

TLC770X Series of BiCMOS SUPPLY VOLTAGE SUPERVISORS

Author: Ingrid Kohl

Literature Number: SLVAE03

April 1995

IMPORTANT NOTICE

Texas Instruments (TI) reserves the right to make changes to its products or to discontinue any semiconductor product or service without notice, and advises its customers to obtain the latest version of relevant information to verify, before placing orders, that the information being relied on is current.

TI warrants performance of its semiconductor products and related software to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

Certain applications using semiconductor products may involve potential risks of death, personal injury, or severe property or environmental damage ("Critical Applications").

TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, INTENDED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT APPLICATIONS, DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS.

Inclusion of TI products in such applications is understood to be fully at the risk of the customer. Use of TI products in such applications requires the written approval of an appropriate TI officer. Questions concerning potential risk applications should be directed to TI through a local SC sales office.

In order to minimize risks associated with the customer's applications, adequate design and operating safe-guards should be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance, customer product design, software performance, or infringement of patents or services described herein. Nor does TI warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used.

Copyright © 1990,1995, Texas Instruments Incorporated

Contents

1. Introduction.....	5
1.1 RESET Circuits.....	5
2. The Behavior of Power Supplies.....	6
2.1 Line Operated Power Supplies.....	6
2.2 Battery Operated Power Supplies	8
3. Circuit Description	9
4. The Behavior of Digital Circuits	17
5. Examples of Applications.....	18
5.1 Voltage Monitoring	18
5.2 Applications in Systems.....	23
5.3 Application Hints.....	23
6. Summary	26
6.1 Design Check List	26
6.2 Comparison of the Bipolar and BiCMOS Versions	27

Figures

1. RESET Circuits	5
2. Principle circuit of a Line (Mains) Power Supply.....	7
3. Voltage waveforms in a line operated power supply	7
4. The effect of bouncing switch contacts on the switch-on time of a battery-operated power supply	8
5. Functional Circuit Diagram.....	9
6. Logic Symbol.....	9
7. Timing Diagram	11
8. Dependence of the delay time on the capacitance C_t	12
9. Truth Table.....	13
10. CMOS input	13
11. Dependence of the lateral current at the CONTROL input on the input voltage ($V_{DD}=5V$).....	14
12. Dependence of the minimum pulse width at the SENSE input on the reduction of the supply voltage ($V_{DD}=5V$).....	15
13. The signal at the SENSE input for determining the minimum pulse width t_p	15
14. Delay of the charging process with very fast rise times of the supply voltage (The time axis is not to scale).....	16
15. RESET procedure with the TMS370.....	17
16. Simple voltage monitoring circuit with the TLC7705	18
17. Voltage monitoring circuit for a microcomputer system with the TLC7701	19
18. Monitoring of a system with two different supply voltages.....	20
19. The monitoring of a positive and negative supply voltage	21
20. Delay circuit in an audio amplifier	22
21. Voltage monitoring in a battery backed memory system	23
22. Current peaks on the supply line when switching the RESET output	24
23. Suggested layout for a circuit board with the TLC7701.....	25

1. Introduction

This report describes the function and application of the supply voltage supervisor circuit TLC770X. Besides a detailed functional description, the behavior of line and battery operated power supplies during power-up as well as the behavior of digital circuits is presented. Finally application-examples of supply voltage supervision in general and supply voltage supervision in systems are described.

1.1 RESET Circuits

In order to ensure the reliable operation of a digital system, it is important that the circuits of which it is composed should have a clearly defined initial state. With microcomputers and microprocessors, this initial state is implemented with a reset signal, which may for example be applied to the Reset input. This ensures that the system is only switched into an active state when the supply voltage has reached its nominal value. In the same way, a break down of the supply voltage affects the operation of integrated circuits and can result in their faulty operation.

For example, with CMOS circuits, a reduction of the operating voltage results in a slowing down of the circuit. This in turn affects the internal timing of the circuitry, and consequently the operation of the complete system.

In order to avoid such disturbances, a circuit is needed which will generate a defined Reset signal. The simplest way of implementing this is with the help of an RC network at the Reset input (Figure 1.)

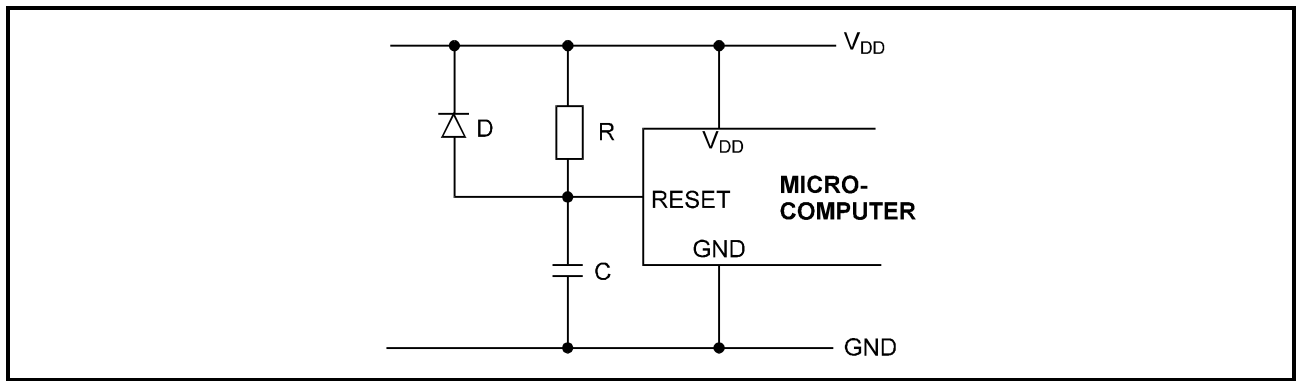


Figure 1. RESET circuit

The voltage at the RESET input rises with a delay determined by the time constant $t = R \times C$, until the threshold value of the Reset input has been reached. At this point, the system is switched into an active state.

This method of generating the Reset pulse is however not very reliable, since the Reset time depends on the boundary conditions of the power supply and of the complete system.

The Reset circuit must keep the resetting input of the system in an active state until the supply voltage has reached its nominal value. After the full supply voltage has been reached, the Reset signal must be kept applied for a certain time, which depends on the resetting time of the system.

The Reset time in the above circuit is however very dependent on the rise time of the supply voltage. For this reason, it can not be guaranteed that the Reset pulse will be applied long enough to bring the system into a defined initial state.

This circuit is not able to recognize minor disturbances of the supply voltage below its minimum permissible value. The Reset input of the microcomputer is only able to recognize a Reset signal when the voltage across the capacitor is below the threshold voltage V_t of the input stage of the microcomputer. The circuit therefore only operates correctly when the supply voltage falls to at least the value $V_t - V_f$. With a TTL input stage, the value of V_t is about

1.5V, and the diode threshold voltage V_f is typically 0.7 V. The supply voltage must therefore go below a value of $1.5\text{ V} - 0.7\text{ V} = 0.8\text{ V}$ in order that a Reset signal shall be generated.

However, even a minor reduction of the supply voltage can cause faults with integrated circuits which may have serious consequences.

Since this circuit only fulfills with some reservations the requirements for a reliable system Reset, more extensive precautions must be taken to exclude faults of this kind.

The following requirements must thus be fulfilled:

- The Reset signal must be applied long enough for the supply voltage to have reached its nominal value.
- After the nominal supply voltage has been reached, the Reset signal must stay active for a certain time, in order to ensure error free initialization and thus correct operation of the system.
- The Reset signal must again initialize the system, should the supply voltage go below the minimum permissible value.

For these applications, Texas Instruments has developed a range of Supply Voltage Supervisors which meet the above requirements.

For applications where very low power consumption is of particular importance, a series of BiCMOS versions with the generic type number TLC770X has now been developed, which has extremely low current consumption.

2. The Behavior of Power Supplies

In order to design correctly a Reset or initialization circuit, it is first necessary to understand the behavior of the voltage which is being monitored.

2.1 Line Operated Power Supplies

With line (mains) operated power supplies (Figure 2.), particular attention must be paid to the behavior when the power supply is switched on.

The voltage waveform at switch-on is influenced by the exact moment of switching, with reference to the phase relationship of the line voltage. The reservoir capacitor C_{Res} will be completely, or only partially charged up, depending on the point in time at which the sine wave is applied at switch-on to the input of the power supply. If the capacitor is only partially charged during the first half sine wave, the result may be that the voltage decreases again before it reaches the full supply voltage.

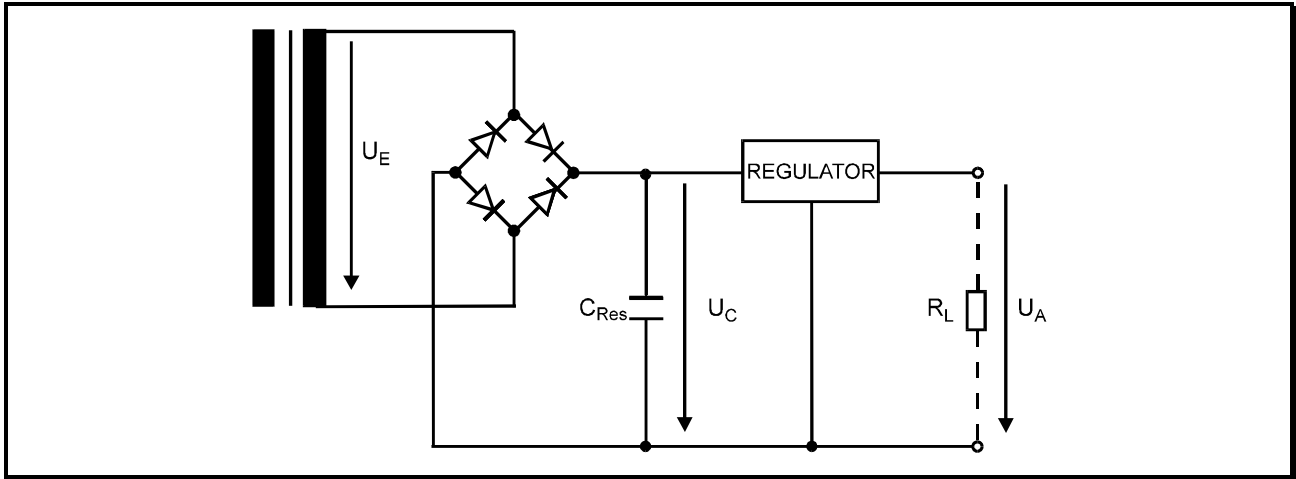


Figure 2. Principle circuit of a Line (Mains) Power Supply C_{Res} $t=0$ and $0 < t_1 < T/2$.

