

LM9074

System Voltage Regulator with Keep-Alive ON/OFF Control

General Description

The LM9074 is a 5V, 3% accurate, 180 mA NPN voltage regulator. The regulator features an active low delayed reset output flag which can be used to reset a microprocessor system on turn-ON and in the event that the regulator output falls out of regulation for any reason. An external capacitor programs a delay time interval before the reset output can return high.

Designed for automotive application the LM9074 contains a variety of protection features such as reverse battery, over-voltage shutdown, thermal shutdown, input transient protection and a wide operating temperature range.

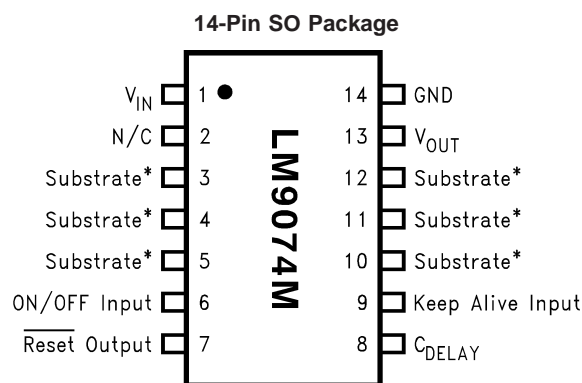
A unique two-input logic control scheme is used to enable or disable the regulator output. An ON/OFF input can be provided by an ignition switch derived signal while a second, Keep-Alive input, is generated by a system controller. This allows for a system to remain ON after ignition has been switched OFF. The system controller can then execute a power-down routine and after which command the regulator OFF to a low quiescent current state (60 μ A max).

Design techniques have been employed to allow the regulator to remain operational and not generate false reset signals when subjected to high levels of RF energy (300V/m from 2 MHz to 400 MHz).

Features

- Automotive application reliability
- 3% output voltage tolerance
- Insensitive to radiated RFI
- Dropout voltage less than 2.5V with 180 mA output current
- Externally programmed reset delay interval
- Keep-alive feature with 2 logic control inputs
- 60V Load dump transient protection
- Thermal shutdown
- Short circuit protection and disable safety features
- Reverse battery protection
- Low OFF quiescent current, 60 μ A maximum
- Wide operating temperature range -40°C to $+125^{\circ}\text{C}$

Connection Diagrams and Ordering Information (Top View)



* Substrate pins must be connected to Ground Pin

DS101305-2

Order Number LM9074M
See NS Package Number M14A

Absolute Maximum Ratings (Note 1)

| | |
|--|--------------------|
| Input Voltage | |
| ON/OFF, Keep-Alive Inputs (through 1 k Ω) | |
| DC Input Voltage | -26V to +26V |
| Positive Input Transient (t<100 ms) | 40V |
| Negative Input Transient (t<1 ms) | -50V |
| Reset Output Sink Current | 5 mA |
| Power Dissipation | Internally Limited |
| Junction Temperature | 150°C |
| ESD Susceptibility (Note 2) | 12 kV, 2 kV |

| | |
|---|-----------------|
| Lead Temperature (Soldering, 10 seconds) | 260°C |
| Storage Temperature | -50°C to +150°C |

Operating Ratings (Note 1)

| | |
|-------------------------------|-----------------|
| Input Voltage | 7.5V to 16.5V |
| Ambient Temperature | -40°C to +125°C |
| θ j-pins, M14A Package | 30°C/W |
| θ ja, M14A Package | 137°C/W |

Electrical Characteristics

The following specifications apply for $V_{CC} = 7.5V$ to $16.5V$, $-40^\circ C \leq T_A \leq 125^\circ C$, unless otherwise specified. $C_{OUT} = 0.1\mu F$.

