

## LM9073

# Dual High Current Low-Dropout System Regulator

### General Description

The LM9073 is a high performance voltage regulator system with operational and protection features that address many requirements of automotive applications. Two regulated outputs are provided. The main regulator provides a precision 2% tolerance 5V output at 700mA with a low dropout characteristic. The second output, an External Supply regulator, provides a 5V output with 2% tolerance for load currents up to 100mA. This External Supply output is fully protected from short circuit to ground or the unregulated input supply (ignition or battery potentials in automotive applications) which makes it suitable for powering remotely located load circuits or sub-systems.

The LM9073 also contains a programmable delayed system reset output. Two control inputs are provided. An ON/OFF input intended for connection to an ignition switch, and a Keep Alive input whereby a system can remain powered after ignition has been switched OFF. Additionally, a watchdog function is built in to enhance system operational reliability.

For EMC concerns the LM9073 remains fully operational and does not generate false reset signals while subjected to greater than 100mA, 1MHz to 400MHz bulk current injection signals on the input supply and External Supply output lines.

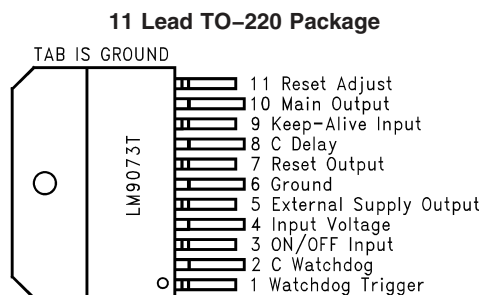
### Features

- Two 5V regulated outputs:
  - 700mA, 2% Main output
  - 100mA, 2% External Supply output
- External Supply output protected from shorts to battery
- Good EMI (1MHz to 400MHz, BCI) immunity
- Separate ON/OFF and Keep-Alive control inputs
- Less than 100µA quiescent current in OFF state
- Programmable delayed reset output
- Adjustable threshold voltage for generating reset
- Built-in system watchdog timer
- Input transient protection over 60V to -45V
- Less than 1V dropout at full load
- Wide -40°C to 125°C operating temperature range
- TO-220 power packages

### Applications

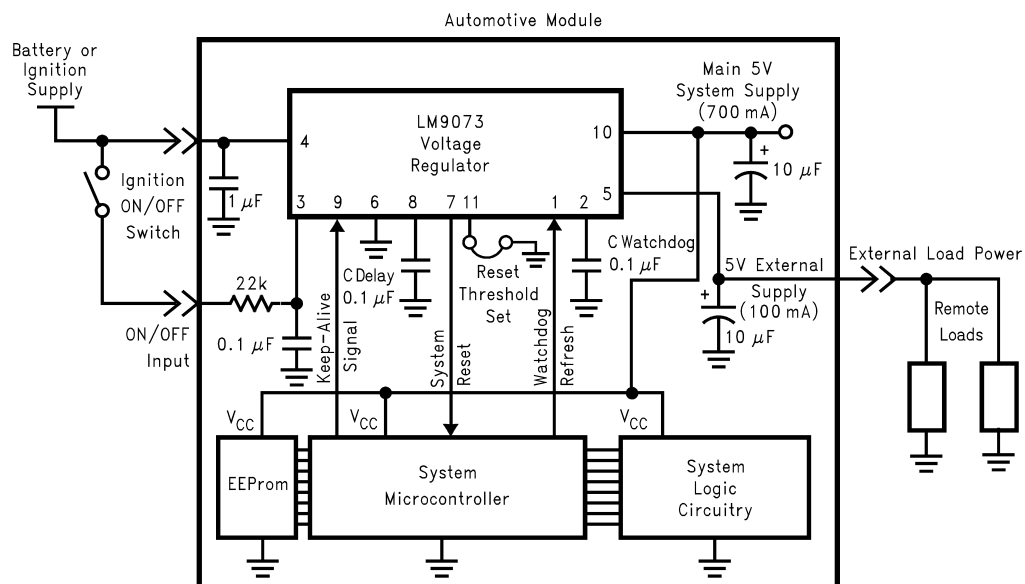
- Automotive module supply power conditioning
- Remote sub-system powering
- Continuous operation for save routines and E<sup>2</sup>PROM programing after power down command
- Safety relates systems – EMC operational with a system watchdog monitor

### Connection Diagram



**Top View**  
**Order Number LM9073T**  
**See NS Package Number TA11B**

# Block Diagram



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**Absolute Maximum Ratings** (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Input Voltage	–45V to 45V
Input Voltage (transient, $t \leq 400\text{ms}$ )	60V
Forced Output Voltages	
Main Output	–0.3V to 7V
External Supply Output	–0.3V to 27V
ON/OFF Input Voltage(Note 6)	–0.3V to 16V
ON/OFF Input Current	$\pm 20\text{mA}$
Keep Alive In, Reset Out, $C_{\text{DELAY}}$	
Reset Adjust, Watchdog Trigger	
In, C Watchdog	–0.3V to 7V

Junction Temperature	150°C
Storage Temperature	–65°C to 150°C
ESD Susceptibility(Note 2)	2000V
Lead temperature (Soldering, 10 Sec)	265°C

**Operating Ratings**(Note 1)

Input Voltage Range	6V to 27V
Ambient Temperature Range	–40°C to 125°C
Thermal Resistance	
$\theta_{\text{JC}}$	4°C/W
$\theta_{\text{JA}}$	43°C/W

**Electrical Characteristics**

The following specifications apply for  $6\text{V} \leq V_{\text{IN}} \leq 19\text{V}$ ,  $t_{\text{CASE}} = 25^\circ\text{C}$  unless otherwise specified.  $C_{\text{OUT}} \geq 6\mu\text{F}$  with  $0.3\Omega \leq \text{ESR} \leq 3.0\Omega$  on each regulator output.