Figure 3. is intended to explain the relationship between the time of switch on and the voltages across the capacitor and at the output of the line power supply.

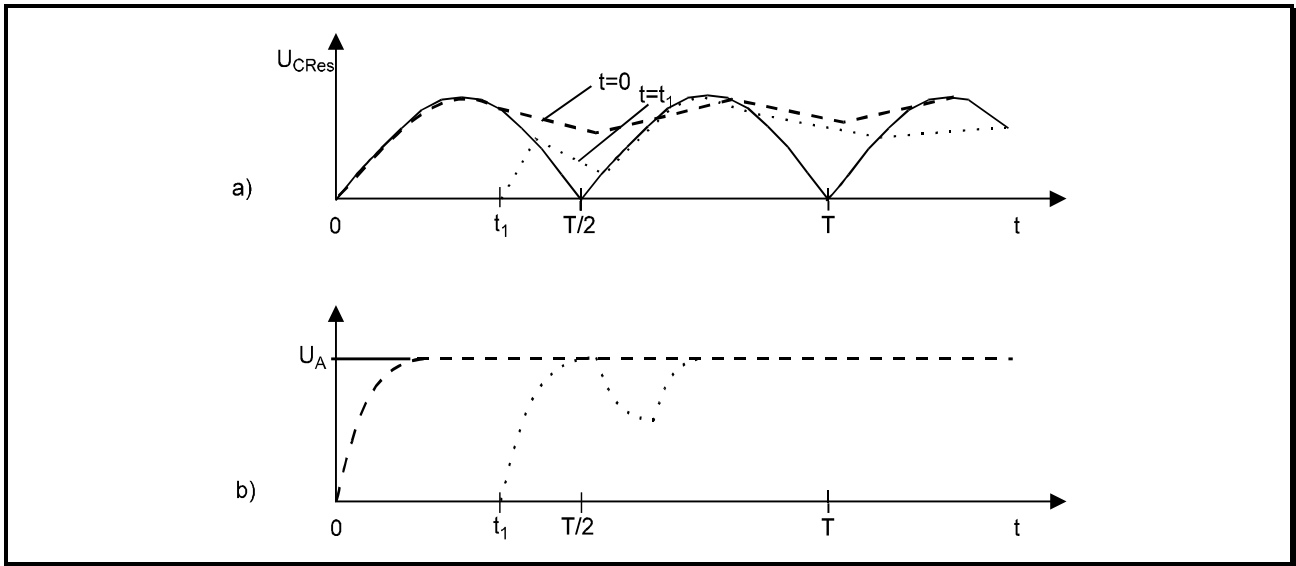


Figure 3. Voltage waveforms in a line operated power supply a) Voltage waveform across the capacitor C_{Res} when switched-on at a time $t=0$ and $0 < t_1 < T/2$. b) Voltage at the output when switched on at a time $0 < t_1 < T/2$.

It can therefore take several cycles until the voltage has stabilized. With line power supplies, the switch-on process has a typical duration of 10 - 20 ms: this means that the Reset signal must remain active at least for that period of time.

The voltage monitoring circuit must keep the Reset signal active at least until the supply voltage has reached a stable state.

2.2 Battery Operated Power Supplies

Battery operated power supplies are playing an ever increasing role, thanks to the continuing trend towards portable systems.

In comparison to line dependent power supplies, battery supplies have the advantage that the voltage at switch on immediately rises to its final value. This does not however take place quite as quickly as one might wish, because the blocking and filter capacitor C_F must also be charged via the internal resistance R_i of the battery. To a first approximation, the following values can be assumed:

$$R_i = 0.1\Omega - 10\Omega \quad ; \quad C_F = 10\mu\text{F} - 1000\mu\text{F}$$

The time period needed by the voltage to reach 95% of its nominal level can be calculated as follows:

$$V_{DD} \left(1 - e^{-\frac{t}{R_i C_F}}\right) = 0.95 V_{DD} \quad \Rightarrow \quad t = -R_i C_F \cdot \log 0.05$$

This results in values for the rise time of between 0.03 and 30 ms.

An additional factor which influences the switching on time of the battery voltage is the bouncing of the contacts of the mechanical switch (Figure 4.).

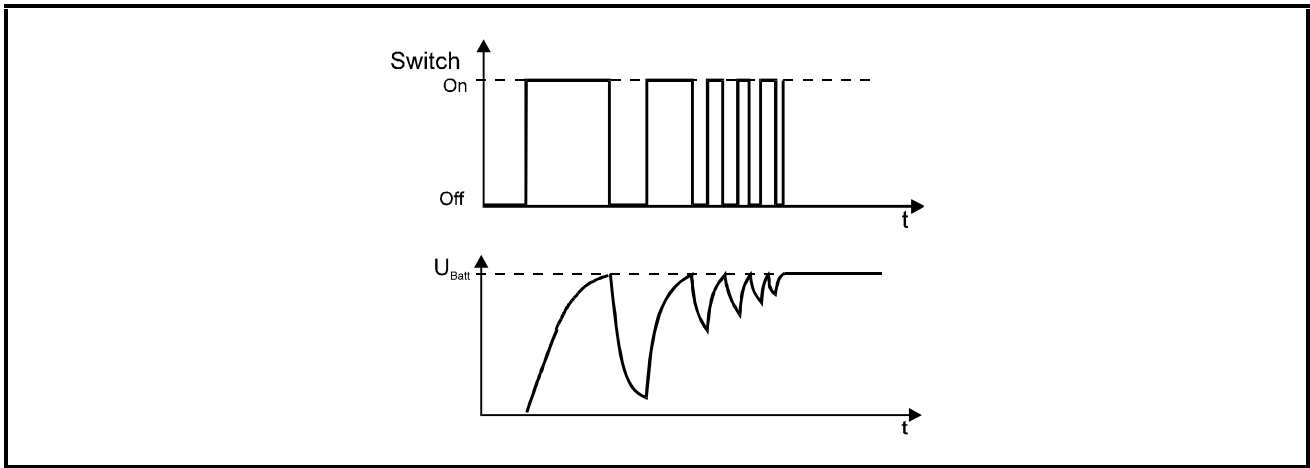


Figure 4. The effect of bouncing switch contacts on the switch-on time of a battery-operated power supply.

The Reset circuit must also in this case remain active until the supply voltage has stabilized.

3. Circuit Description

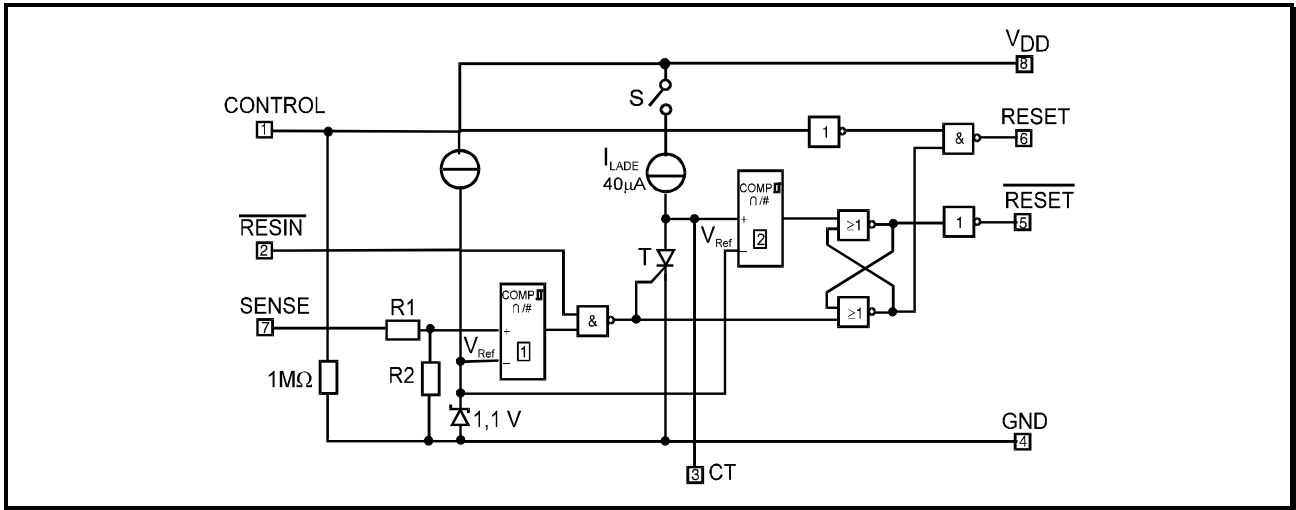


Figure 5. Functional Circuit Diagram

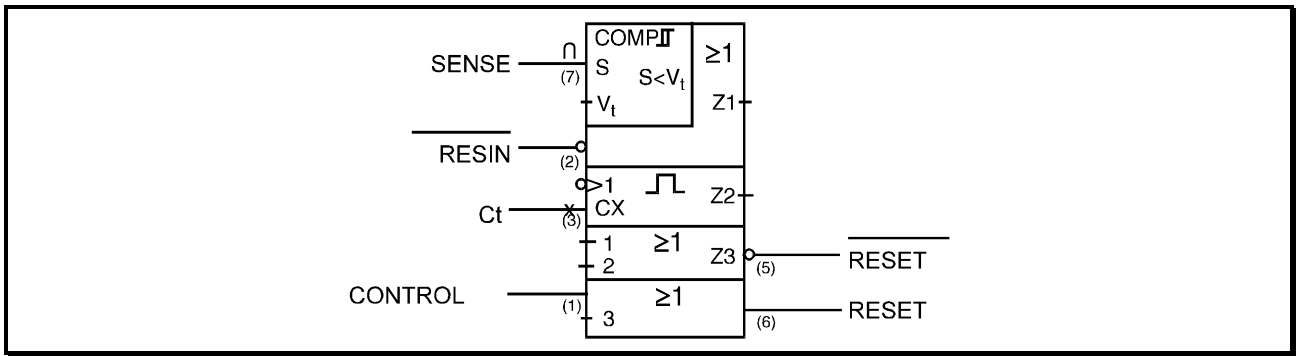


Figure 6. Logic Symbol

The operation of the circuit can be described as follows.