| Symbol | Parameter | Conditions | Min | Max | Units |
|-------------------------|--|---|---------------|---------------|--------------------|
| REGULATOR OUTPUT | | | | | |
| V_{OUT} | Output Voltage | $20\text{ mA} \leq I_{OUT} \leq 180\text{ mA}$ | 4.85 | 5.15 | V |
| ΔV_{OUT} Line | Line Regulation | $I_{OUT} = 20\text{ mA}$, $9V \leq V_{IN} \leq 16.5V$ $I_{OUT} = 20\text{ mA}$, $7.5V \leq V_{IN} \leq 16.5V$ | | 25 50 | mV mV |
| ΔV_{OUT} Load | Load Regulation | $V_{IN} = 14.4V$, $20\text{ mA} \leq I_{OUT} \leq 180\text{ mA}$ | | 50 | mV |
| I_q | Quiescent Current | $4V \leq V_{ON/OFF} \leq V_{IN}$ $20\text{ mA} \leq I_{OUT} \leq 180\text{ mA}$ | | 25 | mA |
| I_{off} | OFF Quiescent Current | $V_{IN} \leq 16.5V$, Regulator OFF $-40^\circ C \leq T_J \leq 60^\circ C$ $60^\circ C \leq T_J \leq 135^\circ C$ | | 20 60 | μA μA |
| V_{do} | Dropout Voltage | $I_{OUT} = 20\text{ mA}$ $I_{OUT} = 180\text{ mA}$ | | 2.0 2.5 | V V |
| I_{sc} | Short Circuit Current | $R_L = 1\Omega$ | 0.4 | 1.0 | A |
| PSRR | Ripple Rejection | $V_{IN} = (14V_{DC}) + (1V_{RMS} @ 120Hz)$ $I_{OUT} = 50\text{ mA}$ | 60 | | dB |
| V_{othOFF} | Safety V_{OUT} Latch-OFF Threshold | In Keep-Alive mode $V_{ON/OFF} = 0V$, $V_{KA} = 0V$ | 4 | 4.5 | V |
| V_o Transient | V_{OUT} during Transients | V_{IN} Peak $\leq 40V$, $R_L = 100\Omega$, $\tau = 100\text{ ms}$ | | 5.5 | V |
| RESET OUTPUT | | | | | |
| V_{th} | Threshold Voltage | ΔV_{OUT} Required to Generate a Reset Output $4.85V \leq V_{OUT} \leq 5.15V$ | -300 | -500 | mV |
| V_{low} | Reset Output Low Voltage | $I_{sink} = 1.6\text{ mA}$, $V_{OUT} > 3.2V$ $1.4V \leq V_{OUT} \leq 3.2V$ | | 0.4 0.8 | V V |
| V_{high} | Reset Output High Voltage | | $0.9 V_{OUT}$ | V_{OUT} | V |
| t_{delay} | Delay Time | $C_{delay} = 0.1\mu F$ | 7 | 45 | ms |
| I_{delay} | Charging Current for C_{delay} | | -7 | 25 | μA |
| R_{pu} | Internal Pull-up Resistance | | 12 | 80 | k Ω |
| CONTROL LOGIC | | | | | |
| V_{KA}^{low} | Low Input Threshold Voltage, Keep-Alive Input | $3.5V \leq V_{OUT} \leq 5.25V$ | $0.3 V_{OUT}$ | $0.5 V_{OUT}$ | V |
| V_{KA}^{high} | High Input Threshold Voltage, Keep-Alive Input | $3.5V \leq V_{OUT} \leq 5.25V$ | $0.6 V_{OUT}$ | $0.8 V_{OUT}$ | V |
| $V_{ON/OFF}^{low}$ | Low Input Voltage, ON/OFF Input | $R_{series} = 1\text{ k}\Omega$ | -2 | 2 | V |
| $V_{ON/OFF}^{high}$ | High Input Voltage, ON/OFF Input | $R_{series} = 1\text{ k}\Omega$ | 4 | V_{IN} | V |

Electrical Characteristics (Continued)

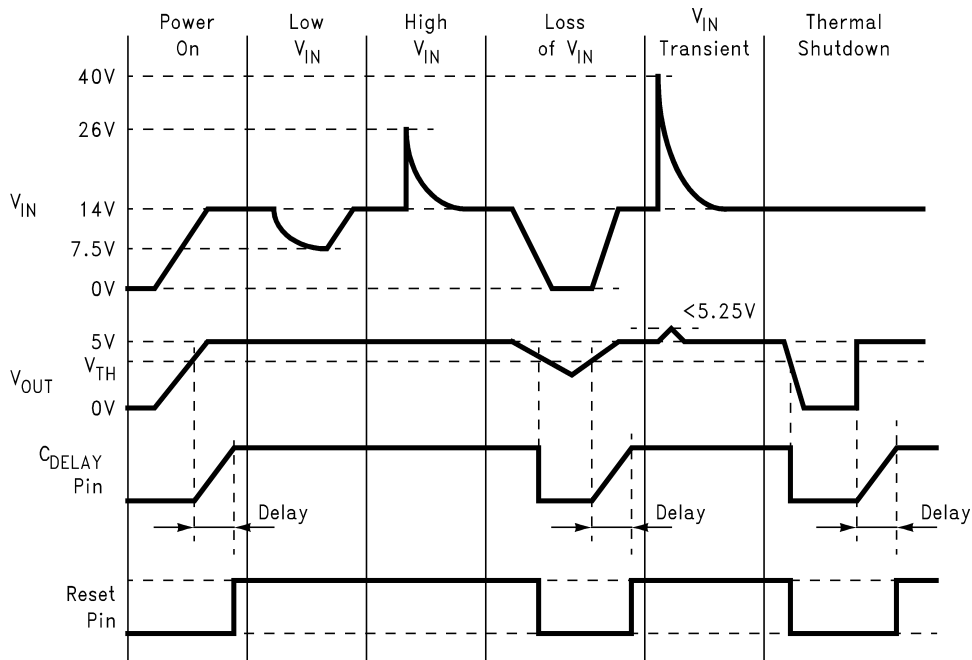
The following specifications apply for $V_{CC} = 7.5V$ to $16.5V$, $-40^{\circ}C \leq T_A \leq 125^{\circ}C$, unless otherwise specified. $C_{OUT} = 0.1\mu F$.