Symbol	Parameter	Conditions	LM9073		Units
			Min	Max	
MAIN REGULATOR					
V <sub>MAIN</sub>	Output Voltage	10mA ≤ I <sub>LOAD</sub> ≤ 700mA	4.9	5.1	V
		19V ≤ V <sub>IN</sub> ≤ V <sub>SD</sub> , 5mA ≤ I <sub>LOAD</sub> ≤ 700mA	4.8	5.2	V
R <sub>MLOAD</sub>	Load Regulation	V <sub>IN</sub> = 16V, 10mA ≤ I <sub>LOAD</sub> ≤ 700mA		25	mV
R <sub>MLINE</sub>	Line Regulation	I <sub>LOAD</sub> = 700mA, 8V ≤ V <sub>IN</sub> ≤ 16V		25	mV
V <sub>MDO</sub>	Dropout Voltage, V <sub>IN</sub> – V <sub>MAIN</sub>	V <sub>IN</sub> > 5.5V, 10mA ≤ I <sub>LOAD</sub> ≤ 700mA(Note 5)		1	V
V <sub>SD</sub>	Overvoltage Shutdown Threshold		30	36	V
I <sub>MSC</sub>	Output Short Circuit Current	R <sub>L</sub> = 1Ω		2000	mA
PSRR	Ripple Rejection	V <sub>IN</sub> = 9V, 50Hz ≤ freq ≤ 20KHZ, V <sub>RIPPLE</sub> = 4V <sub>P-P</sub>	40		dB
External Supply Regulator					
V <sub>EXT</sub>	Output Voltage	3mA ≤ I <sub>LOAD</sub> ≤ 100mA	4.9	5.1	V
		19V ≤ V <sub>IN</sub> ≤ V <sub>SD</sub> 3mA ≤ I <sub>LOAD</sub> ≤ 100mA	4.8	5.2	V
R <sub>ELOAD</sub>	Load Regulation	V <sub>IN</sub> = 16V, 3mA ≤ I <sub>LOAD</sub> ≤ 100mA		25	mV
R <sub>ELINE</sub>	Line Regulation	I <sub>LOAD</sub> = 100mA, 8V ≤ V <sub>IN</sub> ≤ 16V		25	mV
V <sub>EDO</sub>	Dropout voltage, V <sub>IN</sub> – V <sub>EXT</sub>	V <sub>IN</sub> > 5.5V, 3mA ≤ I <sub>LOAD</sub> ≤ 100mA (Note 5)		0.8	V
V <sub>SD</sub>	Overvoltage Shutdown Threshold		30	36	V
I <sub>ESC</sub>	Output Short Circuit Current	R <sub>L</sub> = 1Ω		250	mA
V <sub>ESC</sub>	Output Short Circuit	No effect on other functions	–0.3	27	V
PSRR	Ripple Rejection	V <sub>IN</sub> = 9V, 50Hz ≤ freq ≤ 20KHZ, V <sub>RIPPLE</sub> = 4V <sub>PP</sub>	40		dB
Input Current					
I <sub>QOFF</sub>	Quiescent Input Current with Both Regulators OFF.	8V ≤ V <sub>IN</sub> ≤ 16V		100	μA
		16V ≤ V <sub>IN</sub> ≤ 42V		10	mA
I <sub>Q</sub>	No Load Quiescent Current	8V ≤ V <sub>IN</sub> ≤ 19V, I <sub>L</sub> = 0mA		15	mA
I <sub>NON</sub>	Additional Input Current with both Regulators ON	V <sub>IN</sub> ≥ 8V, I <sub>LTOTAL</sub> = I <sub>MAIN</sub> + I <sub>LEXT</sub> I <sub>LTOTAL</sub> = 700mA + 100mA = 800mA		1.2	X I <sub>LTOTAL</sub>

## Electrical Characteristics (Continued)

The following specifications apply for  $6V \leq V_{IN} \leq 19V$ ,  $t_{CASE} = 25^{\circ}C$  unless otherwise specified.  $C_{OUT} \geq 6\mu F$  with  $0.3\Omega \leq ESR \leq 3.0\Omega$  on each regulator output.

Symbol	Parameter	Conditions	LM9073		Units
			Min	Max	
$I_{IN_{DO}}$	Additional Input Current when in Dropout	$0V < V_{IN} < 8V$ , (Note 4) $I_{LTOTAL} = I_{MAIN} + I_{LEXT}$ $I_{LTOTAL} = 700mA + 100mA = 800mA$		1.5	$\times I_{LTOTAL}$
<b>Reset Output</b>					
$V_{THRL}$	Low Switching Threshold	$V_{MAIN}$ output controls Reset Reset Adjust (pin 11) open circuited	4.0	4.2	V
		Reset Adjust (pin 11) shorted to ground	4.5	4.7	V
$V_{THRH}$	High Switching Threshold	$V_{MAIN}$ output controls Reset	5.35	5.75	V
$V_{LOW}$	Logic Low Output Threshold	$1V \leq V_{MAIN} \leq V_{THRL}$ $R_{RESET} = 50k\Omega$ to $V_{MAIN}$		0.4	V
$V_{HIGH}$	Logic High Output Threshold	Normal operation, $V_{THRL} \leq V_{MAIN} \leq V_{THRH}$ , $I_{SOURCE} = 0$	$V_{MAIN} - 50mV$	$V_{MAIN}$	V
$R_{P-U}$	Internal Pull-Up Resistance		2.4	6.0	k $\Omega$
$T_{DELAY}$	Reset Delay Interval	$C_{DELAY} = 0.1\mu F$	35	70	mS
$T_{RISE}$	Output Rise Time	From 10% $V_{MAIN}$ to 90% $V_{MAIN}$ $C_{LRESET} = 50pF$		1.5	$\mu S$
$T_{FALL}$	Output Fall Time	From 90% $V_{MAIN}$ to 10% $V_{MAIN}$ $C_{LRESET} = 50pF$		0.5	$\mu S$
<b>Watchdog</b>					
$V_{TRIGL}$	Trigger Input Logic Low Voltage			.08	V
$V_{TRIGR}$	Trigger Input Logic High Level		2		V
$T_{WD}$	Watchdog Refresh Window	$C_{WATCHDOG} = 0.1\mu F$ (low leakage) $I_{WATCHDOG}$ for charging the watchdog	35	70	mS
$T_{PW}$	Watchdog Trigger Pulse Width		10		$\mu S$
$R_{TRIG}$	Trigger Input Pull-down Resistance		5	40	k $\Omega$
<b>Control Inputs</b>					
$V_{ON}$	ON Threshold for ON/OFF Input	$R_{series} = 22k\Omega$	3.5	4.5	V
$V_{OFF}$	OFF Threshold for ON/OFF Input	$R_{series} = 22k\Omega$ (Note 3)	1.5	2.5	V
$I_{ON/OFF}$	ON/OFF Input Current	$1.4V \leq V_{ON/OFF} \leq 4.5V$	1	12	$\mu A$
		$-0.3V \leq V_{ON/OFF} \leq 7V$ (Note 6)	-1	5	mA
$ON_{K-A}$	Turn ON Threshold for Keep Alive Input		2		V
$OFF_{K-A}$	Turn OFF Threshold for Keep Alive Input	(Note 3)		0.8	V
$R_{P-D}$	Pull-Down Resistance at Keep Alive Input	$0V \leq V_{K-A} \leq 5V$	5	40	k $\Omega$

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. "Operating Ratings" indicate conditions for which the device is functional, but do not guarantee specific performance limits. "Electrical Characteristics" state DC and AC electrical specifications under particular test conditions which guarantee specific performance limits. This assumes that the device is within the Operating Ratings. Specifications are not guaranteed for parameters where no limit is given, however, the typical value is a good indication of device performance.

**Note 2:** Human body model, 150 pF capacitor discharged through a 1.5 k $\Omega$  resistor.

**Note 3:** If either control input is left open circuited the regulators will turn OFF.

## Electrical Characteristics (Continued)

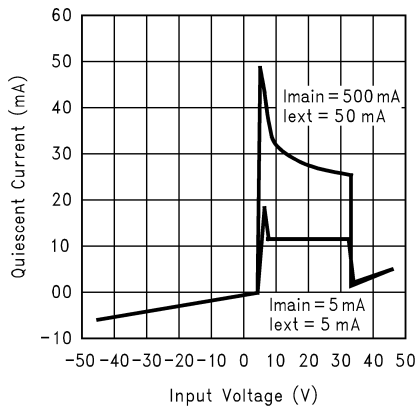
**Note 4:** The input quiescent current will increase when the regulators are in dropout conditions. The amount of additional input current is a direct function of the load current on both outputs. The peak increase in current is limited to 50% of the total load current.

