National Semiconductor

February 1995

LM1042 Fluid Level Detector

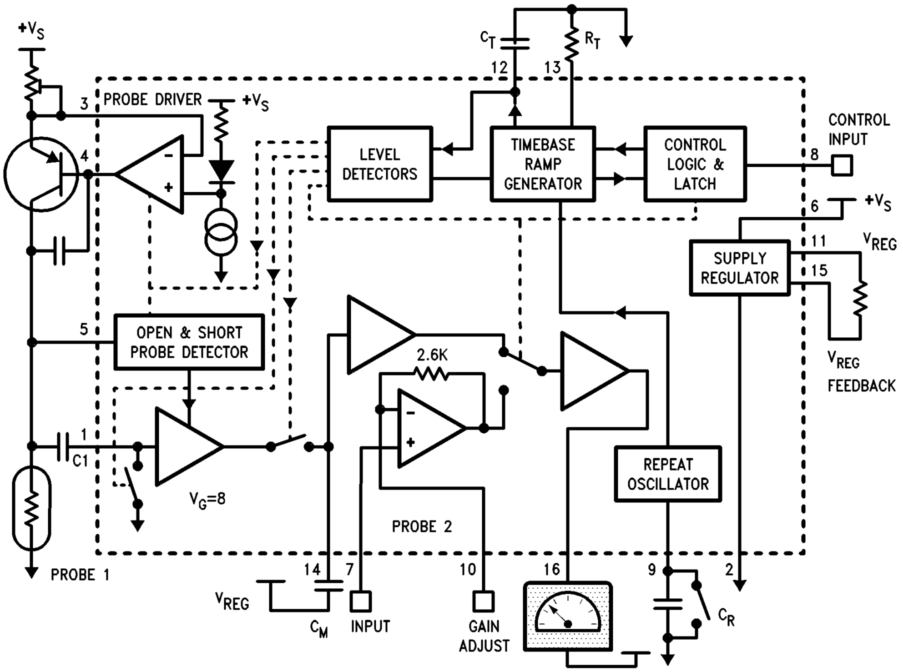
General Description

The LM1042 uses the thermal-resistive probe technique to measure the level of non-flammable fluids. An output is provided proportional to fluid level and single shot or repeating measurements may be made. All supervisory requirements to control the thermal-resistive probe, including short and open circuit probe detection, are incorporated within the device. A second linear input for alternative sensor signals may also be selected.

Features

- Selectable thermal-resistance or linear probe inputs
- Control circuitry for thermal-resistive probe
- Single-shot or repeating measurements
- Switch on reset and delay to avoid transients
- Output amplifier with 10 mA source and sink capability
- Short or open probe detection
- +50V transient protection on supply and control input
- 7.5V to 18V supply range
- Internally regulated supply
- −40°C to +80°C operation

Block Diagram



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RRD-B30M115/Printed in U. S. A.

Absolute Maximum Ratings

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

Supply Voltage V_{CC}	32V
Voltage at Pin 8	32V
Positive Peak Voltage (Pins 6, 8, 3) (Note 1) 10 ms 2A	50V
Output Current Pin 4, (I_4)(sink)	10 mA
Output Current Pin 11 (source)	25 mA
Output Current Pin 16	±10 mA
Operating Temperature Range	−40°C to +80°C
Storage Temperature Range	−55°C to +150°C
Lead Temperature (Soldering 10 sec.)	260°C
Package Power Dissipation $T_A = 25°C$ (Note 8)	1.8W
Device Power Dissipation	0.9W

Electrical Characteristics

$V_{CC} = 13V$, T_A within operating range except where stated otherwise. $C_T = 22\ \mu F$, $R_T = 12k$