| Symbol | Parameter | Conditions | Min | Max | Units |
|----------------------|---|------------------------|-----|-----|------------|
| CONTROL LOGIC | | | | | |
| $I_{ON/OFF}$ | Input Current, ON/OFF Input | $V_{ON/OFF} \leq 4V$ | | 330 | μA |
| | | $4V < V_{ON/OFF} < 7V$ | | 670 | μA |
| | | $V_{ON/OFF} \geq 7V$ | | 10 | mA |
| $R_{pu_{KA}}$ | Internal Pull-up Resistance, Keep-Alive Input | | 20 | 100 | k Ω |
| $R_{pd_{ON/OFF}}$ | Internal Pull-down Resistance ON/OFF Input | | 50 | 210 | k Ω |

Note 1: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. **Operating Ratings** indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and conditions, see the **Electrical Characteristics**.

Note 2: All pins will survive an ESD impulse of $\pm 2000V$ using the human body model of 100 pF discharged through a 1.5 k Ω resistor. In addition, input pins V_{IN} and the ON/OFF input will withstand ten pulses of ± 12 kV from a 150 pF capacitor discharged through a 560 Ω resistor with each pin bypassed with a 22 nF, 100V capacitor.

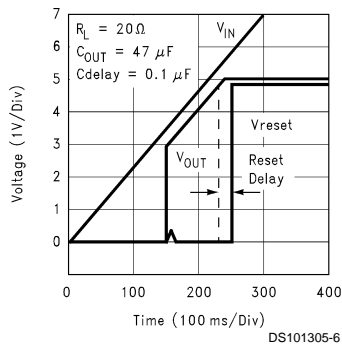
Reset Operation and Protection Features



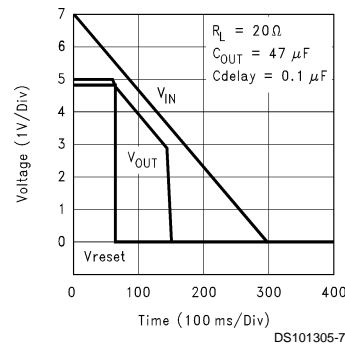
DS101305-5

Typical Performance Characteristics ($T_A = 25^{\circ}C$ unless indicated otherwise)

Turn ON Characteristics

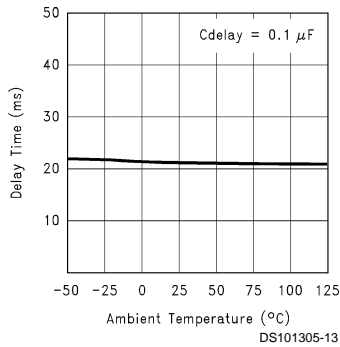


Turn OFF Characteristics



Typical Performance Characteristics $(T_A = 25^\circ\text{C}$ unless indicated otherwise) (Continued)

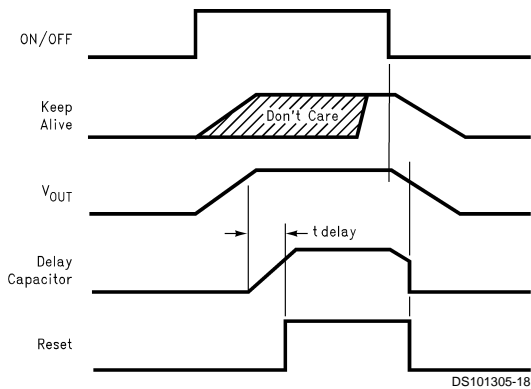
Reset Delay Time vs Temperature



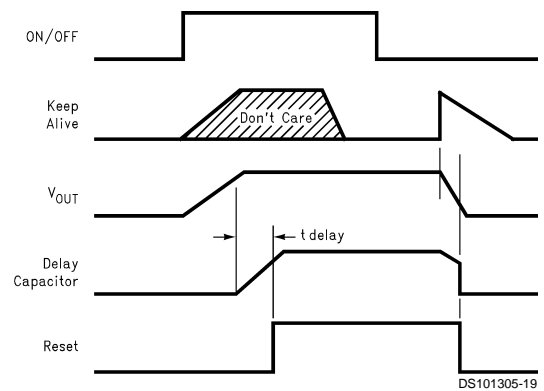
ON/OFF, Keep-Alive and Safety Latch-Off Control Diagrams