**Note 5:** The dropout voltage specifications actually indicate the saturation voltage of the PNP power transistors used in each regulator. Over the full load current and temperature ranges the Main regulator will output at least 4.5V and the External Supply regulator at least 4.7V with an input voltage of only 5.5V

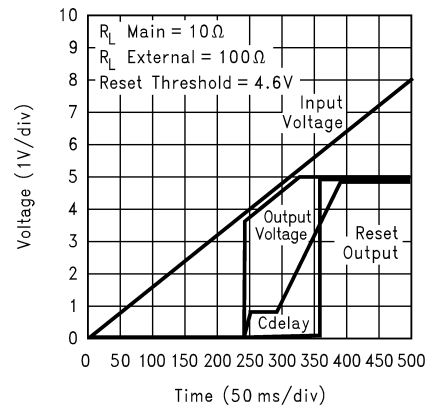
**Note 6:** The ON/OFF input is internally clamped to a 7V zener diode through a 1K $\Omega$  resistor.

## Typical Performance Characteristics

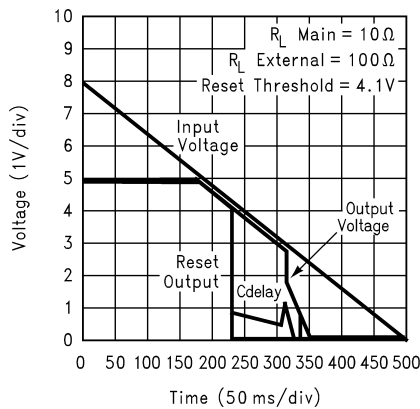
Quiescent Input Current vs. Input Voltage



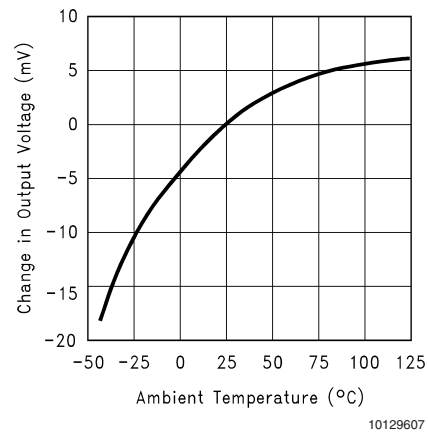
Turn-On Characteristic



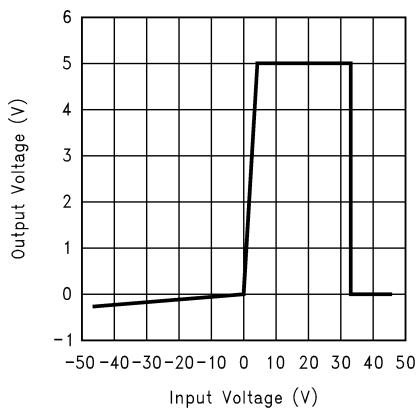
Turn-Off Characteristic



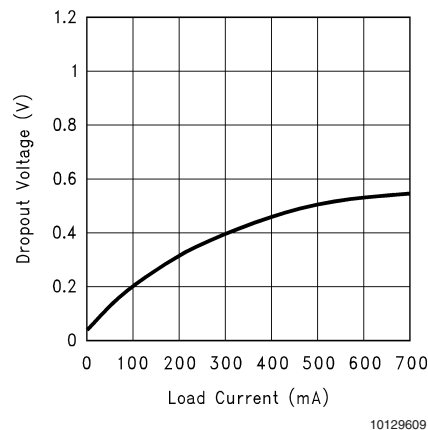
Normalized Output Voltages vs Temperature



Output Voltages at Input Voltage Extremes

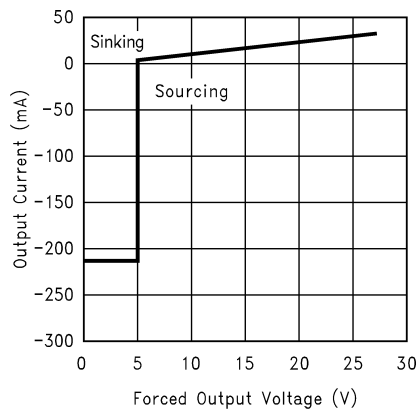


Main Output Dropout Voltage vs Load Current



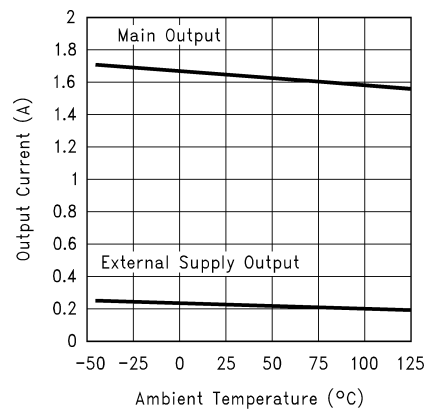
# Typical Performance Characteristics (Continued)

## External Supply Output Short Circuit Current



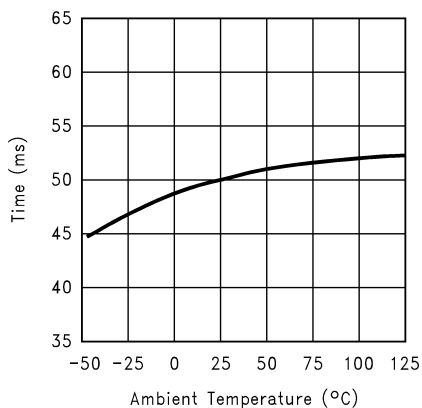
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## Output Short Circuit Current vs Temperature



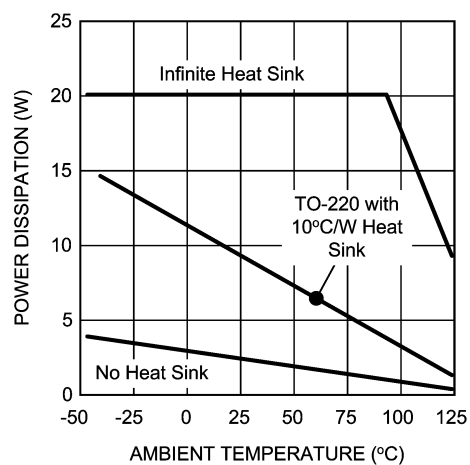
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## Watchdog and Reset Delay Time vs Temperature



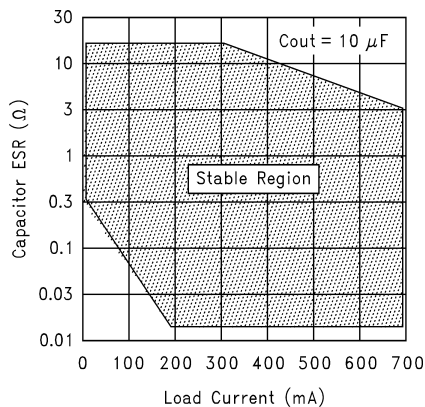
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## Maximum Power Dissipation



