PONTIFICIA UNIVERSIDAD CATÓLICA DEL PERÚ

FACULTAD DE CIENCIAS E INGENIERÍA

IMPLEMENTACIÓN DE UN PROTOTIPO DE AGITADOR ELECTROMECÁNICO CON MOVIMIENTO ORBITAL

Tesis para optar el Título de Ingeniero Electrónico, que presenta el bachiller*:*

Anthony Anibal Lázaro Concepción

ASESORES: Willy Eduardo Carrera Soria
Sayda Estela Mujica Bueno

Lima, junio del 2015

ÍNDICE DE ANEXOS

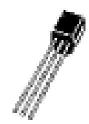
ANEXO A: HOJA DE DATOS DEL SENSOR DE TEMPERATURA LM335

SGS-THOMSON
MICROELECTRONICS

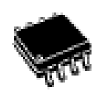
LM135
LM235-LM335,A

PRECISION TEMPERATURE SENSORS

- DIRECTLY CALIBRATED IN °K
- 1°C INITIAL ACCURACY
- OPERATES FROM 450µA TO 5mA
- LESS THAN 1Ω DYNAMIC IMPEDANCE



Z
TO92
(Plastic Package



D
SO8
(Plastic Micropackage)

DESCRIPTION

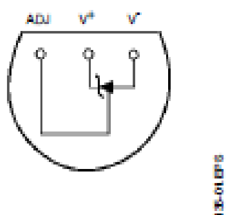
The LM135, LM235, LM335 are precision temperature sensors which can be easily calibrated. They operate as a 2-terminal Zener and the breakdown voltage is directly proportional to the absolute temperature at 10mV/°K. The circuit has a dynamic impedance of less than 1Ω and operates within a range of current from 450µA to 5mA without alteration of its characteristics. Calibrated at +25°C, the LM135, LM235, LM335 have a typical error of less than 1°C over a 100°C temperature range. Unlike other sensors, the LM135, LM235, LM335 have a linear output.

ORDER CODES

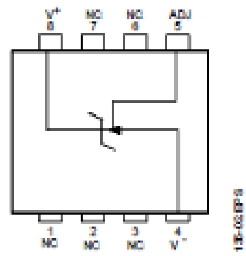
Part number	Temperature Range	Package	
		Z	D
LM135	–55°C, +150°C	•	•
LM235	–40°C, +125°C	•	•
LM335,A	–40°C, +100°C	•	•