Note: If Keep-Alive is provided by a microprocessor powered by the output voltage of the LM9074, the logic "1" voltage level will track V_{OUT} as the regulator turns OFF.

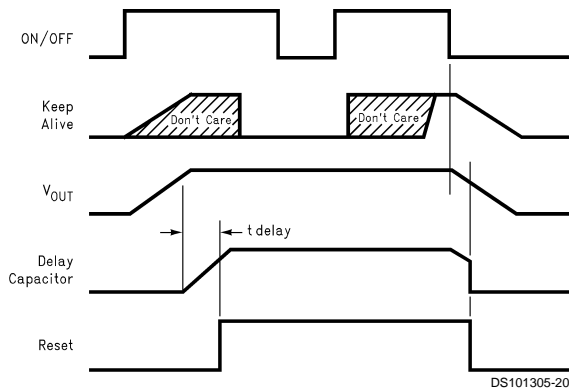
Simple ON/OFF control
(Keep-Alive input must be high to turn OFF output)



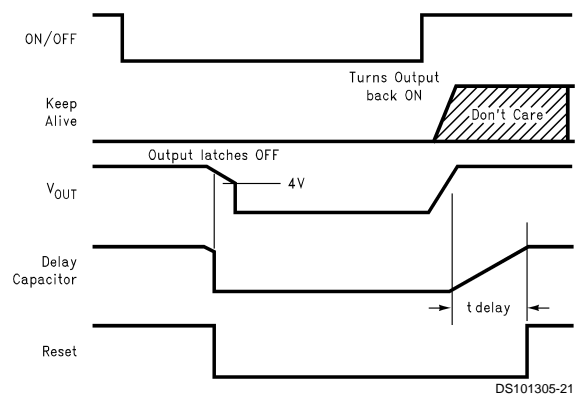
Keep-Alive Mode; Turn ON with ON/OFF control,
Keep output biased with Keep-Alive input,
Turn OFF with Keep-Alive (Keep-Alive low keeps
output ON, Keep-Alive going high turns output OFF)



Switch ON with ON/OFF input; Keep output
biased with Keep-Alive; Hold output ON with
ON/OFF; Turn OFF with ON/OFF input.
(Temporary Keep-Alive Mode)



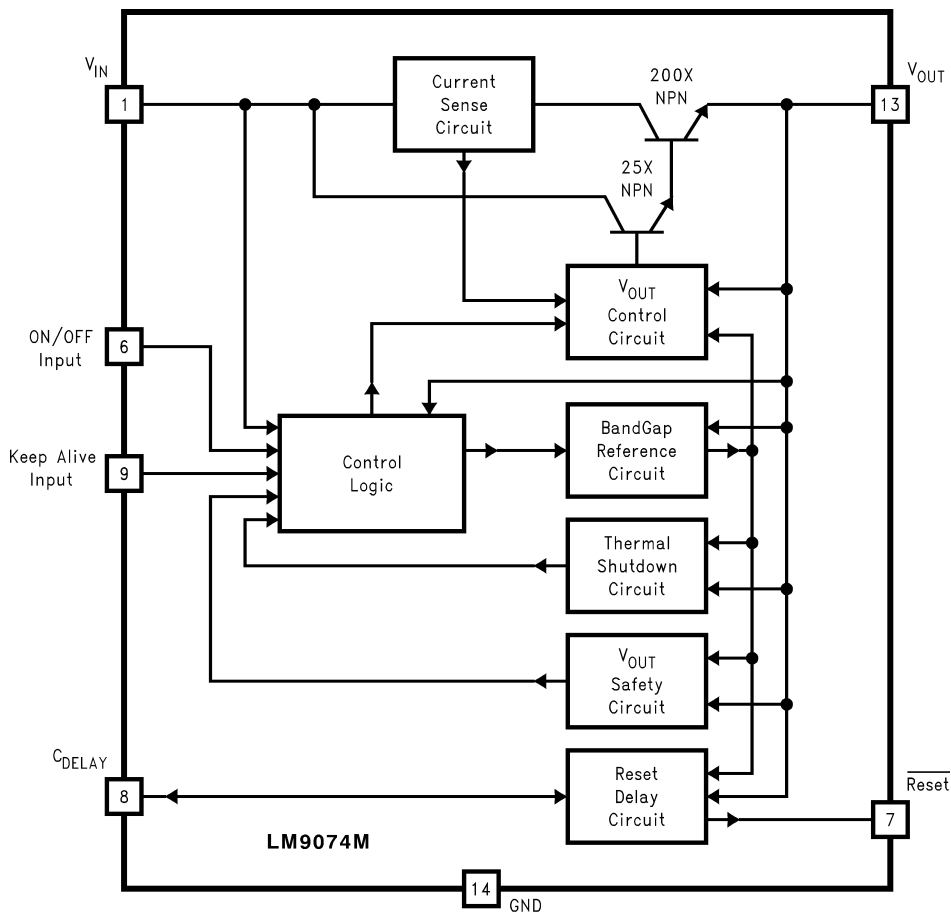
Safety Latch OFF of V_{OUT} when in Keep-Alive Mode
(ON/OFF going high required to turn Output back ON)