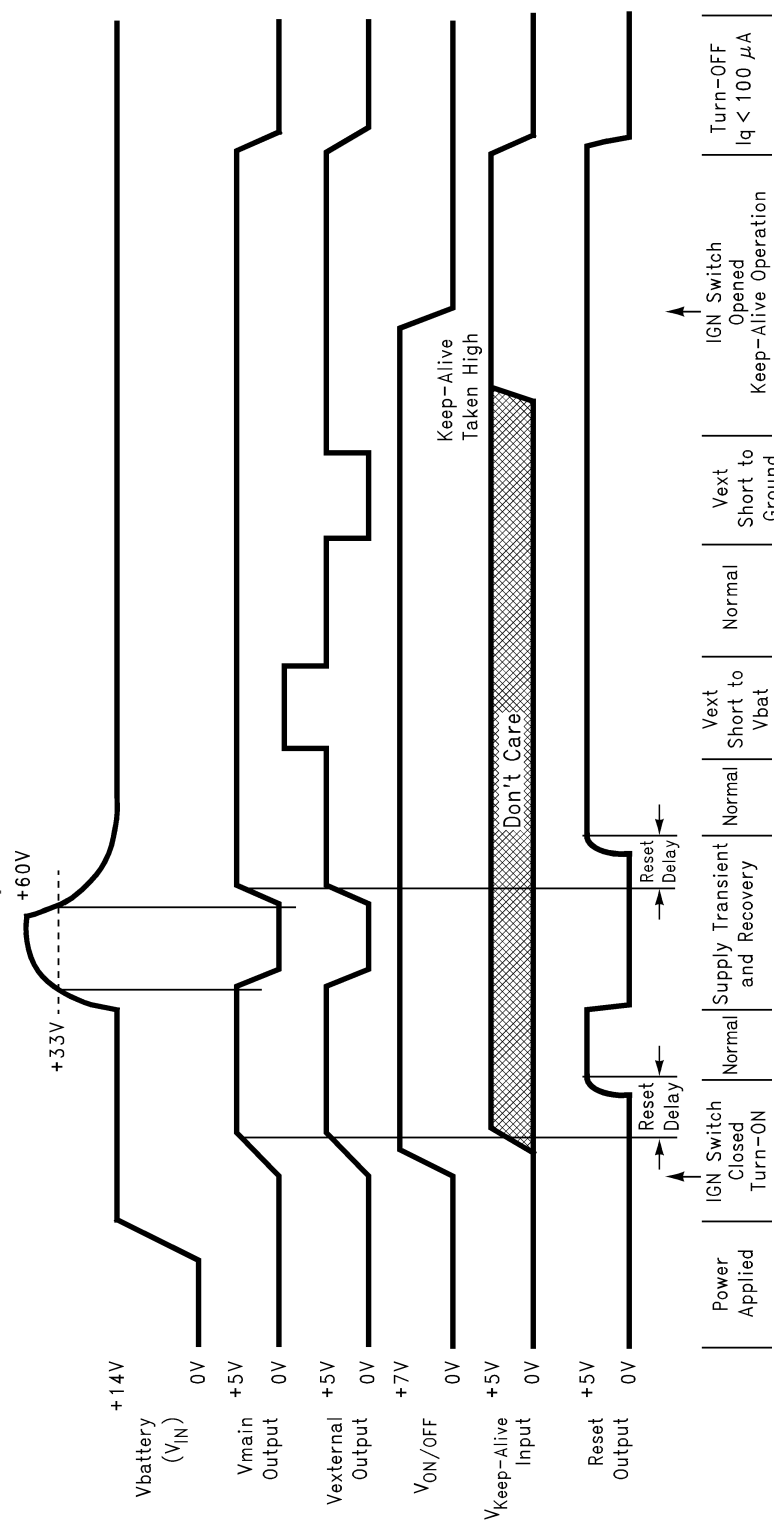
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## Output Capacitor ESR



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# Operational Characteristics



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## Control Logic Truth Table

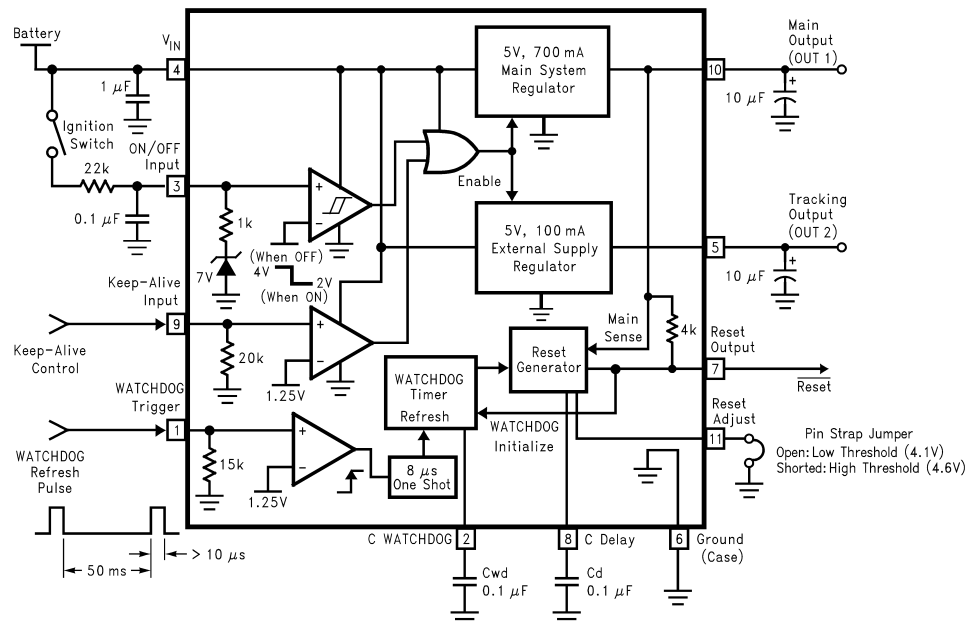
ON/OFF Input	Keep-Alive Input	Main Output Voltage	External Supply Output Voltage	Reset Output	Operating Condition
L	L	0V	0V	0V	OFF, Input current < 100μA
Rising Edge	L	5V	5V	Rising after delay	Outputs turn ON, Power ON delayed reset
H	X	5V	5V	5V	Normal ON condition
H	X	<4V or <4.5V or <5.35V	X	0V	Main output pulled out of regulation, Reset flag generated. Threshold depends on Reset Adjust setting (pin 11)
Falling Edge	H	5V	5V	5V	Keep-Alive, Continued normal operation
L	Rising Edge	5V	5V	Rising after delay	Outputs turned ON by Keep-Alive Input

## Application Information

### PIN DESCRIPTION AND FUNCTIONALITY

The LM9073 is a precision dual voltage regulator optimized for use in powertrain module applications but will also find

use in a wide variety of automotive and industrial applications where precision supply regulation is required in harsh operating environments. The following will describe the functionality of each of the package pins.



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FIGURE 1. Circuit Block Diagram

### INPUT VOLTAGE (PIN 4)

The LM9073 has been designed to connect directly to the ignition or battery supply in automotive applications. For this type of supply the regulator has been designed to withstand up to +60V and -45V supply transients such as load dump. An overvoltage shut down protection circuit turns OFF both of the regulator outputs should supply transients exceed typi-

cally +33V to fully protect all load circuitry. This higher threshold allows normal operation with 24V<sub>DC</sub> applied to the input as in the event when two batteries are used to start a vehicle. Protection of the system is also provided for inadvertent reverse polarity battery connections.

The current drain on the supply line is directly proportional to the load currents on the two voltage regulators. With no load



## Application Information (Continued)

current on either output the regulator requires 15mA maximum quiescent current for biasing internal circuitry. During dropout conditions ( $V_{IN} < 5.5V$ ) the additional input current can rise to 50% of the total load current. With less than 3V applied to the input, internal biasing circuitry shuts OFF.

When switched OFF the regulator can remain connected to the battery supply with a current drain of less than 100µA.

### MAIN OUTPUT (PIN 10)

The Main Output regulator provides a well controlled (2% tolerance maximum) 5V supply line with a total load current ranging up to 700mA. This relatively high level of output current is sufficient to provide power to a large number of load circuits in a variety of module applications.

This output has a short to ground current limit between 900mA and 2A. It is not protected for shorts to battery however, but can withstand an output short to a potential of 7 Volts or less.

