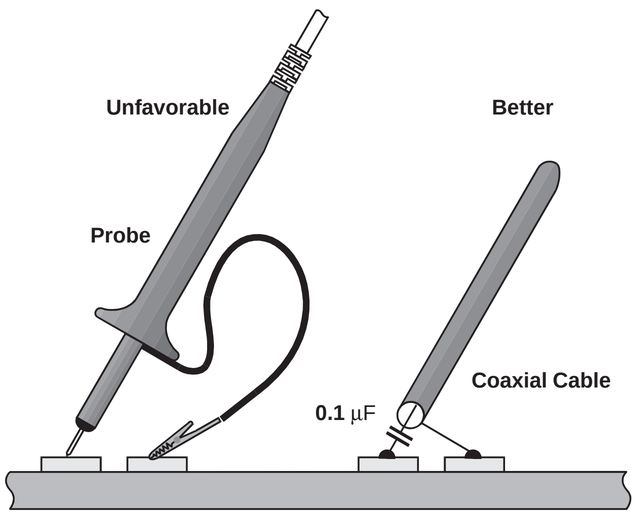


**Figure 23. Uncoupling of Interference Voltages on the Supply Lines**

To avoid the problem caused by the probe ground wire, use a coupling capacitor (0.1 µF) to connect a coaxial cable to the measuring point and to lead the signal to be measured to the oscilloscope, as shown in Figure 23. A 50-Ω matching resistor must be provided at the end of coaxial cable (oscilloscope input). This reduces the effective antenna surface considerably. Moreover, it makes it possible to lead the coaxial cable through a ventilation slit in the device housing and operate the device in its intended status.

# 8 Summary

The electromagnetic compatibility of a circuit or device can be adversely affected by a variety of factors, not the least of which is a system’s safety of operation. To ensure this safety of operation, TI offers the TPS312x series supervisory circuits, which include a range of components that monitor vital parameters of a device. Chief among the parameters monitored is the correct supply voltage. Digital circuits (such as microprocessors and microcomputers) typically require initialization after the supply voltage is switched on, and must be monitored for proper functioning by watchdog circuits. This is especially true in systems where safety is paramount. The TPS312x series components perform both of these functions well. With a supply voltage falling to 1.2 V and a typical current consumption of approximately 20 μA, these components are ideally suited for battery-powered devices. Using TI TPS312x series components allows the design engineer to monitor the functions of a device in a simple and cost-effective manner.

# 9 References


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Texas Instruments: Data sheet TPS3809, Literature # SLVS228

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Further information can be found on the Internet at Texas Instruments: http://www.ti.com