The voltage to be monitored is applied to the SENSE input. This voltage is then subdivided by the voltage divider R_1/R_2 , and compared in the comparator 1 with a reference voltage V_{ref} , which is internally generated in the device.

The resistance values given in the Data Sheet for the resistive voltage divider at the SENSE input are typical values only, since they are liable to considerable scatter during the manufacturing process ($\approx \pm 20\%$). Of importance is only the ratio of the resistors, and this is only liable to slight process scatter, and in addition can be adjusted during the manufacture of the component. The 1 V version TLC7701 is however an exception: with this component, an external voltage divider must be used to determine the threshold voltage. This should be of high resistance (100 - 200 k Ω /V), in order that the current consumption does not become excessive. The final resulting threshold voltage V_t' can then be calculated as follows:

$$V_t' = V_{ref} \cdot \frac{(R_1 + R_2)}{R_2} \quad \text{with } V_{ref} = 1.1 \text{ V}$$

If for example a voltage of 2.5 V ($\pm 5\%$ tolerance) is to be monitored, the lower tolerance limit must be chosen for the calculation of the resistance values. V_t' is then calculated as follows:

$$V_t' = 2.5 \text{ V} \cdot 0.95 = 2.375 \text{ V}$$

The values of the resistors which result are then:

$$R_1 = 174 \text{ k}\Omega \quad \text{and} \quad R_2 = 150 \text{ k}\Omega$$

The resistors must be of very close tolerance ($\pm 1\%$).

The reference voltage $V_{ref} = 1.1 \text{ V}$ is generated with a Band-Gap reference. This precise reference voltage has excellent temperature stability, and allows a very close tolerance of the output voltage V_{ref} . The resulting tolerance is typically better than 1%, with a maximum of 1.5%.

As long as the voltage at the SENSE input is less than the threshold voltage V_t , the thyristor T is conducting and the capacitor C_t is discharged. If the voltage at the SENSE input increases and becomes more than the voltage V_t , then the thyristor T blocks as a result the low current flowing through it (less than its holding current), and the capacitor C_t becomes charged via the current source I_{charge} . In order to keep the current consumption of the circuit low, the current source I_{charge} is only switched on via the switch S when a charging of the capacitor really needs to be performed. This condition is fulfilled when the voltage at the SENSE input has reached the threshold value V_t ($V_{SENSE} > V_t$), and the charging process of the capacitor C_t has not yet been completed ($V_{Ct} \leq V_{Ref}$). In all other operating states, the current source I_{charge} remains switched off.

The voltage across the capacitor C_t is in turn compared by the comparator 2 with the reference voltage V_{ref} . If the capacitor voltage exceeds the reference voltage, then the subsequent logic circuitry switches the outputs RESET and $\overline{\text{RESET}}$ into the inactive state. This results in RESET Low becoming, and $\overline{\text{RESET}}$ becoming High.

Figure 7. shows the relationship between the behavior of the voltage at the SENSE input and the output $\overline{\text{RESET}}$.

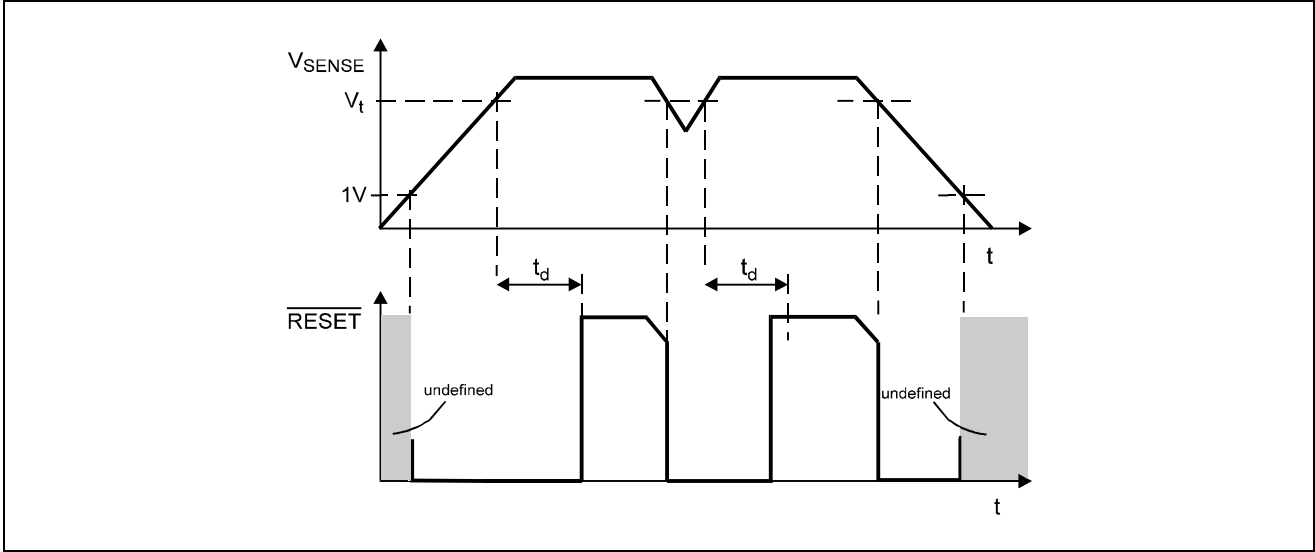


Figure 7. Timing Diagram

The capacitor C_t determines the time period t_d , for which the outputs are kept in an active state after reaching the threshold voltage V_t . The relationship between the time delay t_d and the capacitance C_t can be calculated as follows:

$$t_d = 2.1 \cdot 10^4 \frac{V}{A} \cdot C_t$$

The time period t_d can be chosen to be of any desired length. For long delay times t_d , appropriately big capacitors must then be used. In order to ensure that, when using large capacitance values of several microfarads and more, the discharge current does not cause a malfunction, a current limiting circuit has been integrated into the device. The maximum capacitance which can be used depends in the last resort on the leakage current of the capacitor. The latter works in opposition to the charging current I_{Charge} , and thus influences the delay time t_d .

Capacitors of 1000 μF and more having sufficiently low leakage current can be used. With a capacitance $C_t = 1000 \mu\text{F}$, the maximum delay time which results is then:

$$t_d = 2.1 \cdot 10^4 \cdot 1000 \mu\text{F} = 21 \text{ s}$$

Smaller values than 100 pF for the capacitance C_t do not appear to be advisable, since the effective capacitance is then increasingly influenced by the parasitic capacitance of the module, and a larger departure of the actual delay time t_d from the calculated value can then be expected.

The minimum advisable delay time can thus be calculated to be:

$$t_d = 2.1 \cdot 10^4 \cdot 100 \text{ pF} = 2.1 \mu\text{s}$$

The input C_t may be left open (unconnected) if no time delay, or only a very short one, is desired. In this case it is however not possible to predict the value t_d of the time delay, since the parasitic capacitance at Pin 3 is influenced by various factors, such as the sockets used, the metallisation on the circuit board, and the way it is constructed.

Figure 8. shows the dependence of the delay time t_d on the capacitance C_t .