To maintain stability of this supply line an output bypass capacitor is required. This capacitor must be at least 6 $\mu$ F with an equivalent series resistance (ESR) between 0.3 $\Omega$  and 3 $\Omega$  over temperature.

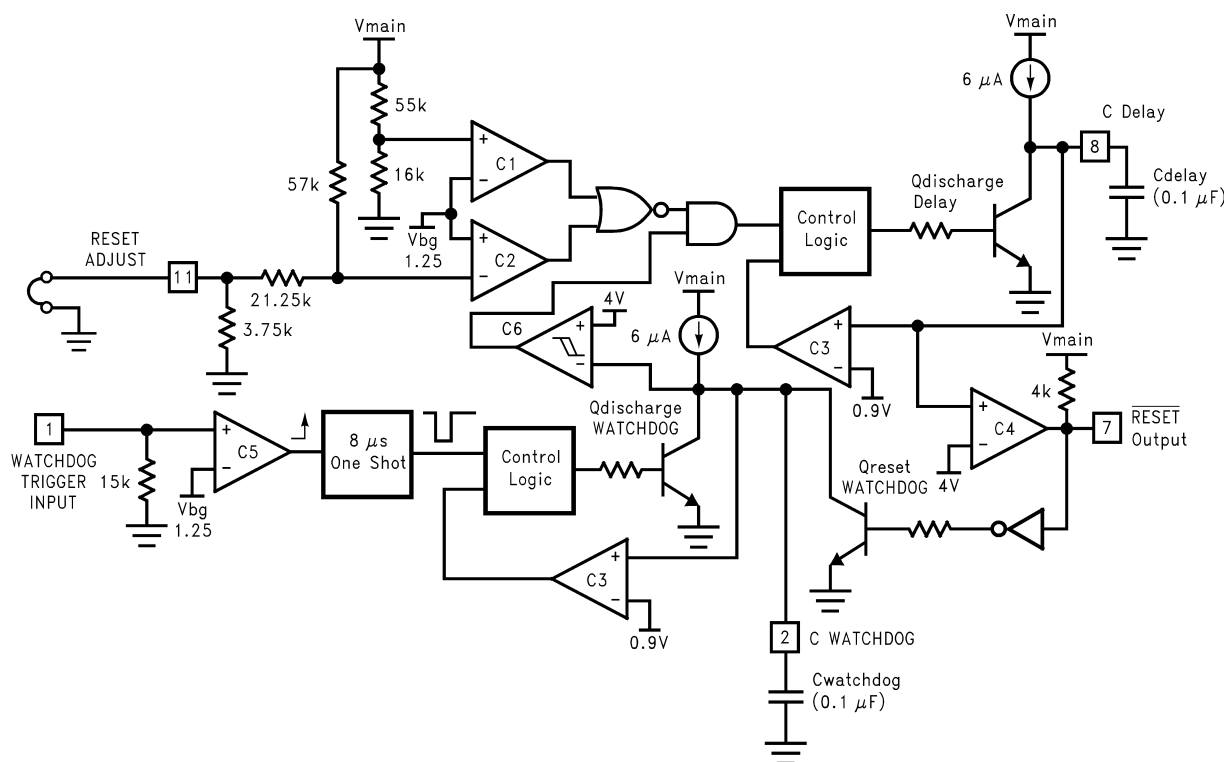
The Main Output is sensed for the generation of the system reset output.

### EXTERNAL SUPPLY OUTPUT (PIN 5)

The External Supply Output regulator is a secondary 5V, 2% tolerance regulated output of the LM9073. this 100mA output is available to bias sensors and other devices located external to the main system module.

For providing remote power the External Supply Output is fully protected against short circuit connections to the battery or input supply (up to 27V) and to ground. These shorted fault conditions do not effect the operation of the main supply nor generate a reset of the system.

Like the main output a bypass capacitor is required for stability. This capacitor should be also greater than  $6\mu\text{F}$  with an ESR between  $0.3\Omega$  and  $3\Omega$ .



**FIGURE 2. Reset Generator and Watchdog Circuitry**

## RESET OUTPUT (PIN 7)

The Reset Output is an active low logic signal provided to reset a system microcontroller on power up and in the event that the Main Output falls out of regulation. This output is guaranteed to provide a logic low level ( $<0.4V$ ) whenever the Main Output supply is below a threshold set by the Reset Adjust pin strap option (see Reset Adjust section) or is pulled

above 5.75V. This general reset prevents erratic system operation which may occur with out-of-specification supply potentials.

The Reset Output has an active pull down which can sink up to 15mA of current and a passive pull-up (through a 4K $\Omega$  resistor) to the Main Output to ensure voltage compatibility with the system supply. Capacitive loading on this reset line will directly affect the rise time of the reset signal. The Reset

## Application Information (Continued)

Output will maintain a logic low level with a Main Output voltage of only 1V. Below 1V the active pull-down device switches OFF (sink current of only 500 $\mu$ A). At such a low supply potential, system controllers are generally inoperative.

The Reset Output has a built-in delay time interval which is programmable by the section of the delay capacitor.

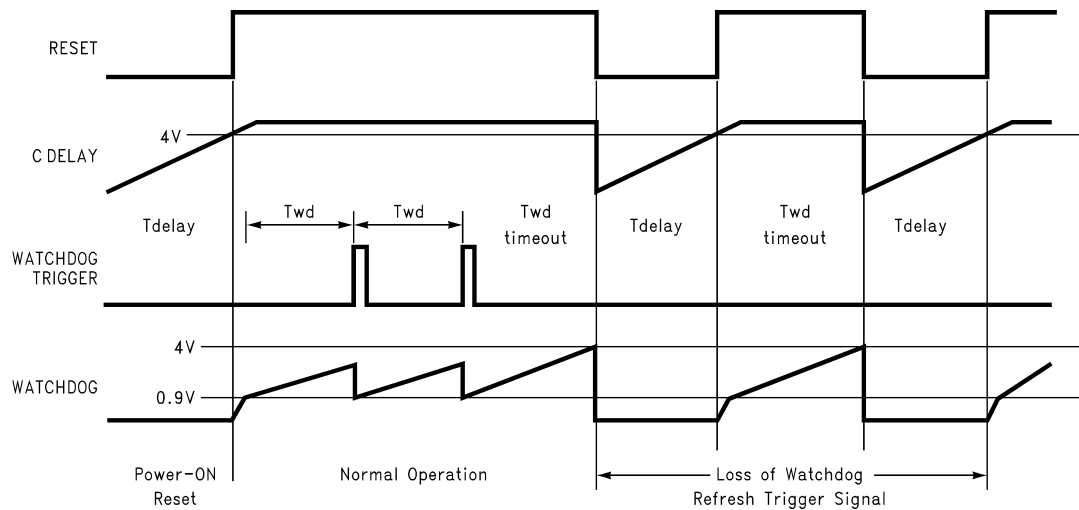
### RESET ADJUST (PIN 11)

The low V<sub>main</sub> threshold voltage for generating a system reset can be shifted by 500mV through the use of a pin strap to ground on pin 11. With this pin shorted to ground the threshold is between 4.5V and 4.7V. With this pin left open the threshold is shifted to between 4.0V and 4.2V. This lower threshold allows the system to remain operational longer during power down. The higher threshold ensures that the system is reset when the nominal 5V supply is low by 10%, which in some cases can produce uncertain microprocessor operation.