Control Logic Truth Table

| ON/OFF Input | Keep-Alive Input | Output Voltage | Reset Output | Operating Condition |
|--------------|------------------|---------------------------------------|---------------|---|
| L | X | 0V | L | Low quiescent current standby (OFF) condition |
| ↑ | X | 5V | ↑ after delay | Output turns ON |
| H | X | 5V | H | Normal ON condition |
| ↓ | H | 0V | L | Output turns OFF |
| ↓ | L | 5V | H | Output kept ON by Keep-Alive Input |
| ↑ | L | 5V | H | Output remains ON (or turns ON) |
| H | X | $\Delta V_{OUT} \geq -300 \text{ mV}$ | L | Output pulled out of regulation, reset flag generated |
| L | L | $V_{OUT} \leq 4V$ | L | Output latches OFF |

Block Diagram



Application Information

The LM9074 voltage regulator has been optimized for use in microprocessor based automotive systems. Several unique design features have been incorporated to address many FMEA (Failure Mode Effects Analysis) concerns for fail-safe system performance.

FAULT TOLERANT FEATURES

While not specifically guaranteed due to production testing limitations, the LM9074 has been tested and shown to continue to provide a regulated output and, not generate an erroneous system reset signal while subjected to high levels of RF electric field energy (up to 300 V/m signal strength over

a 2 MHz to 400 MHz frequency range). This is very important in vehicle safety related applications where the system must continue to operate normally. To maintain this immunity to RFI the output bypass capacitor is important (47 μF is recommended).

This regulator is suitable for applications where continuous connection to the battery is required (*Refer to the Typical Application Circuit*). ON/OFF control of the regulator and system can be accomplished by switching the ON/OFF input to the battery or ignition supply V_{IN} supply through a SPST switch. If this input becomes open circuited, an internal pull-down resistor ensures that the regulator turns OFF. When the regulator is switched OFF the current load on the

Application Information (Continued)

battery drops to less than 60 μA . With the possibility in many applications for V_{IN} and the ON/OFF input pins to be connected in a system through long lengths of wire, the ESD protection of these pins has been increased to 12 kV with the addition of small input bypass capacitors.

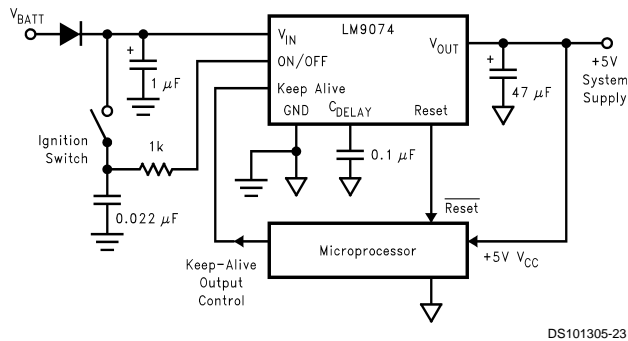


FIGURE 1. Typical Application Circuit

An output bypass capacitor of at least 0.1 μF is required for stability (47 μF is recommended). An input capacitor of 1 μF or larger is recommended to improve line transient and noise performance.