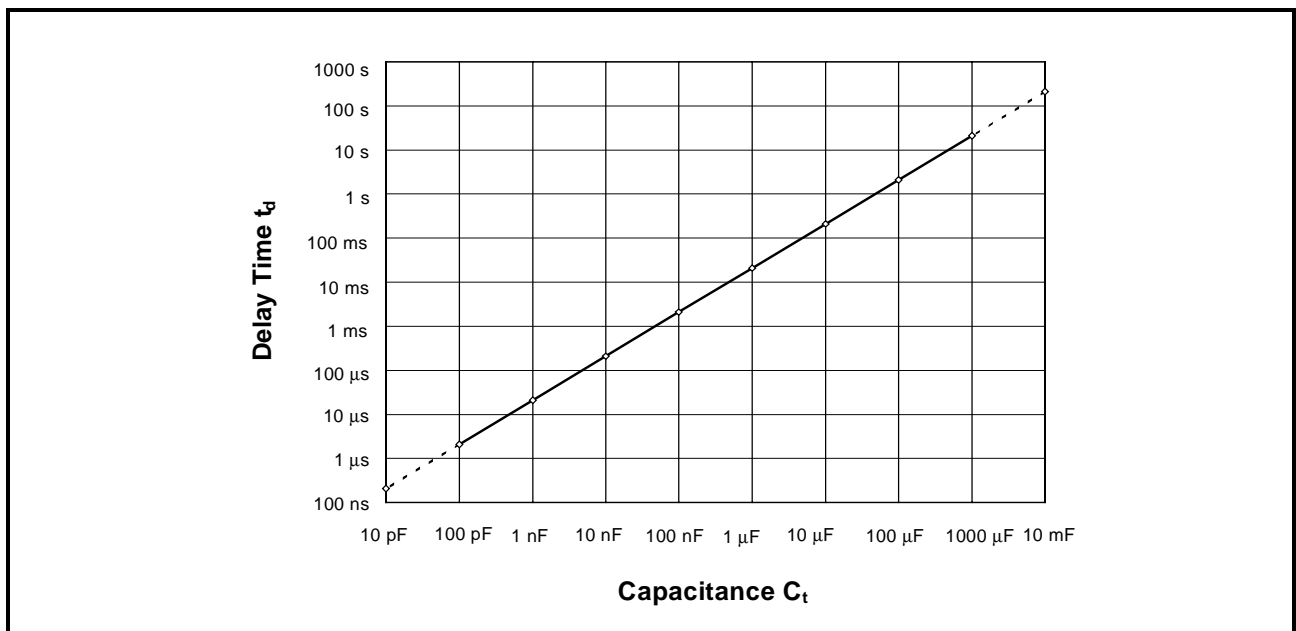


Figure 8. Dependence of the delay time on the capacitance C_t

The two inputs CONTROL and $\overline{\text{RESIN}}$ have a direct effect on the outputs. In this case, the $\overline{\text{RESIN}}$ input influences both outputs, and the CONTROL input only the RESET output. The relationship can be seen in the truth table shown in Figure 9.

CONTROL	$\overline{\text{RESIN}}$	SENSE > V_t	RESET	$\overline{\text{RESET}}$
L	L	false	H	L
L	L	true	H	L
L	H	false	H	L
L	H	true	L*	H*
H	L	false	H	L
H	L	true	H	L
H	H	false	H	L
H	H	true	H	H*

* $t > t_d$

Figure 9. Truth Table

With a Low level at the $\overline{\text{RESIN}}$ -Input, the capacitor C_t will be discharged and the outputs switch into the active state. After the input has again become High and the time period t_d has elapsed, the outputs switch back into the inactive state.

The input $\overline{\text{RESIN}}$ can, for example, be used in order to activate the RESET procedure manually by means of a switch. This input is also needed when several different supply voltages must be monitored in a single system (see Section 5).

The CONTROL input is provided with a 1 M Ω Pull-Down resistor. If the input CONTROL is left unconnected, it will thus be held at a Low level. The reason for this Pull-Down resistor is to ensure compatibility with the bipolar version TL770X. With the latter device, the input REF (Pin 1) had always to be connected to a 0.1 μF capacitor; if the TL770X is replaced in an existing circuit with the TLC770X, then no circuit changes will be necessary.

Open circuit inputs should however be avoided, with the exception of the CONTROL input, in order to ensure reliable operation of this component.

If the CMOS inputs are not connected as in Figure 10., undefined voltage levels can arise at these inputs and cause uncontrolled states and lateral currents, which in turn can result in a considerable increase in the current consumption.

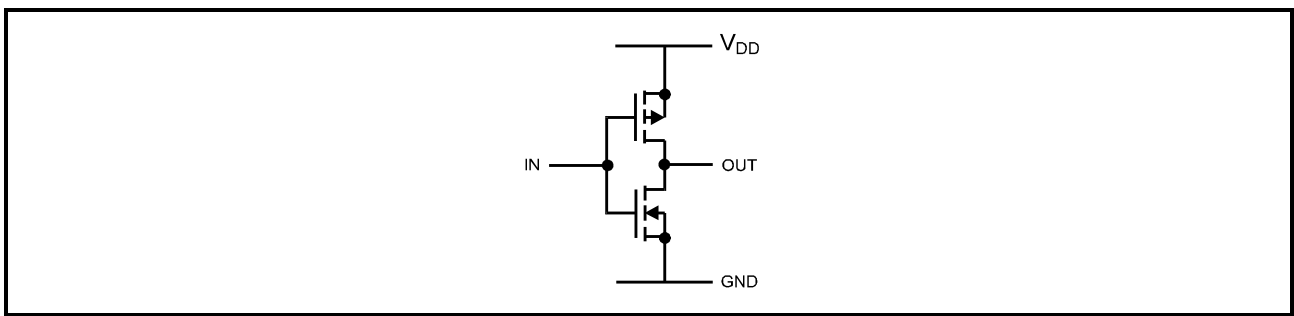


Figure 10. CMOS input

The reason for these undefined voltage levels at open circuit inputs is the leakage current of the circuit, and the high insulation resistances ($10^{12}\Omega$ and $10^{15}\Omega$) in the area of the inputs of these circuits. The result is that any conceivable voltage value between V_{DD} and GND can result at the input IN.

The dependence of the lateral current on the voltage level at input IN is shown in Figure 11.. For all other inputs, the lateral current at the CONTROL input was measured in the same way. If a defined High or Low level is applied to

input IN, then only one transistor will be conducting, and no lateral current flows through the circuit. With input levels that are between the specified High and Low levels, a current flows between the supply voltage V_{DD} and Ground.

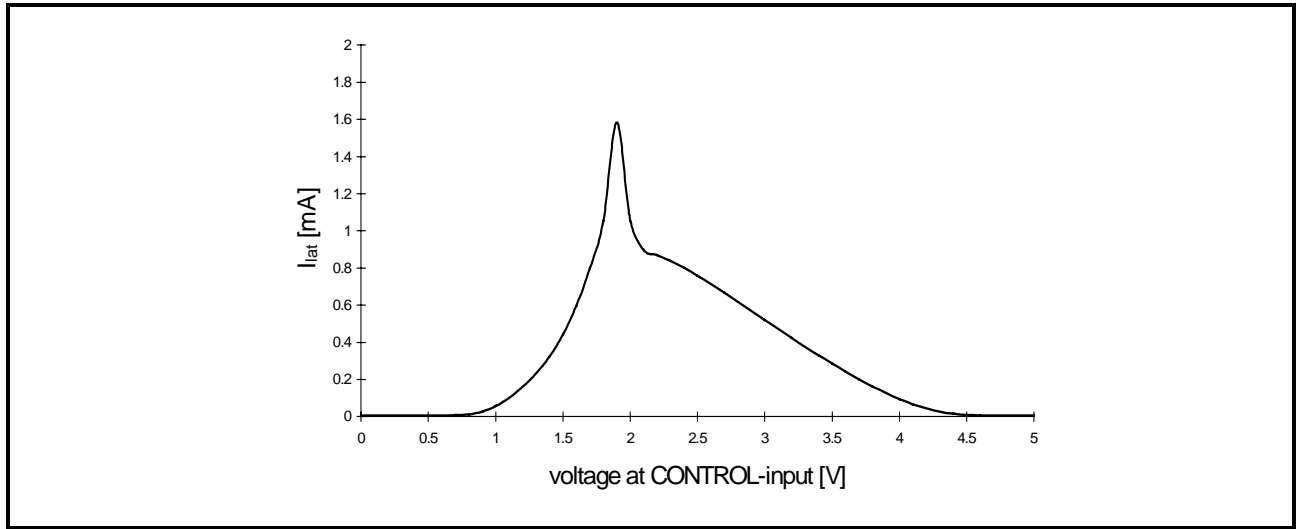


Figure 11. Dependence of the lateral current at the CONTROL input on the input voltage ($V_{DD}=5V$)

The typical current consumption of a TLC770X is only $10 \mu A$, whereas the lateral current can be about 100x higher.

With some applications (see Section 5, Figure 21.) undefined levels may exist at the CONTROL input. In order to prevent the CONTROL input from causing an increase of current consumption, it is inhibited as a result of internal circuitry if the \overline{RESET} – Output is active; that is, when a Low level is applied to the input \overline{RESIN} , or the voltage at the SENSE input is below the threshold voltage V_t .

In the quiescent state, the input \overline{RESIN} must be at a High level, and the input CONTROL at Low.

With supply voltages of less than the threshold voltage V_t of the MOS transistors ($V_t \approx 1V$), the device can not operate, and in this situation it is not possible to say what the voltage level at the output will be. Although with this order of voltage no definite function can be expected from the circuit being monitored, this does not mean any restriction in practice. With a supply voltage above 1 V there will be a Low level at the \overline{RESET} output, provided the input conditions are fulfilled. With a supply voltage of more than 2 V, all parts of the circuit in the TLC770X operate as specified in the Data Sheet.

In order that the circuit may recognize voltage reductions at the SENSE input, these voltages must be applied for a certain time period. This time depends on the magnitude of the voltage reductions: the greater these are, the shorter is the time period needed to start the RESET procedure. Figure 12. shows this relationship.