### DELAY CAPACITOR (PIN 8)

The Delay Capacitor (C<sub>DELAY</sub>) controls a time interval during which the Reset Output remains low after the Main Output has established normal operating condition. This feature holds the system in reset for a time to allow all load circuitry to properly bias before executing functions. This interval is applied at power-up and following any event that may trigger the system reset function.

Figure 2 illustrates the delayed reset generator. Two comparators continually monitor the Main Output supply. Window comparators C1 and C2 detect if the Main Supply is below 4.6V (4.1V with Reset Adjust open circuited) or exceeds 5.5V typically. If this is true (at power-on for example) the control logic turns ON the discharge transistor and holds C<sub>DELAY</sub> low (at 0.9V). Comparator C4 then outputs a logic low system Reset signal within 2 $\mu$ S after detecting the out of regulation condition.



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FIGURE 3. Watchdog and Reset Operation

The Delay Capacitor remains discharged until the window comparator senses that the Main Output is within normal operating range (C1 and C2 outputs are both low). When this condition is met, the discharge transistor is turned OFF and C<sub>DELAY</sub> is charged positively by an internal 6 $\mu$ A current source. The Reset Output will remain low until the delay capacitor has reached 4V, at which point it will go high and the system will begin normal operation. This delay time interval is controlled by the section of C<sub>DELAY</sub> and can be determined from the following equation:

$$T_{\text{DELAY}} = (0.5 \times 10^6) \times C_{\text{DELAY}}$$

A 0.1 $\mu$ F capacitor will produce a typical delay interval of 50mSec.

To ensure a consistent delay time interval, the discharge transistor is always latched ON by the window comparators, and can not be switched OFF to start a new delay interval until C<sub>DELAY</sub> has been discharged to less than or equal to 0.9V. This sets a fixed starting voltage (0.9V) and ending voltage (4V) for the charging of the Delay Capacitor.

### WATCHDOG CAPACITOR (PIN 2)

The LM9073 also provides a simple system watchdog timer. The watchdog timer requires the system controller to issue a pulse at a regular interval (programmable through the selection of C<sub>watchdog</sub>) to provide an indication that the system is properly executing controlling software code. The absence of a pulse before the watchdog timer comes out could indicate that the system is caught in a infinite loop and the system is reset.

The watchdog capacitor is held discharged to ground at any time that the system is reset. When the reset is released the capacitor quickly charges to 0.9V (with a charging current of approximately 50 $\mu$ A) then slowly charges positive with a charging current of 6 $\mu$ A. If this capacitor ever charges up to 4V or more, a system reset is generated.

The watchdog time interval is set by the selection of C<sub>watchdog</sub> and can be found from the following equation:

$$T_{\text{WD}} = (0.5 \times 10^6) \times C_{\text{watchdog}}$$

## Application Information (Continued)

The watchdog timer function can be disabled by grounding pin 2 or replacing Cwatchdog by a resistor with a value less than 22k $\Omega$ . With this only the reset generator can reset the system.

### WATCHDOG TRIGGER (PIN 1)

The Watchdog Trigger input accepts a pulse from the system controller to refresh the watchdog capacitor and prevent it from reaching 4V and resetting the system. This positive pulse must be at least 10 $\mu$ S long and triggers an internal one-shot pulse. This internal pulse latches ON Qdischarge Watchdog (figure 2) and discharges Cwatchdog to 0.9V. This latching action ensures a consistent watchdog timer interval by not allowing the capacitor to charge positively until it has been discharged to 0.9V.

As shown in Figure 3, each watchdog trigger input pulse resets the timer capacitor. If the watchdog trigger signal does not refresh the timer before Cwatchdog reaches 4V, a system reset is generated. Once reset, a full reset delay interval occurs. At the end of this interval the regulator will automatically try to re-start the system by taking reset high. If the system does not respond properly by issuing a watchdog trigger signal in time, the system will once again reset. In this situation the reset output will continually cycle high (re-starting the system) for the watchdog time interval and low (re-setting the system) for the reset delay interval.

A low to high transition is required during the watchdog timer interval at the trigger input. If this line is ever fixed high the timer will time-out and the system will reset.

### ON/OFF INPUT (PIN 3)

The ON/OFF Input enables both the Main and External Supply outputs. In a typical application this input is con-

nected to the input supply through a series resistor (nominally 22K $\Omega$ ) and a switch (Ignition, as an example). When the switch is closed this input is pulled high and switches ON both regulator outputs. This input is internally clamped to a 7V zener diode through a series 1k $\Omega$  resistor. The external series resistor together with an optional 0.1 $\mu$ F capacitor to ground provide filtering and current limiting to withstand transients that may appear on the input supply to maintain normal operation of the system.

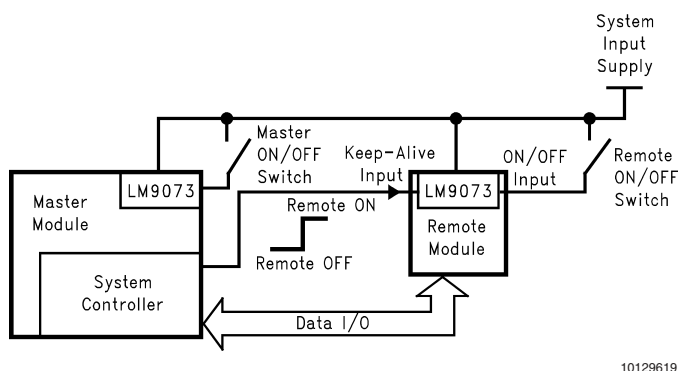
The switching threshold of the ON/OFF comparator has 2 Volts of hysteresis to ensure noise free control of the system. To turn the regulators ON this input must be taken above 4V. To turn the system OFF the ON/OFF Input must be open circuited or pulled below 2 Volts.

### KEEP-ALIVE INPUT (PIN 9)

This CMOS logic level compatible input provides a system with the ability to control it's own ON/OFF sequencing. The Keep-Alive Input is OR'ed with the ON/OFF Input so either one can independently control the regulators.

As shown in the Operational Characteristics, a system controller can take the Keep-Alive Input high at any time. If the ON/OFF switch is opened, this high level on Keep-Alive will keep the regulators ON and the entire system operational. This control is useful for providing as much time as necessary for a system to perform "housekeeping" chores such as programming EEPROM with system information prior to turning itself OFF (by taking the Keep-Alive Input low) and reverting to the low quiescent current state.

A second use of the Keep-Alive Input can be from other modules which need information from the module powered by LM9073. A high CMOS logic level ( $>1.25V$ ) on this input will power up the system as needed independent from the normal ON/OFF switch.



#### FIGURE 4. Remote ON/OFF Control

## SYSTEM KEEP-ALIVE OPERATION

Figure 5 illustrates the basic concept of Keep-Alive operation. The LM9073 provides the regulated supplies to an entire microcontroller based system or module including remote sensors. The system is switched ON or OFF by a switch connected to the unregulated input supply and the ON/OFF input, pin 3. When closed the regulators turn ON and the system is held in a reset state for the duration of the delayed reset interval controlled by  $C_{DELAY}$ .