With the Keep-Alive input, a system microprocessor has the ability to keep the regulator ON (with a logic “0” on Keep-Alive) after the ON/OFF input has been commanded OFF. A power-down sequence, when system variables are typically stored in programmable memory, can be executed and take as much time as necessary. At the end of the operation the micro then pulls Keep-Alive high and the regulator and system turn OFF and revert to the low quiescent current standby mode.

For additional system reliability, consideration has been made for the possibility of a short circuited load at the output of the regulator. When the regulator is switched ON, conventional current limiting and thermal shutdown protect the regulator. When the regulator is switched OFF however, a grounded V_{CC} supply to the micro (due to the shorted regulator output) will force the Keep-Alive input to be low and thus try to maintain the Keep-Alive mode of operation. With

a shorted load, the drain on the battery could be as high as 1.5A. A separate internal circuit monitors the output voltage of the regulator. If V_{OUT} is less than 4V, as would be the case with a shorted load, the Keep-Alive function is logically disabled to ensure that the regulator turns OFF and reverts to less than a 60 μA load on the battery.

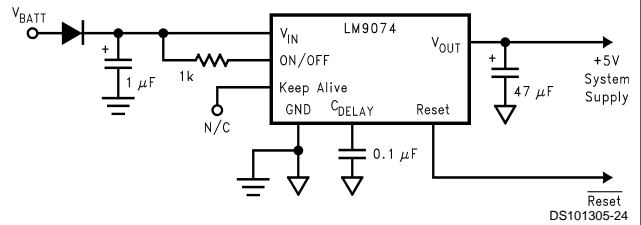


FIGURE 2. Control Logic Not Used

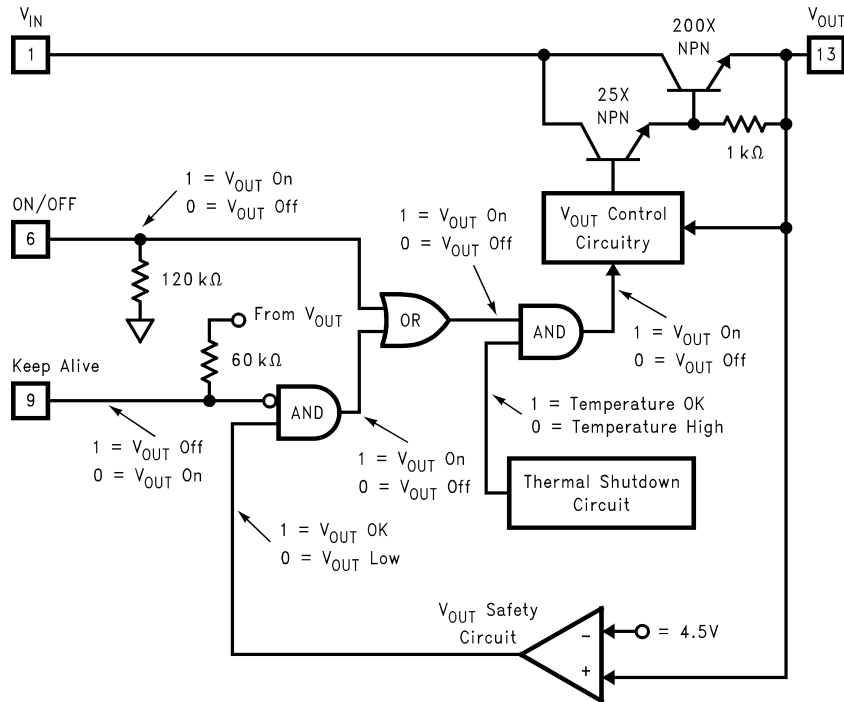
Conventional load dump protection is built in to withstand up to +60V and -50V transients. A 1 k Ω resistor in series with the ON/OFF and Keep-Alive inputs are recommended to provide the same level of transient protection for these pins if required. Protection against reverse polarity battery connections is also built in. With a reversed battery the output of the LM9074 will not go more negative than one diode drop below ground. This will prevent damage to any of the 5V load circuits.

For applications where the control logic is not required the logic pins should be configured as shown in Figure 2. A separate device, called the LM9071, can be used. The LM9071 is available in a 5-lead TO-220 package and does not provide control logic functions, but still retains all of the protection features of the LM9074.