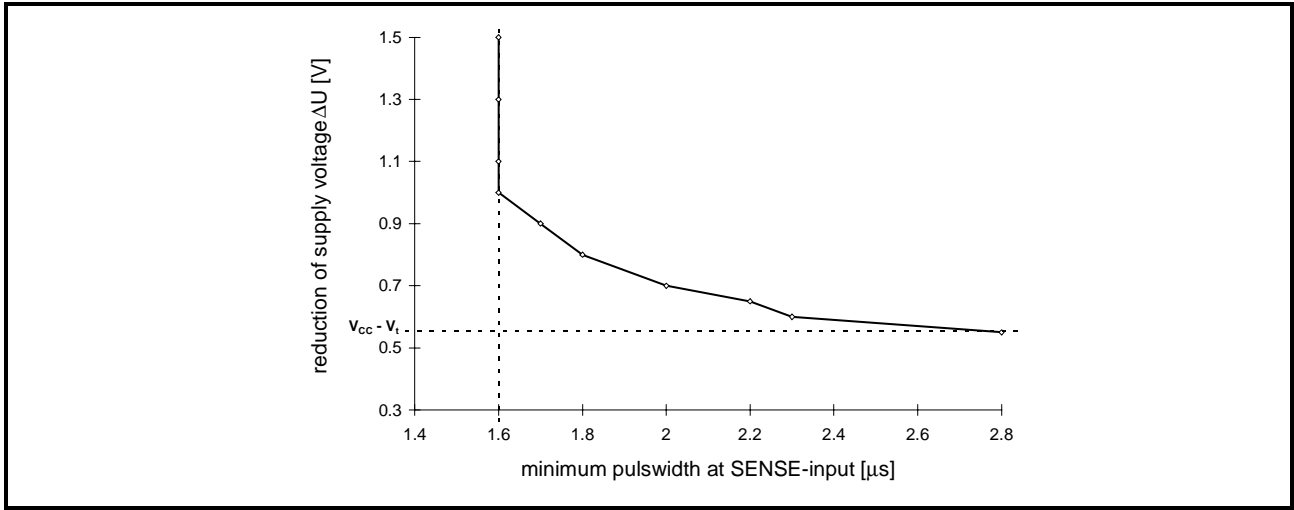


Figure 12. Dependence of the minimum pulse width at the SENSE input on the reduction of the supply voltage ($V_{DD}=5V$)

Below the minimum pulse width of 1.6 μs , no further reaction of the circuit can be expected. In order to determine the minimum pulse width, a pulse was applied to the SENSE input (see Figure 13.) whose amplitude ΔV was varied. The minimum pulse width t_p gives the value at which the circuit no longer shows any reaction for specific amplitude ΔV .

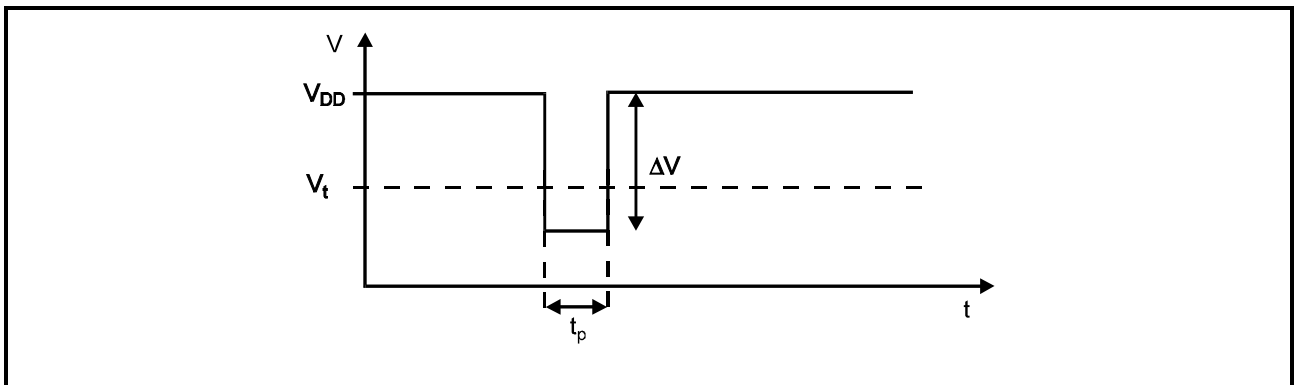


Figure 13. The signal at the SENSE input for determining the minimum pulse width t_p

In certain applications a slower reaction of the voltage monitoring circuit may be required than that which is provided by the integrated circuit itself. In this case, a low pass filter can be inserted before the SENSE input which will filter out voltage reductions of short duration. The resistance of this RC network must not however be chosen with too high a value, in order not excessively to influence the integrated voltage divider at the SENSE input. Since this integrated voltage divider has a resistance of several 100 k Ω , resistors at the input of about 1000 Ω can be used, without significantly influencing the threshold voltage.

A factor which influences briefly the reaction of the circuit is the presence of very fast rise times of the supply voltage (rise time < 20 μs). These can cause parts of the circuit of the TLC770X to be over driven for short periods. In view of the high internal resistance of the circuit, it takes a certain time before the desired operating points have again been reached. The result of this is a delay of the charging process of the capacitor of about $t_v \approx 1 ms$ (see Figure 14.).

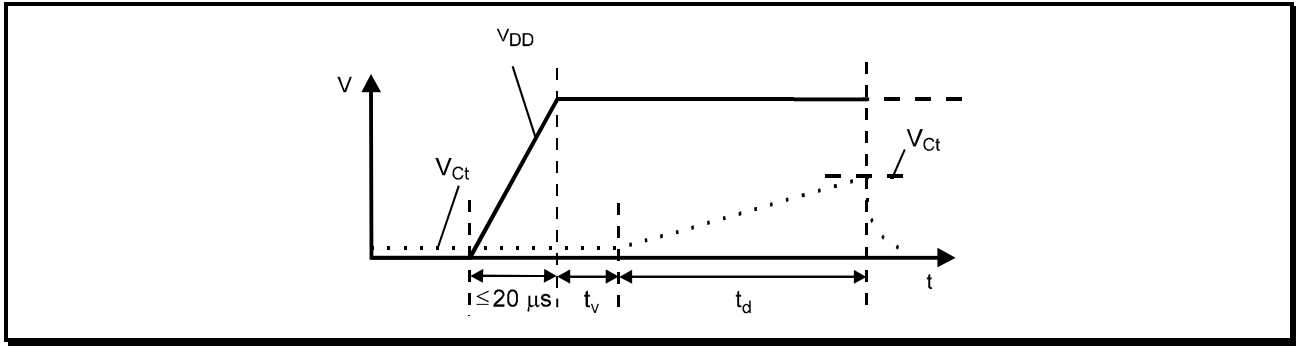


Figure 14. Delay of the charging process with the very fast rise times of the supply voltage. (The time axis not to scale)

However, as explained in Section 2, such fast rise times of the supply voltage do not normally occur, so that in practice this effect is not of significance.

4. The Behavior of Digital Circuits

The behavior of the circuit which is being monitored, and the switch on times which result, must be understood in order to make correct use of the Supply Voltage Supervisor TLC770X.

The delay time t_d which must be adjusted on these components depends on the time which the system requires to become stable after the supply voltage has been switched on.

The circuit which is being monitored must be switched into an active state only when all parts of the circuit are fully operational.

At this point special attention must be paid to two factors.

The oscillators used in the circuit (usually crystal oscillators) must be oscillating properly before the Reset signal becomes inactive. The higher the quality factor of such an oscillator (i.e. the lower the damping), the longer will be the time to begin oscillating. In the case of very good oscillator circuits, this can be in the order of several 10's of ms. For this period of time, no precise reaction of the system being monitored can be predicted.

The Reset circuit of the microprocessor is the second factor which must be taken into account when choosing the delay time t_d which will be used.

If a Low level is applied to the $\overline{\text{RESET}}$ -Input of a microprocessor, then a Reset program will be initiated which brings the processor into a defined initial state. This Reset signal must therefore be applied to the Reset input for a time long enough for the program to have been fully completed, and for the system to have reached a defined state.

With a TMS320C30 (see Figure 15.) the processing of the Reset program lasts for 10 clock cycles of the internal clock pulse H1. The clock cycle of H1 is double as long as the clock cycle of the oscillator CLKIN. With a clock frequency of the external clock CLKIN of 20 MHz, the time t which results is:

$$t = 10 \cdot 10^{-7} \text{ s} = 1000 \text{ ns}$$

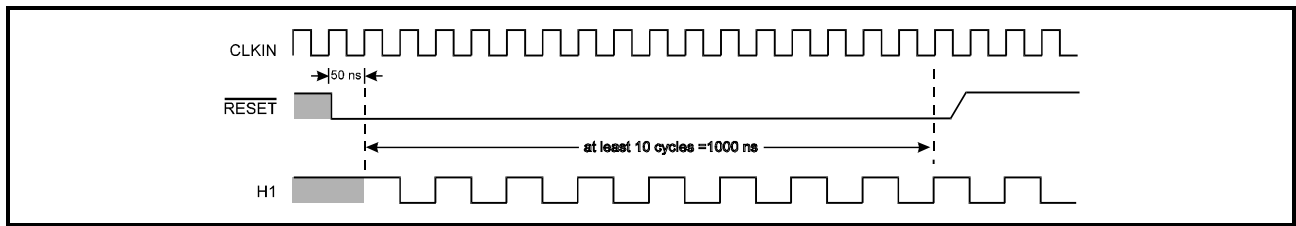


Figure 15. RESET procedure with the TMS370

The RESET signal must therefore be applied for at least 1000 ns, in order to bring the system into a defined initial state.

In accordance with the considerations discussed above, the RESET signal must be applied at least until the supply voltage has reached its nominal value, until the oscillator is correctly oscillating, and until the initialization program of the processor has been completed. Only after this time has elapsed can correct operation of the system be assured. In practice, the delay time will therefore be chosen to be several 100's of ms.

5. Examples of Applications

To allow these Supply Voltage Supervisors to be used in a variety of systems, they have been provided with various threshold voltages V_t .

- TLC7701: This device is needed when there are no “standard” supply voltages to be monitored. The desired threshold voltage can be set by means of external voltage divider (See Section 3).
- TLC7703: For battery operated applications with nominal supply voltages of 3.3V, but with which a minimum supply voltage of 2.7V is permissible, in order to extend the operating time.
- TLC7733: For applications requiring a nominal supply voltage of 3.3V ($\pm 10\%$).
- TLC7705: For applications in microcomputer systems, which operate from a supply voltage of 5V.

5.1 Voltage Monitoring

For the construction of a circuit to monitor a “standard” voltage, the only additional external component needed is the timing capacitor C_t . (See Figure 16.)