Once normal operation of the system begins, the controller needs to set an output line connected to the Keep-Alive input, pin 9, high. The system remains in normal operation

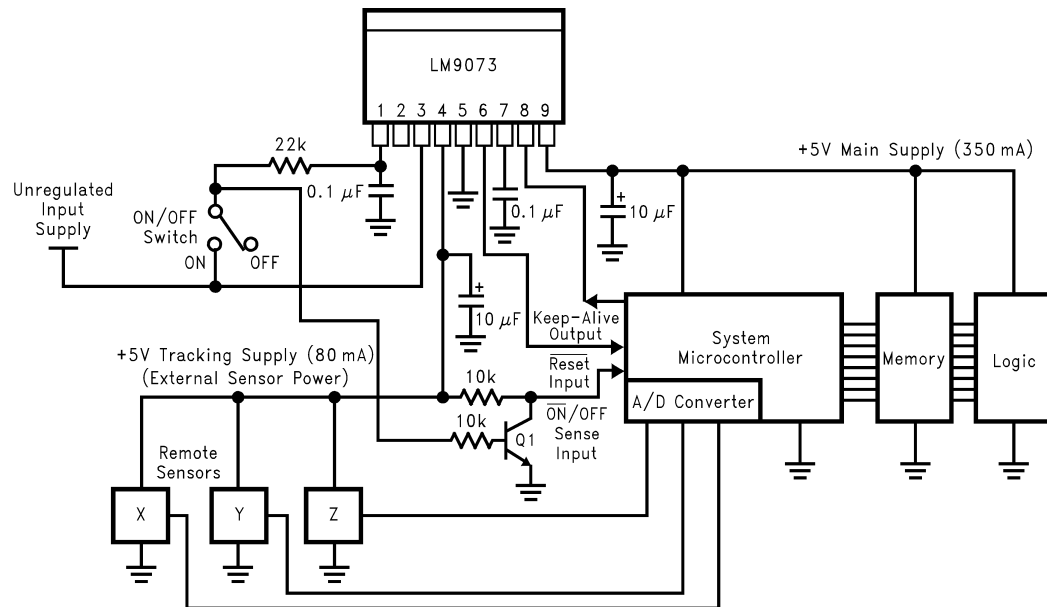
until switched OFF by opening the ON/OFF switch. With Keep-Alive high the entire system remains normally biased and will remain operational until the Keep-Alive input is taken low.

Transistor Q1 is shown as a means to inform the controller that the ON/OFF switch has been opened. This high level on an input line tells the controller that the system has been switched OFF. This indicates the start of the Keep-Alive interval. The system can perform whatever actions required to obtain the proper OFF state before actually powering down. These general housekeeping tasks can include putting external devices in the proper OFF condition and storing

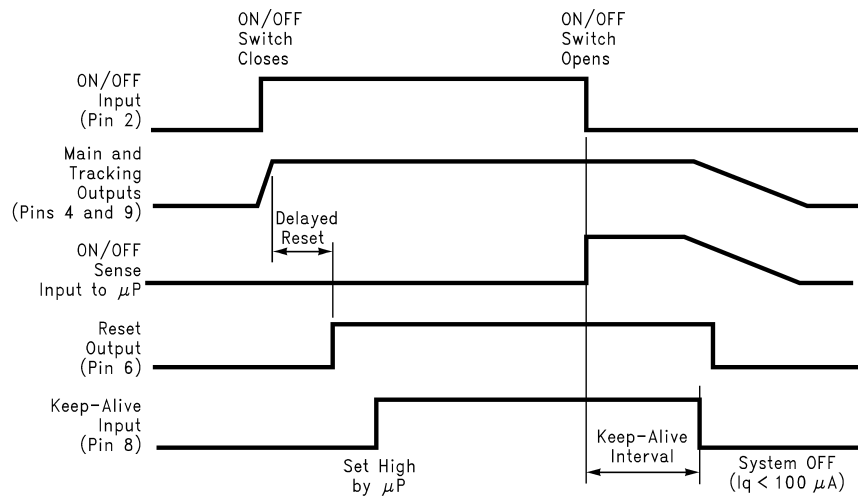
## Application Information (Continued)

various system variables in EPROM for example. With the controller in command of the Keep-Alive interval these tasks can take whatever time necessary to complete.

When completed the controller takes the Keep-Alive input to a low level and the entire system shuts down. The LM9073 powers down to a low quiescent current mode with less than 100 $\mu$ A drawn from the input supply.



### Control Waveforms



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FIGURE 5. Basic Keep-Alive Operation

To initiate the Keep-Alive routine before actual power down, it is important for the system controller to know when the system has been switched OFF. To eliminate any interface between the controller and the ON/OFF switch and potentially noisy unregulated input supply, and simple logic scheme shown in Figure 6 can be used. With this circuitry the Reset output from the LM9073 provides the ON/OFF sensing input to the controller.

When switched OFF, the main regulator output will fall out of regulation and generate a low logic level on the Reset output. This input to the controller provides the switch OFF indication and initiates the Keep-Alive interval.

Control of the Keep-Alive duration is set by a logic 1 on the Keep-Alive output line from the system controller. This high level prevents the Reset output from resetting the entire system and also gates the Keep-Alive input signal to the LM9073. The inverted Reset signal provides a logic 1 to the Keep-Alive input of the LM9073.

The Main output will only drop out of regulation for a very short time before the Keep-Alive input turns it back on.

The Reset output remains low for the delay time interval. When it turns high the Main output switches OFF and back ON again very quickly. This continues until the system controller takes the Keep-Alive output line to a logic low level.