Symbol	Parameter	Conditions	Tested Limits (Note 2)		Design Limits (Note 3)			Units
			Min	Max	Min	Typ	Max	
V_{CC}	Supply Voltage		7.5	18	7.5	13	18	V
I_S	Supply Current			35			35	mA
V_{REG}	Regulated Voltage	Pins 15 and 11 connected	5.7	6.15	5.65	5.9	6.2	V
	Stability Over V_{CC} Range	Referred to value at $V_{CC} = 13V$ (Note 4)		±0.5			±0.5	%
$V_6 - V_3$	Probe Current Reference Voltage		2.15	2.35	2.10	2.25	2.40	V
	Probe Current Regulation Over V_{CC} Range	(Note 4)		±0.5			±0.8	%
T_1	Ramp Timing	See *Figure 5*	20	37	15	31	42	ms
$T_2 - T_1$					3		16	ms
$T_4 - T_1$	Ramp Timing		1.4	2.1	1.4	1.75	2.1	s
T_{STAB}	Ramp Timing Stability	Over V_{CC} Range		+5			±5	%
R_T	Ramp Resistor Range		3	15	3		15.0	kΩ
V_8	Start Input Logic High Level		1.7		1.7			V
V_8	Start Input Logic Low Level			0.5			0.5	V
I_8	Start Input Current	$V_8 = V_{CC}$		100			100	nA
I_8	Start Input Current	$V_8 = 0V$		300			300	nA
V_{16}	Maximum Output Voltage	$R_L = 600\Omega$ from Pin 16 to V_{REG}	$V_{REG} - 0.3$		$V_{REG} - 0.3$			V
	Minimum Output Voltage			0.5		0.2	0.6	V
G_1	PROBE 1 Probe 1 Gain	Pin 1 80 mV to 520 mV (Notes 6, 7)	9.9	10.4		10.15		
	Non-linearity of G_1	Pin 1 80 mV to 520 mV (Note 7)	−1	+1	−2	0	2	%
OS_1	Pin 1 Offset	(Note 7)				±5		mV
G_2	PROBE 2 Probe 2 Gain	Pin 7 240 mV to 1.562V (Note 7)	3.31	3.49		3.4		
	Non-linearity of G_2	Pin 7 240 mV to 1.562V (Note 7)	−1	+1	−2	0.2	2	%
OS_7	Pin 7 Offset	(Note 7)				±5		mV
R_7	Input impedance					5		MΩ

Electrical Characteristics

$V_{CC} = 13V$, T_A within operating range except where stated otherwise. $C_T = 22\ \mu F$, $R_T = 12k$ (Continued)

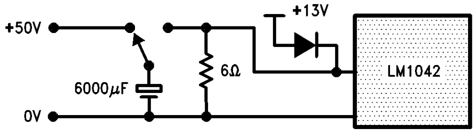
Symbol	Parameter	Conditions	Tested Limits (Note 2)		Design Limits (Note 3)			Units
			Min	Max	Min	Typ	Max	
V_1	Probe 1 Input Voltage Range	$V_{CC} = 9V$ to 18V $V_{CC} = 7.5V$, $I_4 < 2.5$ mA ($V_{REG} = 6.0V$)	1	5	1 1		5 3.5	V V
V_5	Probe 1 Open Circuit Threshold	At Pin 5	$V_{REG} - 0.7$	$V_{REG} - 0.5$	$V_{REG} - 0.85$	$V_{REG} - 0.6$	$V_{REG} - 0.35$	V
V_5	Probe 1 Short Circuit Threshold		0.5	0.7	0.35	0.6	0.85	V
I_{14}	Pin 14 Input Leakage Current	Pin 14 = 4V	−2.0	2.0			2.0	nA
I_1	Pin 1 Input Leakage Current	Pin 1 = 300 mV	−5.0	5.0		1.5	5.0	nA
T_R	Repeat Period	$C_R = 22\ \mu F$ (Note 5)	12	28	9.1	17	36	s
	C_R Discharge Time	$C_R = 22\ \mu F$				70	135	ms
C_M	Memory Capacitor Value						0.47	μF
C_1	Input Capacitor Value						0.47	μF

Sensitivity fo Electrostatic Discharge—

Pins 7, 10, 13, and 14 will withstand greater than 1500V when tested using 100 pF and 1500Ω in accordance with National Semiconductor standard ESD test procedures.

All other pins will withstand in excess of 2 kV.