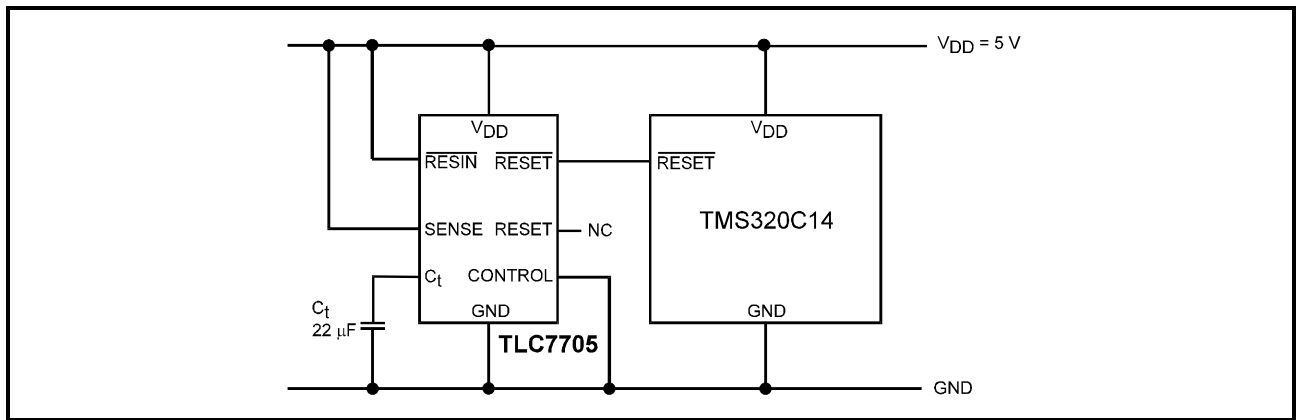


Figure 16. Simple voltage monitoring circuit with the TLC7705

The inputs $\overline{\text{RESIN}}$ and CONTROL are not needed in this application, and are therefore connected to a defined High or Low level.

For other voltage values, an external resistive voltage divider at the SENSE input (Figure 17.) is needed.

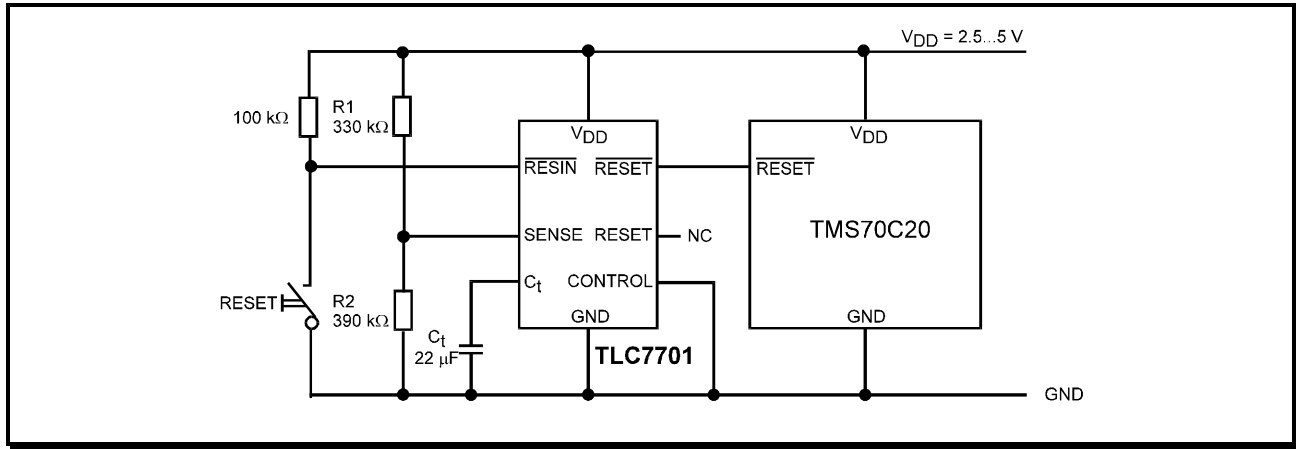


Figure 17. Voltage monitoring circuit for a microcomputer system with the TLC7701

For the TMS70C20, a minimum supply voltage of 2V is required. The threshold voltage V_t' of the monitoring circuit is therefore set to this same value with the help of a voltage divider R_1/R_2 .

$$V_t' = V_{\text{ref}} \cdot \frac{(R_1 + R_2)}{R_2} \quad \text{with } V_{\text{ref}} = 1.1 \text{ V}$$

The Reset signal can also be manually initiated with the RESET key.

An additional possible application is the monitoring of several different supply voltages in a single system (Figure 18.).

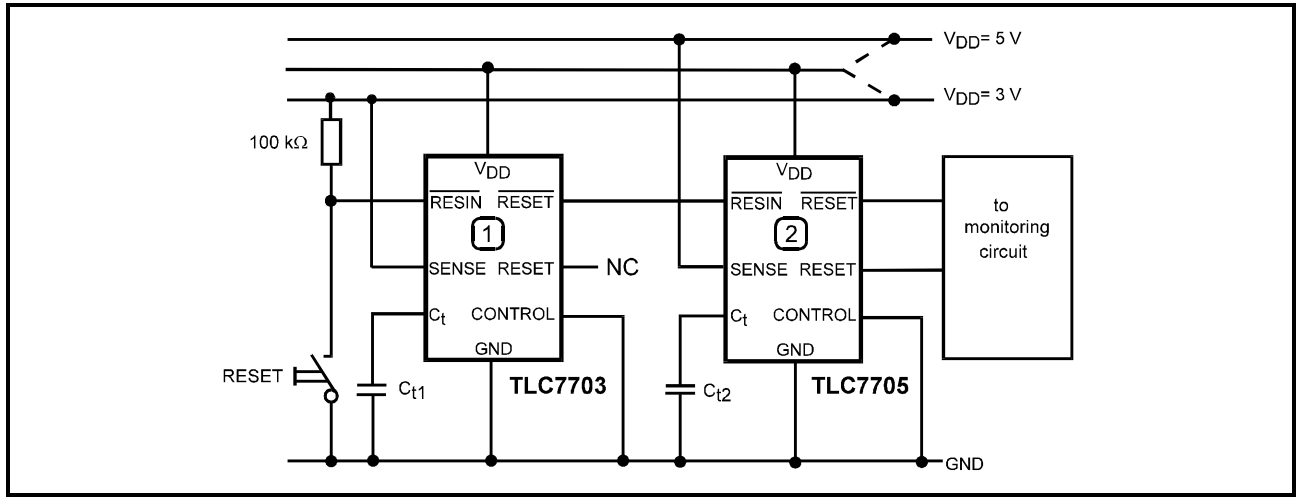


Figure 18. Monitoring of a system with two different supply voltages

In this circuit, two different supply voltages of 3 V and 5 V are monitored. The system in which they are required is brought into an active state only when both supply voltages have reached their nominal values.

The delay time of the first device ① is of minor significance; it is required only to indicate a failure of the supply voltage which it is monitoring. For this reason, the capacitor C_{t1} can be chosen with a comparatively low value (e.g. 1 nF). When the 3 V supply voltage has reached its nominal value, the delay circuit of the second device ② begins to operate. The delay time is determined by the capacitor C_{t2} , and should be chosen depending on the time taken to switch on by the system.

In order to provide a defined RESET signal should one of the supply voltages fail, both devices are powered from the same operating voltage. In such a case it makes sense to supply the monitoring circuits from the same voltage source as the device to which the RESET signal is supplied.

It is also possible in this case to initiate a system RESET manually, by means of a switch at the $\overline{\text{RESIN}}$ input of the TLC7703.