## Application Information (Continued)

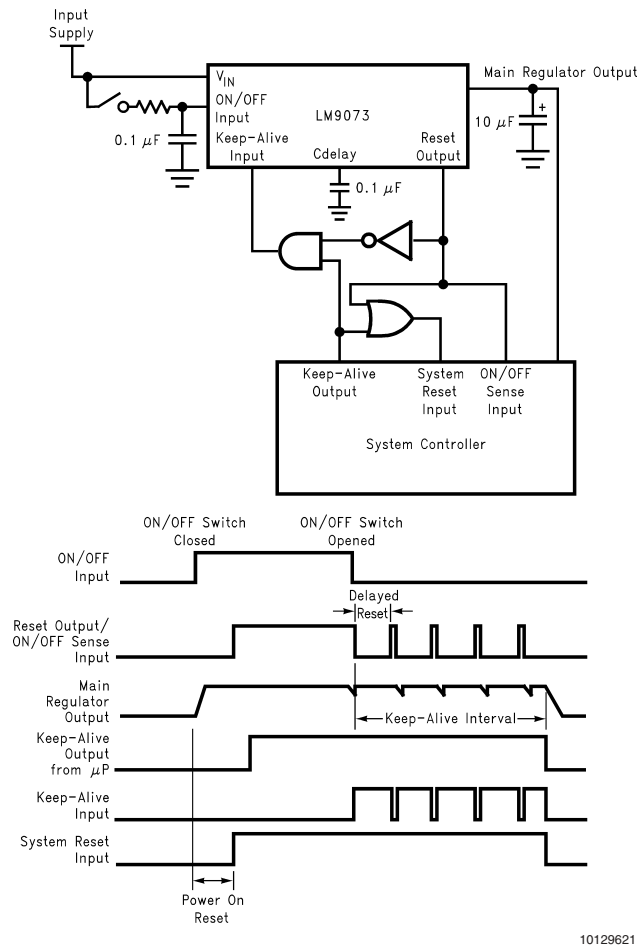


FIGURE 6. Simple Logic Configuration to Provide ON/OFF Sensing

### INPUT STABILITY

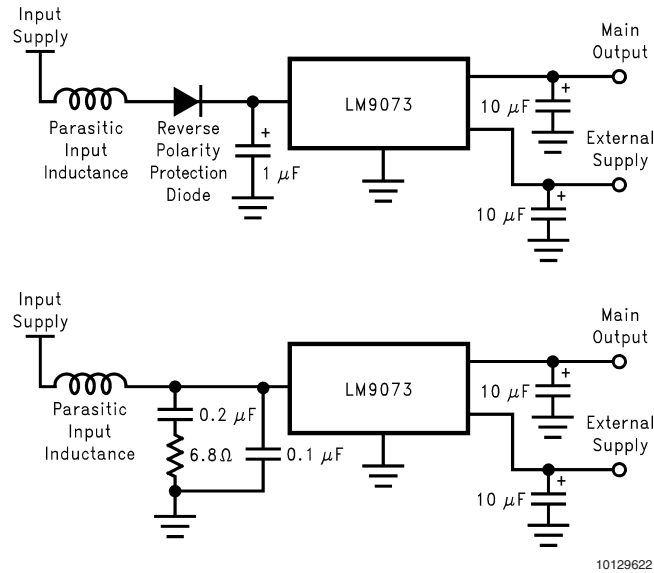
Low dropout voltage regulators which utilize a PNP power transistor usually exhibit a large increase in current when in dropout ( $V_{in} < 5.5V$ ). This increase is caused by the saturation characteristics ( $\beta$  reduction) of the PNP transistor. To significantly minimize this increase in current the LM9073 detects when the PNP enters the saturation and reduces the operating current.

This reduction in input current can create a stability problem in applications with higher load current ( $>200mA$ ), where the input voltage is applied through a long length of wire which in effect add a significant amount of inductance in series with

the input. The drop in input current may create a positive input voltage transient which may take the PNP out of saturation. If the input voltage is held constant at the threshold where the PNP is going in and out of saturation, an oscillation may be created.

This is only observed where a large series inductance is present in the input supply line and when the rise and fall time of the input supply is very slow. If the application and removal of the input voltage changes at a rate greater than  $500mV/mS$  it will move through the dropout region of the regulator ( $V_{in}$  of  $3V$  to  $5.5V$ ) too quickly for an oscillation to be established.

## Application Information (Continued)



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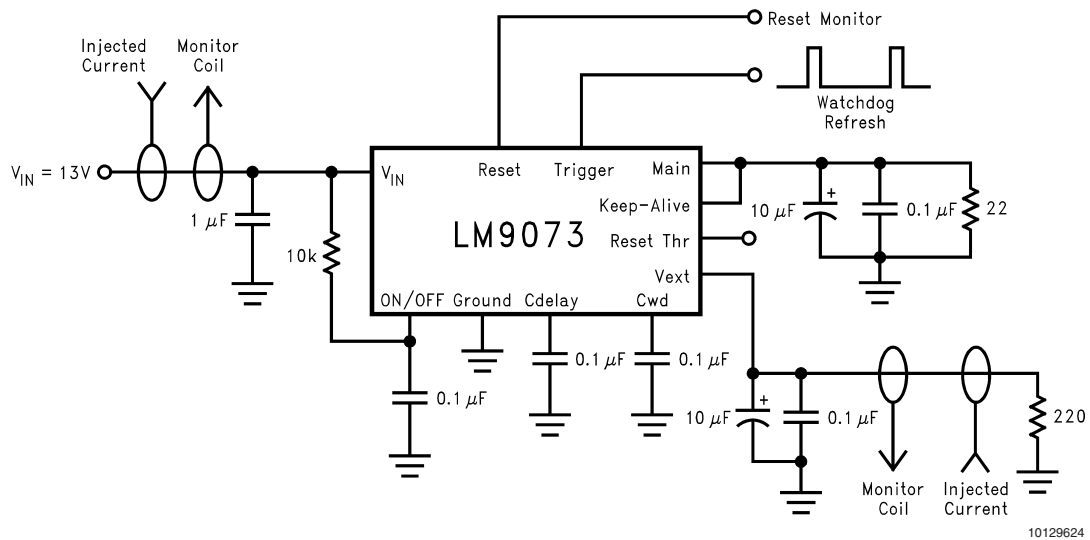
**FIGURE 7. Input Bypassing**

In the event that an oscillation is present, input bypassing can also help de-tune the resonance. Figure 7 illustrates two input bypassing approaches. The straight forward addition of a larger valued electrolytic capacitor could suffice. In this case however, if reverse battery connections are possibility it is necessary to add a series protection diode as shown to prevent damaging the polarized input capacitor.

An alternative input bypassing scheme is also shown. This eliminates the use of polarized input capacitors and a series protection diode. The values shown were derived empirically in a representative typical application. Appropriate values for any given application require experimentation.

### THERMAL MANAGEMENT

The LM9073 is packaged in a narrow lead-pitch TO-220 package. To obtain operation over the highest possible load current and input voltage ranges, care must be taken to control the operating temperature of the device. Thermal shutdown protection is built with a threshold above 150°C. Conventional heat sinking techniques can be used with the TO-220 package.



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**FIGURE 8. EMC Test Circuit**

## Application Information (Continued)

### ELECTRO-MAGNETIC COMPATIBILITY (EMC)

Systems utilizing the LM9073 will not experience loss of supply or false reset signals from the regulator when subjected to high frequency interference from a standard Bulk Current Injection test (ISO11452 Part 4 test method). The following test conditions and configuration (*Figure 8*) can be used to verify this performance:

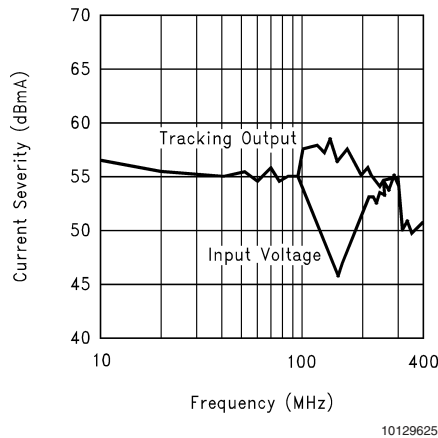
- Frequency Range 1MHz to 400MHz
- Modulation 1 (no modulation)
- Modulation 2 1kHz sine wave, 80% AM
- Dwell Time 1 second
- Frequency Steps 1MHz (from 1MHz to 10MHz)
- 2MHz (from 10MHz to 200MHz)

- 20MHz (from 200MHz to 400MHz)
- Test Method Closed loop current probe

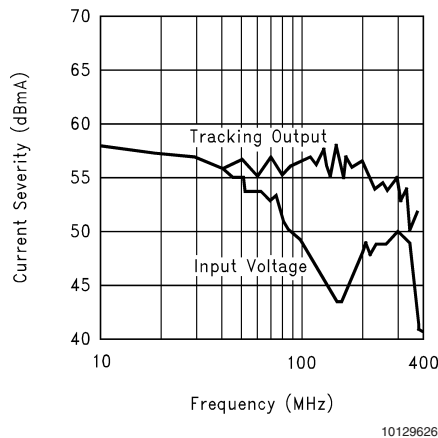
In this test configuration the current injected in to either the input pin or the tracking output pin is increased until a reset output is generated. These two pins are the most critical as they typically will connect to a module through long lengths of wire most likely to pick up high frequency energy. *Figure 9* illustrates examples of test results on the LM9073 with both types of modulation.

These results are just examples as actual results in any given application will depend on numerous external factors such as component selection, pc board layout, etc. The current power of the injected signal is expressed in dB relative to 1mA (i.e. 40dBmA = 100mA)

**BCI Susceptibility, Modulation 1 (CW)**



**BCI Susceptibility, Modulation 2 (CW)  
(1kHz, 80% AM Modulation)**



**FIGURE 9. Examples of BCI Test**