Note 1: Test circuit for over voltage capability at pins 3, 6, 8.



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Note 2: Guaranteed and 100% production tested at 25°C. These limits are used to calculate outgoing quality levels.

Note 3: Limits guardbanded to include parametric variations. $T_A = -40°C$ to $+80°C$ and from $V_{CC} = 7.5V$ to 18V. These limits are not used to calculate AOQL figures.

Note 4: Variations over temperature range are not production tested.

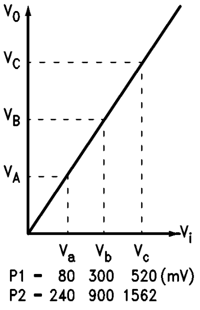
Note 5: Time for first repeat period, see *Figure 6*.

Note 6: Probe 1 amplifier tests are measured with pin 12 ramp voltage held between the T_3 and T_4 conditions (pin 12 ≈ 1.1V) having previously been held above 4.1V to simulate ramp action. See Figure 5.

Note 7: When measuring gain separate ground wire sensing is required at pin 2 to ensure sufficiently accurate results.

Linearity is defined as the difference between the predicted value of V_B (V_B*) and the measured value.

Note 8: Above $T_A = 25°C$ derate with $\theta_{jA} = 70°C/W$.



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For probe 1 and probe 2—Gain (G) $= \dfrac{V_C - V_A}{V_c - V_a}$

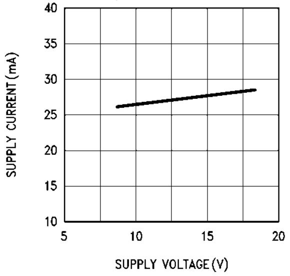
Input offset $= \left[\dfrac{V_C}{G} - V_c\right]$