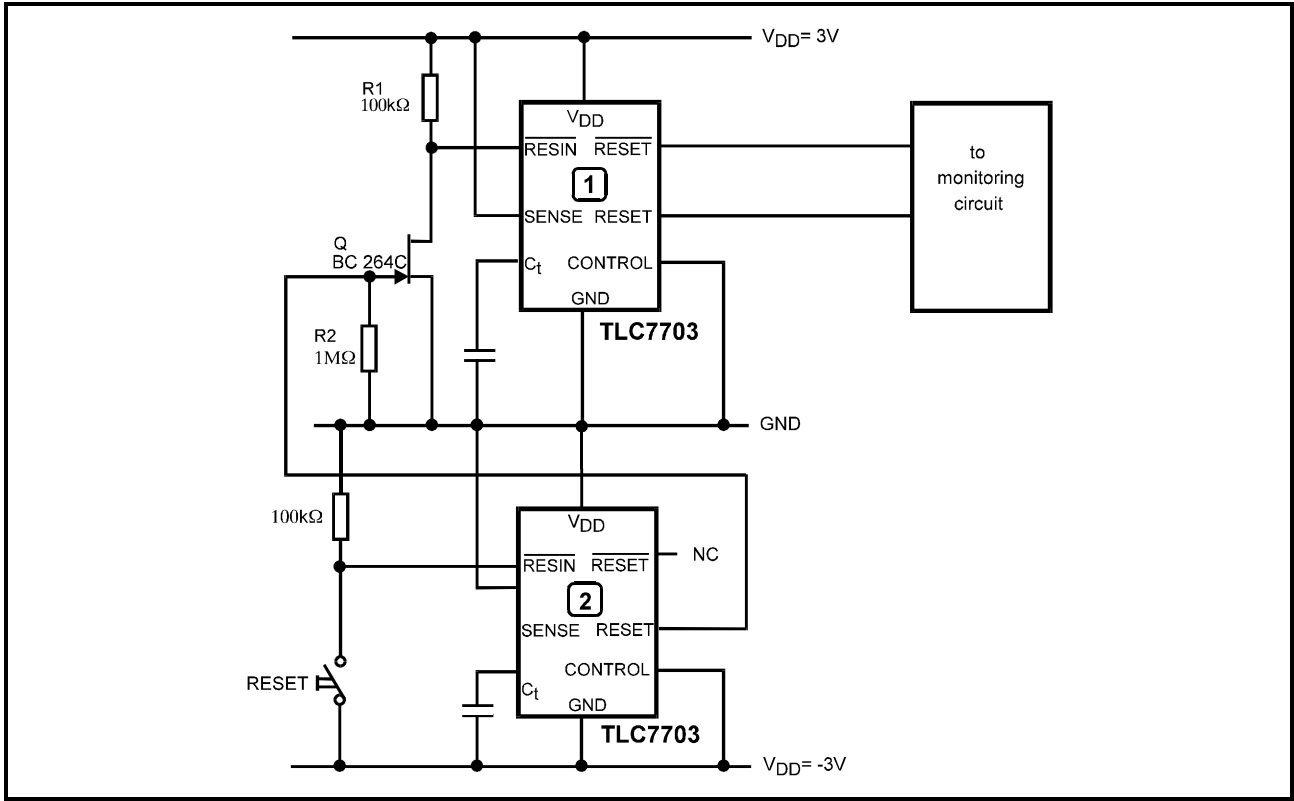


Figure 19. The monitoring of a positive and negative supply voltage

The circuit shown in Figure 19. demonstrates the monitoring of a positive and a negative supply voltage. The device ① monitors the positive supply voltage and generates the system Reset. The delay time of device ① thus depends on the switch on times of the circuit being monitored. The device ② must only inform device ① of the failure of the negative supply voltage. For this purpose, the RESET output of device ② is connected to the gate of the JFET BC264C.

As long as device ② supplies a RESET signal, the transistor Q will remain conducting, and there will be a Low level at the input $\overline{\text{RESIN}}$ of device ①. Only when the negative supply voltage has reached its nominal value and transistor Q has thus become non conducting will the $\overline{\text{RESIN}}$ input connected to it be pulled to High, and the delay time of device ① commence. After this, the system will be switched into an active state.

In order to ensure that a defined RESET signal is generated if there is a complete failure of the negative voltage, a 1 M Ω Pull-Down resistor is connected to the gate of the transistor, which makes sure that the transistor conducts in such a case, and that there is a Low level at the $\overline{\text{RESIN}}$ input of the device ①.

A Supply Voltage Supervisor can also be used in an audio amplifier, in order only to connect the loudspeaker via the relay REL after a certain time delay (see Figure 20.).

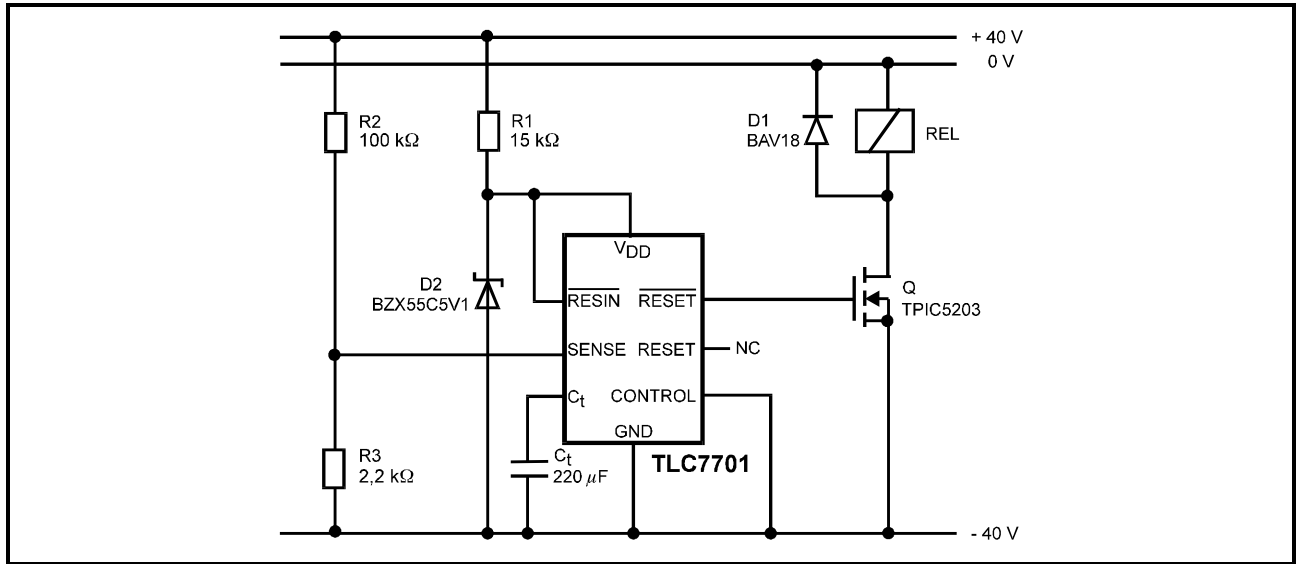


Figure 20. Delay circuit in an audio amplifier

For cost reasons the positive and negative supply voltages which are used in such amplifiers are only controlled with a single monitoring circuit. For simplicity, the negative supply voltage was chosen as the reference potential of the circuit.

The supply voltage of the TLC7701 is divided down by a resistor R_1 and a zener diode D2 and stabilized at 5.1 V. The desired threshold voltage V_t' is set by the resistive voltage divider R_2 and R_3 . This voltage divider must lie between the negative and positive supply voltages, in order to indicate a failure of either supply.

The time delay is set by means of the capacitor $C_t = 220 \mu\text{F}$ to about 5 s. The output $\overline{\text{RESET}}$ is connected to the gate of the transistor Q. As long as the $\overline{\text{RESET}}$ output is Low, the transistor Q will remain non conducting, and no current will flow through the relay REL. After the elapse of the delay time t_d , the $\overline{\text{RESET}}$ signal becomes High, and the transistor Q conducts and energizes the relay REL.

The output circuit is protected with a clamp diode, in order to eliminate safely the energy stored in the coil of the relay REL when the transistor is switched off.

5.2 Applications in Systems

An additional potential application of the TLC770X is in battery backed memory systems (Figure 21.).

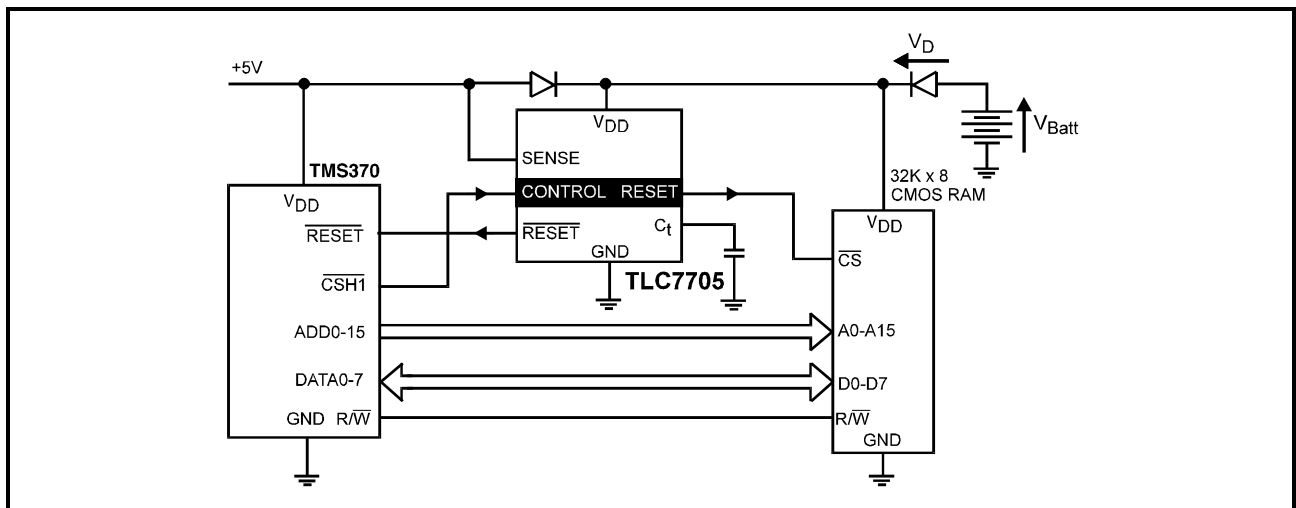


Figure 21. Voltage monitoring in a battery backed memory system

The operation of the system with the full supply voltage and after the elapse of the delay time t_d can be described as follows.

The microcomputer controls the input CONTROL of the TLC7705, by means of the signal $\overline{\text{CSH1}}$. Whenever the microcontroller makes access to the memory, the output $\overline{\text{CSH1}}$ becomes Low, and it selects the memory ($\overline{\text{CS}} = \text{Low}$) via the path CONTROL-RESETE of the TLC7705 (see Figure 5.).

Should there be a failure of the supply voltage, the memory must be isolated from the microcontroller, so that there can be no uncontrolled write and read accesses to the memory. Therefore, whenever the supply voltage falls below the permissible nominal value, the memory is put into an inactive state ($\overline{\text{CS}} = \text{High}$) by means of the output RESETE. To ensure that in such a case there will be no loss of data in the memory, the latter, together with the monitoring circuit, are supplied by the battery should there be a failure of the supply voltage. In this situation the very low current consumption of the TLC7705 is an advantage, since this results in a very long life for the battery. The CONTROL input is switched off in this state, so that undefined levels at the microcontroller output $\overline{\text{CSH1}}$ will not result in an increase of the current consumption (see Section 3).

5.3 Application Hints

When using the TLC770X, the following precautions must be taken in order to ensure that a RESET circuit operates absolutely correctly.