RESET FLAG

Excessive loading of the output to the point where the output voltage drops by 300 mV to 500 mV will signal a reset flag to the micro. This will warn of a V_{CC} supply that may produce unpredictable operation of the system. On power-up and recovery from a fault condition the delay capacitor is used to hold the micro in a reset condition for a programmable time interval to allow the system operating voltages and clock to stabilize before executing code. The typical delay time interval can be estimated using the following equation:

Application Information (Continued)



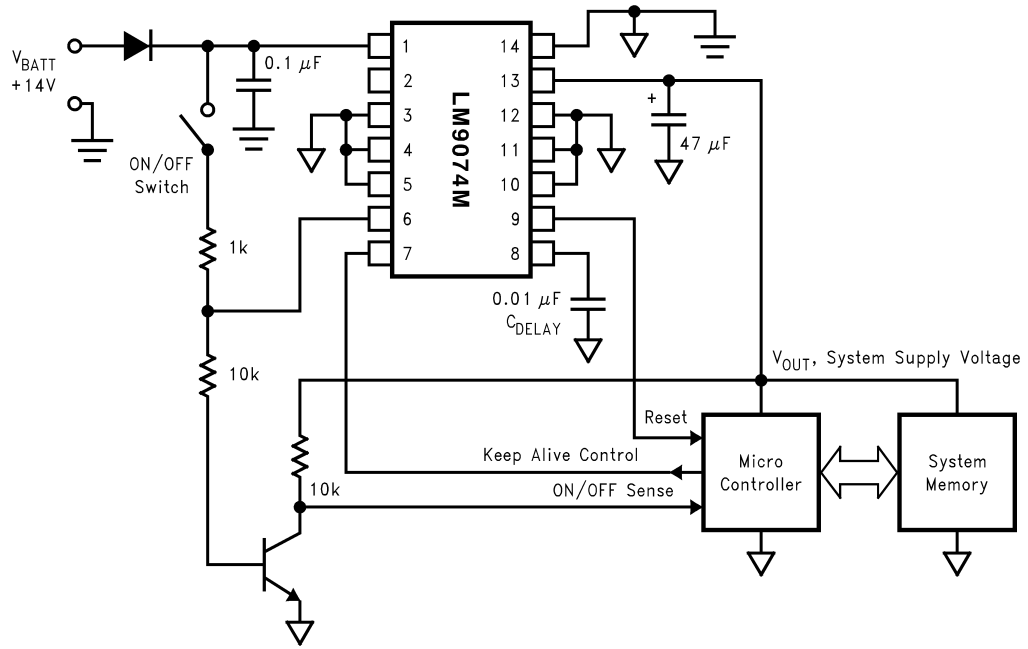
DS101305-26

MICROPROCESSOR SYSTEM REGULATOR WITH KEEP-ALIVE INTERVAL AT TURN-OFF

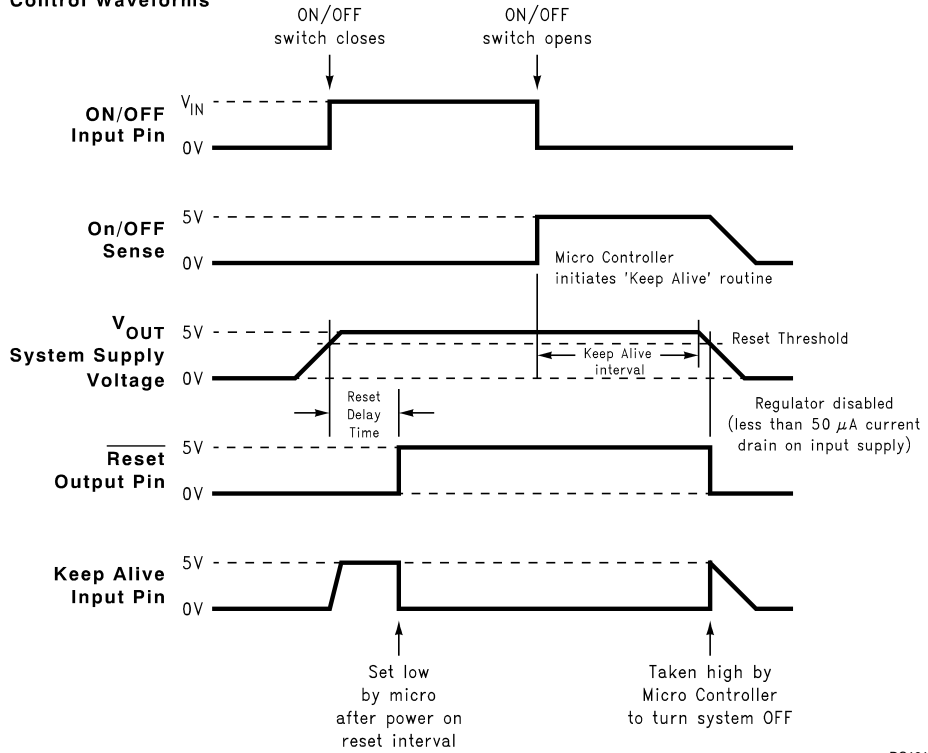
The following circuit illustrates a system application utilizing both of the logic control inputs of the LM9074. Closing the ON/OFF switch powers ON the system. Once powered, the system controller sets the Keep-Alive line low. The NPN transistor is used only to signal the controller that the ON/OFF switch has been opened and the system is to be turned

OFF. Upon detecting this high level at the ON/OFF Sense input line, the controller can then perform a power down routine. The system will remain fully powered until the controller commands total shut down by taking the Keep-Alive line high. The system then shuts OFF and reverts to a very low current drain standby condition until switched back on.