Linearity $= \left[\dfrac{V_B^*}{V_B} - 1\right] \times 100\%$

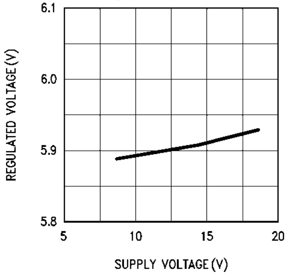
$V_B^* = V_A + G(V_b - V_a)$

Typical Performance Characteristics

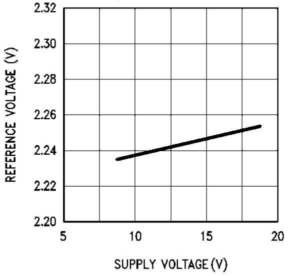
Supply Current vs Supply Voltage



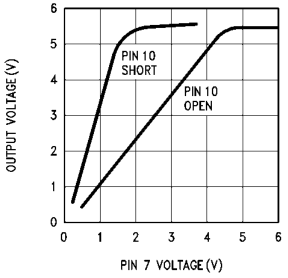
Regulated Voltage vs Supply Voltage



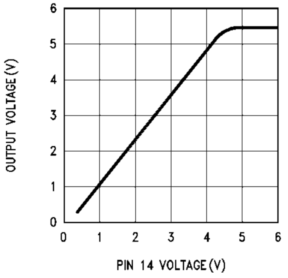
Probe Reference V vs Supply Voltage



Output Voltage vs Pin 7 Voltage



Output Voltage vs Pin 14 Voltage



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Pin Function Description

Pin 1	Input amplifier for thermo-resistive probe with 5 nA maximum leakage. Clamped to ground at the start of a probe 1 measurement.
Pin 2	Device ground — 0V.
Pin 3	This pin is connected to the emitter of an external PNP transistor to supply a 200 mA constant current to the thermo-resistive probe. An internal reference maintains this pin at $V_{SUPPLY} - 2V$.
Pin 4	Base connection for the external PNP transistor.
Pin 5	This pin is connected to the thermo-resistive probe for short and open circuit probe detection.
Pin 6	Supply pin, +7.5V to +18V, protected against +50V transients.
Pin 7	High Impedance input for second linear voltage probe with an input range from 1V to 5V. The gain may be set externally using pin 10.
Pin 8	Probe select and control input. If this pin is taken to a logic low level, probe 1 is selected and the timing cycle is initiated. The selection logic is subsequently latched low until the end of the measurement. If kept at a low level one shot or repeating probe 1 measurements will be made depending upon pin 9 conditions. A high input level selects probe 2 except during a probe 1 measurement period.
Pin 9	The repeat oscillator timing capacitor is connected from this pin to ground. A 2 μA current charges up the capacitor towards 4.3V when the probe 1 measurement cycle is restarted. If this pin is grounded the repeat oscillator is disabled and only one probe 1 measurement will be made when pin 8 goes low.
Pin 10	A resistor may be connected to ground to vary the gain of the probe 2 input amplifier. Nominal gain when open circuit is 1.2 and when shorted to ground 3.4. DC conditions may be adjusted by means of a resistor divider network to V_{REG} and ground.
Pin 11	Regulated voltage output. Requires to be connected to pin 15 to complete the supply regulator control loop.
Pin 12	The capacitor connected from this pin to ground sets the timing cycle for probe 1 measurements.
Pin 13	The resistor connected between this pin and ground defines the charging current at pin 12. Typically 12k, the value should be within the range 3k to 15k.
Pin 14	A low leakage capacitor, typical value 0.1 μF and not greater than 0.47 μF, should be connected from this pin to the regulated supply at pin 11 to act as a memory capacitor for the probe 1 measurement. The internal leakage at this pin is 2 nA max for a long memory retention time.
Pin 15	Feedback input for the internal supply regulator, normally connected to V_{REG} at pin 11. A resistor may be connected in series to adjust the regulated output voltage by an amount corresponding to the 1 mA current into pin 15.
Pin 16	Linear voltage output for probe 1 and probe 2 capable of driving up to ±10 mA. May be connected with a 600Ω meter to V_{REG}.

Application Notes

THERMO-RESISTIVE PROBES — OPERATION AND CONSTRUCTION

These probes work on the principle that when power is dissipated within the probe, the rise in probe temperature is dependent on the thermal resistance of the surrounding material and as air and other gases are much less efficient conductors of heat than liquids such as water and oil it is possible to obtain a measurement of the depth of immersion of such a probe in a liquid medium. This principle is illustrated in *Figure 1*.

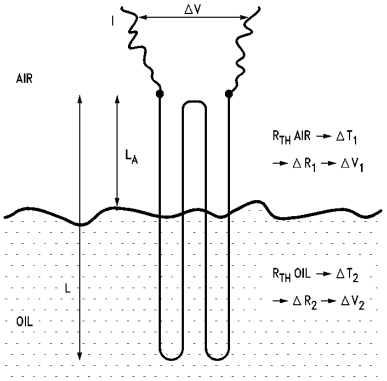

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FIGURE 1

During the measurement period a constant current drive I is applied to the probe and the voltage across the probe is sampled both at the start and just before the end of the measurement period to give ΔV. R_{TH} Air and R_{TH} Oil represent the different thermal resistances from probe to ambient in air or oil giving rise fo temperature changes ΔT_1 and ΔT_2 respectively. As a result of these temperature changes the probe resistance will change by ΔR_1 or ΔR_2 and give corresponding voltage changes ΔV_1 or ΔV_2 per unit length.

Hence

$$\Delta V = \frac{L_A}{L}\Delta V_1 + \frac{(L - L_A)}{L}\Delta V_2$$

and for $\Delta V_1 > \Delta V_2$, R_{TH} Air $>$ R_{TH} Oil, ΔV will increase as the probe length in air increases. For best results the probe needs to have a high temperature coefficient and low thermal time constant. One way to achieve this is to make use of resistance wires held in a suitable support frame allowing free liquid access. Nickel cobalt iron alloy resistance wires are available with resistivity 50 $\mu\Omega$cm and 3300 ppm temperature coefficient which when made up into a probe with 4 × 2 cm 0.08 mm diameter strands between supports (10 cm total) can give the voltage vs time curve shown in *Figure 2* for 200 mA probe current. The effect of varying the probe current is shown in *Figure 3.* To avoid triggering the probe failure detection circuits the probe voltage must be between 0.7V and 5.3V (V_{REG} − 6V), hence for 200 mA the permissible probe resistance range is from 3.5Ω to 24Ω. The example given has a resistance at room temperature of 9Ω which leaves plenty of room for increase during measurements and changes in ambient temperature.