When switching the outputs, for some nanoseconds both transistors at the output will be momentarily conducting, and - as is usual with digital CMOS circuits having push-pull outputs-current peaks of several mA will be generated on the supply line (see Figure 22.).

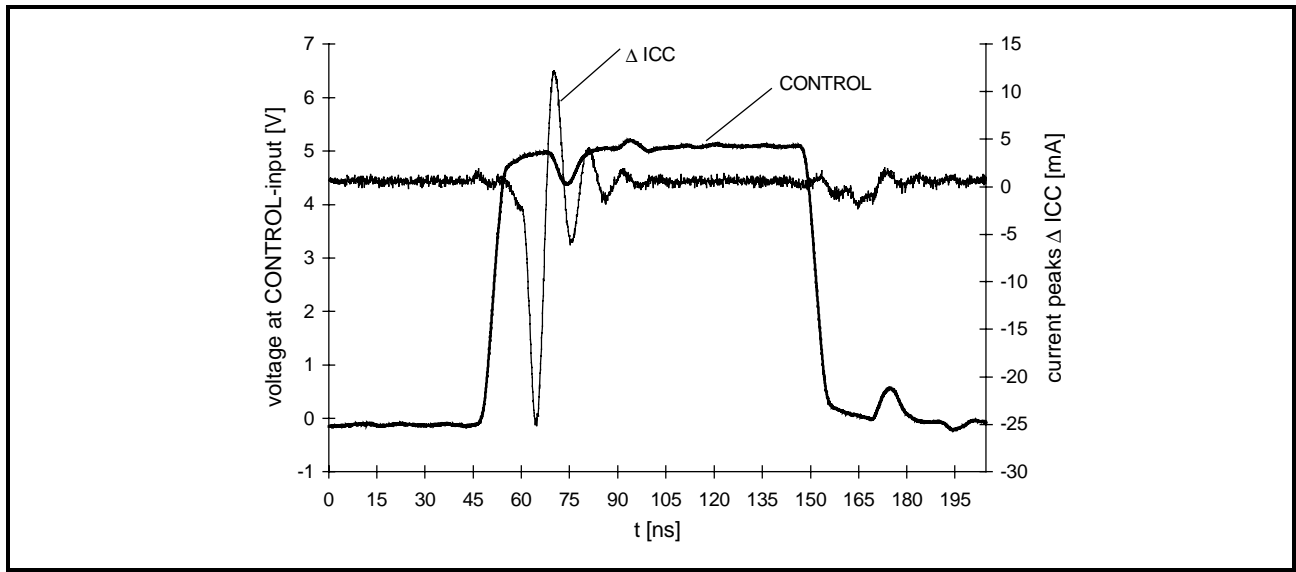


Figure 22. Current peaks on the supply line when switching the RESET output

To prevent these current peaks causing malfunction of the circuit, a blocking capacitor having a value of $0.1 \mu\text{F}$ should be connected between the supply line and Ground. This will ensure that the switching currents which arise do not generate unacceptable disturbances on the supply line.

When laying out the circuit board for a monitoring circuit, care must be taken that no currents resulting from other nearby circuits can flow in the lines leading to the monitor section. An additional critical point in the layout is the connections to the blocking capacitor C_B , through which flow the current peaks mentioned above. A good solution to this is the use of a star-shaped connection of all connections to Ground, which will reduce undesirable coupling to a minimum.

Figure 23. shows a suggested layout for the connection of the capacitors C_t and C_B , and of the external voltage divider R_1/R_2 . The connections are taken directly to the corresponding connecting pins on the package, in order to avoid the above mentioned undesirable influences.

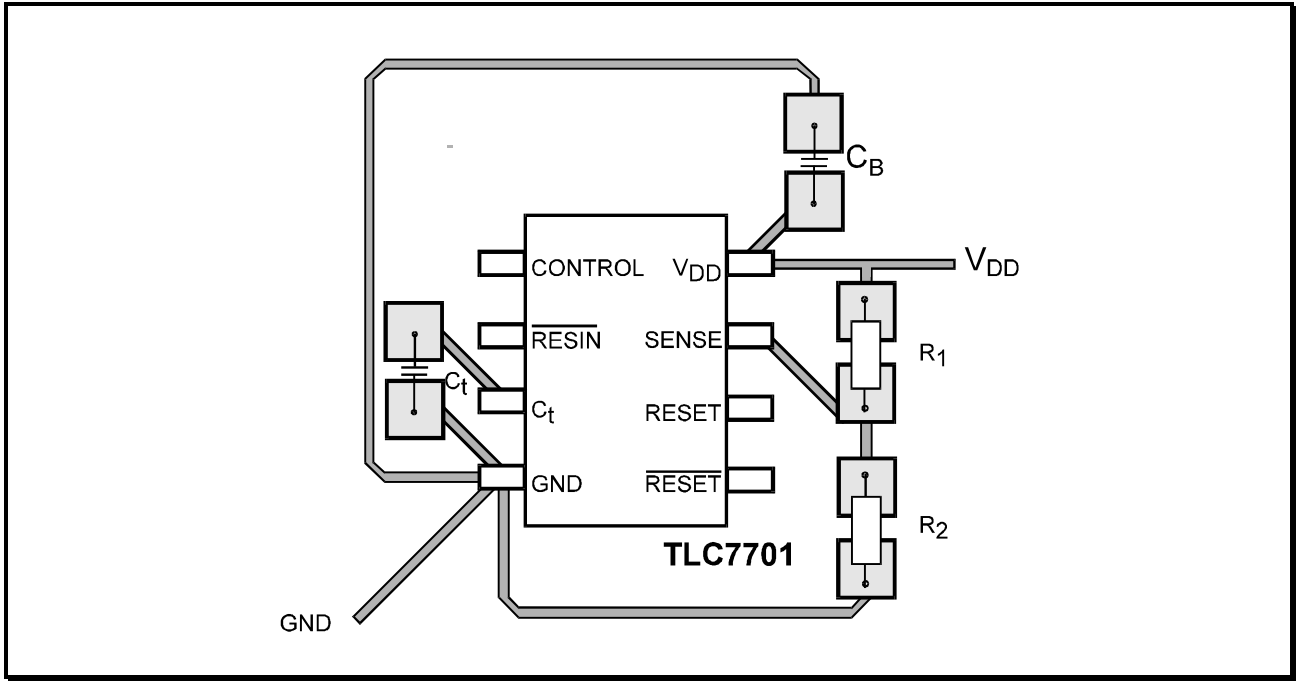


Figure 23. Suggested layout for a circuit board with the TLC7701

6. Summary

6.1 Design Check List

When considering the main features of the Supply Voltage Supervisor TLC770X, the various factors which need to be taken into account when using this series of components can be summarized as follows.

1. Setting of the delay time t_d

	Switch-On Time
Line operated power supply	10 ms - 100 ms
Battery power supply	0.03 ms - 30 ms
Oscillator (Start-up Time)	10 ms - 100 ms
Reset program	Several microseconds
Range of delay times t_d to be set	(20 ms).....500 ms

2. Circuit board construction

- Use of a blocking capacitor of 0.1 μ F between the supply line and the Ground connection, in order to avoid disturbances on the supply line.
- Connections to external components should be kept as short as possible.
- A star-shaped connection from the integrated circuit to Ground should be made (see Figure 23.).
- The Supply Voltage Supervisor should be situated in an interference-free environment on the edge of the circuit board.

6.2 Comparison of the Bipolar and BiCMOS Versions

The BiCMOS version TLC770X was developed specially for applications in battery operated circuits. The more demanding requirements of this version, with respect to low power drain and high precision of the analog parts of the circuit, made necessary the use of combined bipolar and CMOS technology. The processes used in manufacture, having structural dimensions of 2 μm , only allow the use of supply voltages of up to 6 V. For higher supply voltages, it will be more appropriate to use the well-known bipolar version TL770X.

A significant improvement of the BiCMOS version is the very low current consumption. Whereas the TL770X has a typical current consumption 1.8 mA, the corresponding value for the BiCMOS version is only 10 μA . The power consumption of a system can thus be significantly reduced by using the TLC770X.

An improvement with respect to the bipolar version is the need for fewer external components. The input REF of the TL770X must be made with a capacitor, in order to avoid oscillation of the reference voltage. This capacitor is not needed with the TLC770X. The REF input has been replaced by the CONTROL input, which provides the additional option of making access directly to the RESET output. Pull-Up and Pull-Down resistors at the outputs are not necessary with the BiCMOS version, since it incorporates a Totem-Pole output circuit.

If the intention is to replace a TL770X with a TLC770X in an existing system, no circuit changes will in most cases be necessary. The capacitor of 0.1 μF at the REF pin which is needed with the bipolar version can remain in circuit. It will be held in a discharged state (Low level) by the integrated resistor at the input which is now known as CONTROL. With the same value of the capacitor C_t at the input, the TLC770X gives a delay time which is about 50 % longer than the TL770X. If necessary, the value of the capacitor can be appropriately reduced. The Pull-Up or Pull-Down resistors which are necessary at the outputs of the TL770X do not need to be removed when a TLC770X, with Totem-Pole output and not needing a Pull-Up resistor, is used. It is, however, necessary to make sure that the output current of the circuit resulting from the resistor does not exceed the maximum value specified in the Data Sheet. If however the Pull-Up resistor with the bipolar version was connected to a higher potential than the supply voltage of the integrated circuit, then this resistor must be removed. When the TLC7701 is used instead of the TL7702 (both circuits do not have any integrated voltage divider at the SENSE input), then the external voltage divider must be changed appropriately (see Section 3).

Providing as it does a very precise threshold voltage, the Supply Voltage Supervisor series TLC770X is most suitable for designing simple and reliable Reset circuits.