Application Information (Continued)

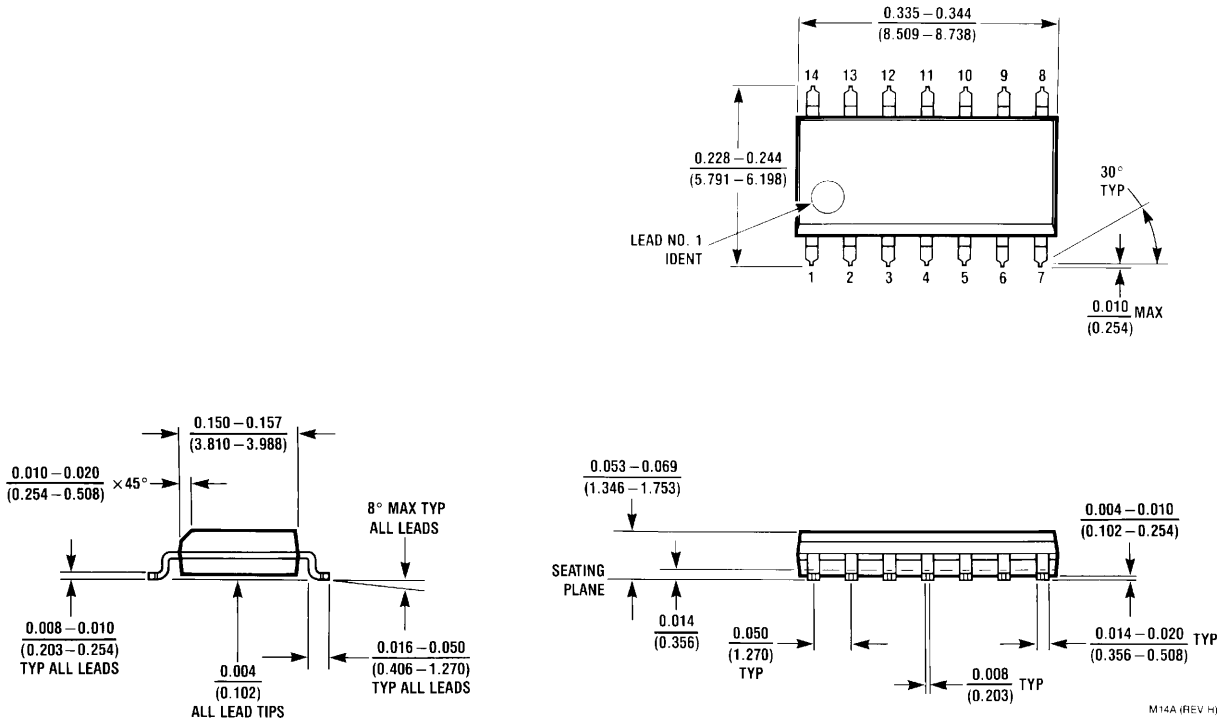


Control Waveforms



DS101305-25

Physical Dimensions inches (millimeters) unless otherwise noted



14-Lead (0.150' Wide) Molded SO Package
Order Number LM9074M
NS Package Number M14A

LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.
2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.



National Semiconductor Corporation
 Americas
 Tel: 1-800-272-9959
 Fax: 1-800-737-7018
 Email: support@nsc.com

National Semiconductor Europe
 Fax: +49 (0) 1 80-530 85 86
 Email: europe.support@nsc.com
 Deutsch Tel: +49 (0) 1 80-530 85 85
 English Tel: +49 (0) 1 80-532 78 32
 Français Tel: +49 (0) 1 80-532 93 58
 Italiano Tel: +49 (0) 1 80-534 16 80

National Semiconductor Asia Pacific Customer Response Group
 Tel: 65-2544466
 Fax: 65-2504466
 Email: sea.support@nsc.com

National Semiconductor Japan Ltd.
 Tel: 81-3-5639-7560
 Fax: 81-3-5639-7507

www.national.com