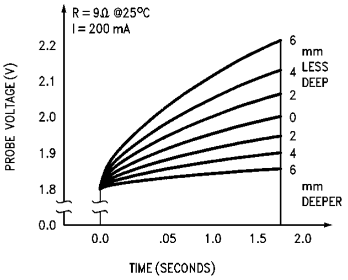

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FIGURE 2

Various arrangements of probe wire are possible for any given wire gauge and probe current to suit the measurement range required, some examples are illustrated schematically in *Figure 4.* Naturally it is necessary to reduce the probe current with very fine wires to avoid excessive heating and this current may be optimized to suit a particular type of wire. The temperature changes involved will give rise to noticeable length changes in the wire used and more sophisticated holders with tensioning devices may be devised to allow for this.

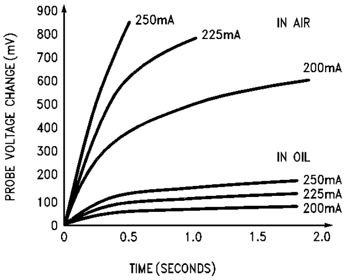

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FIGURE 3

Probes need not be limited to resistance wire types as any device with a positive temperature coefficient and sufficiently low thermal resistance to the encapsulation so as not to mask the change due to the different surrounding mediums, could be used. Positive temperature coefficient thermistors are a possibility and while their thermal time constant is likely to be longer than wire the measurement time may be increased by changing C_T to suit.

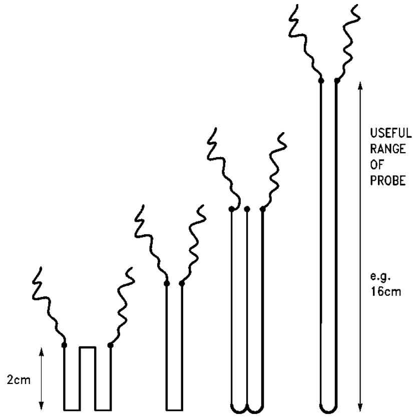

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FIGURE 4

Application Notes (Continued)

CIRCUIT OPERATION

1) Thermo-Resistive Probes

These probes require measurements to be made of their resistance before and after power has been dissipated in them. With a probe connected as probe 1 in the connection diagram the LM1042 will start a measurement when pin 8 is taken to a logic low level ($V_8 < 0.5V$) and the internal time-base ramp generator will start to generate the waveform shown in *Figure 5.* At 0.7V, T_1, the probe current drive is switched on supplying a constant 200 mA via the external PNP transistor and the probe failure circuit is enabled. At 1V pin 1 is unclamped and C_1 stores the probe voltage corresponding to this time, T_2. The ramp charge rate is now reduced as C_T charges toward 4V. As the 4.1V threshold is passed a current sink is enabled and C_T now discharges. Between 1.3V and 1.0V, T_3 and T_4, the amplified pin 1 voltage, representing the change in probe voltage since T_2 (and as the current is constant this is proportional to the resistance change) is gated onto the memory capacitor at pin 14. At 0.7V, T_5, the probe current is switched off and the measurement cycle is complete. In the event of a faulty probe being detected the memory capacitor is connected to the regulated supply during the gate period. The device leakage at pin 14 is a maximum of 2 nA to give a long memory retention time. The voltage present on pin 14 is amplifed by 1.2 to drive pin 16 with a low impedance, ±10 mA capability, between 0.5V and 4.7V. A new measurement can only be started by taking pin 8 to a low level again or by means of the repeat oscillator.

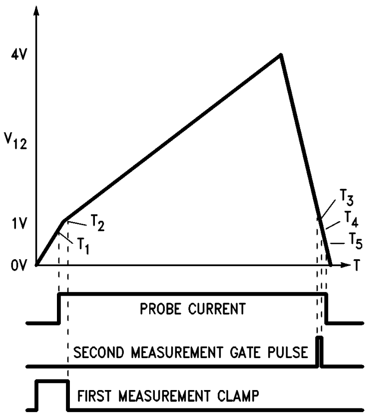

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FIGURE 5

2) Repetitive Measurement

With a capacitor connected between pin 9 and ground the repeat oscillator will run with a waveform as shown in *Figure 6* and a thermo-resistive probe measurement will be triggered each time pin 9 reaches a threshold of 4.3V, provided pin 8 is at a logic low level. The repeat oscillator runs independently of the pin 8 control logic.

As the repetition rate is increased localized heating of the probe and liquid being measured will be the main consideration in determining the minimum acceptable measurement intervals. Measurements will tend to become more dependent on the amount of fluid movement changing the rate of heat transfer away from the probe. The typical repeat time versus timing capacitor value is shown in *Figure 7.*

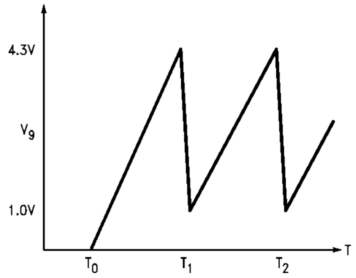

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FIGURE 6

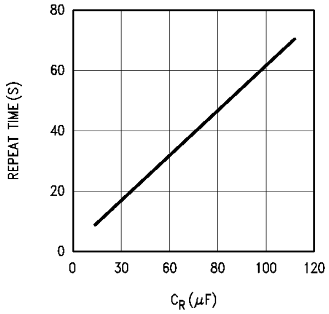

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FIGURE 7

3) Second Probe Input

A high impedance input for an alternative sensor is available at pin 7. The voltage applied to this input is amplified and output at pin 16 when the input is selected with a high level on pin 8. The gain is defined by the feedback arrangement shown in *Figure 8* with adjustment possible at pin 10. With pin 10 open the gain is set at a nominal value of 1.2, and this may be increased by connecting a resistor between pin 10 and ground up to a maximum of 3.4 with pin 10 directly grounded. A variable resistor may be used to calibrate for the variations in sensitivity of the sensor used for probe 2.

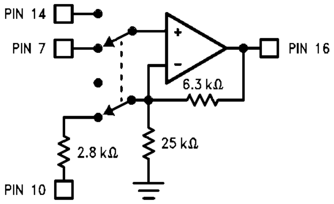

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FIGURE 8

POWER SUPPLY REGULATOR

The arrangement of the feedback for the supply regulator is shown in *Figure 9.* The circuit acts to maintain pin 15 at a constant 6V and when directly connected to pin 11 the regulated output is held at 6V. If required a resistor R may be connected between pins 15 and 11 to increase the output voltage by an amount corresponding typically to 1 mA flowing in R. In this way a variable resistor may be used to trim out the production tolerance of the regulator by adjusting for $V_{REG} \geq 6.2V$.

Application Notes (Continued)

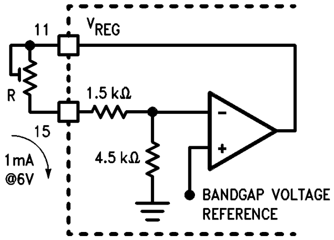

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FIGURE 9

PROBE CURRENT REFERENCE CIRCUIT

The circuit defining the probe circuit is given in *Figure 10.* A reference voltage is obtained from a bandgap regulator derived current flowing in a diode resistor chain to set up a voltage 2 volts below the supply. This is applied to an amplifier driving an external PNP transistor to maintain pin 3 at 2V below supply. The emitter resistance from pin 3 to supply defines the current which, less the base current, flows in the probe. Because of the sensitivity of the measurement to probe current evident in *Figure 3* the current should be adjusted by means of a variable resistor to the desired value. This adjustment may also be used to take out probe tolerances.

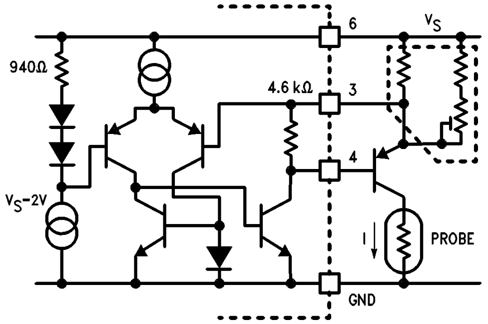

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FIGURE 10

TYPICAL APPLICATIONS CIRCUIT

A typical automotive application circuit is shown in *Figure 11* where the probe selection signal is obtained from the oil pressure switch. At power up (ignition on) the oil pressure switch is closed and pin 8 is held low by R4 causing a probe 1 (oil level) measurement to be made. Once the engine has started the oil pressure switch opens and D1 pulls pin 8 high changing over to the second auxiliary probe input. The capacitor C_5 holds pin 8 high in the event of a stalled engine so that a second probe 1 measurement can not occur in disturbed oil. Non-automotive applications may drive pin 8 directly with a logic signal.

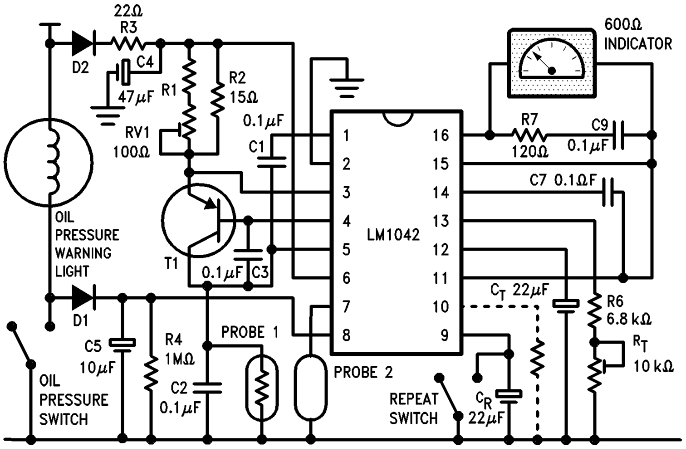

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FIGURE 11. Typical Application Circuit

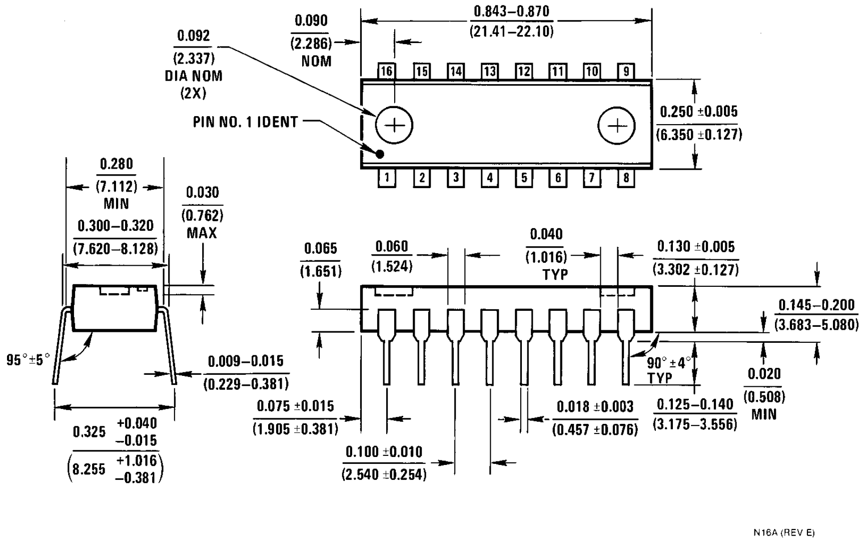
Ordering Information

Order Number LM1042N

See NS Package Number N16A

Physical Dimensions inches (millimeters)

Lit. # 107305



Order Number LM1042N
NS Package Number N16A

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