PIN CONNECTIONS

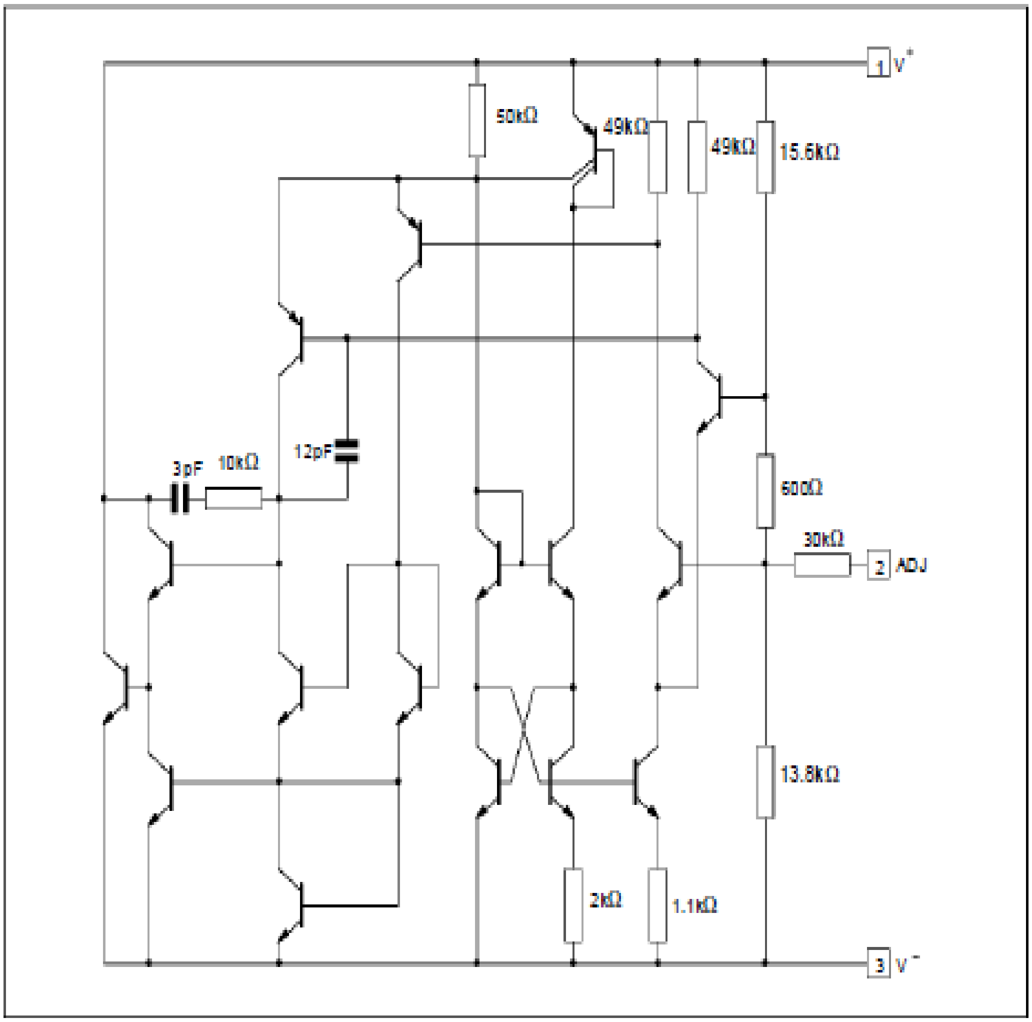
TO92
(Bottom view)



SO8
(Top view)



SCHEMATIC DIAGRAM



ABSOLUTE MAXIMUM RATINGS

Symbol	Parameter	LM135	LM235	LM335,A	Unit
 I_R I_F	Current Reverse Forward	 15 10	 15 10	 15 10	mA
T_{oper}	Operating Free-air Temperature Range - (note 1) Continuous Intermittent	 -55 to +150 +150 to +200	 -40 to +125 +125 to +150	 -40 to +100 +100 to +125	°C
T_{stg}	Storage Temperature Range	-65 to +150	-65 to +150	-65 to +150	°C

Note : 1. $T_j \leq 150°C$

TEMPERATURE ACCURACY

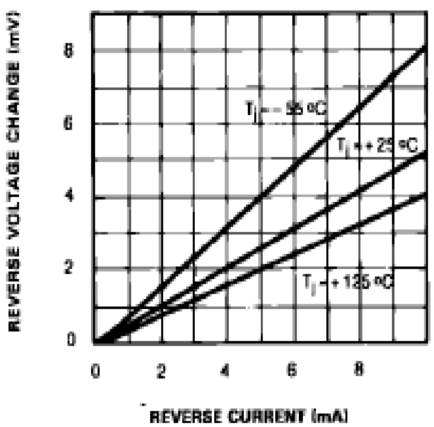
Parameter	LM135 - LM235 LM335A			LM335			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Operating Output Voltage T_{case} = +25°C, I_R = 1mA	2.95	2.98	3.01	2.92	2.98	3.04	V
Uncalibrated Temperature Error (I_R = 1mA) T_{case} = +25°C $T_{min.} \leq T_{case} \leq T_{max.}$		1 2	3 5		2 4	6 9	°C
Temperature Error with 25°C Calibration $T_{min.} \leq T_{case} \leq T_{max.}$, I_R = 1mA LM135 - LM235 LM335 LM335A		0.5 0.5	1.5 1		1	2	°C
Calibrated Error at Extended Temperature $T_{case} = T_{max.}$ (intermittent)		2			2		°C
Non-linearity (I_R = 1mA) LM135 - LM235 LM335 LM335A		0.3 0.3	1 1.5		0.3	1.5	°C

ELECTRICAL CHARACTERISTICS - (note 1)

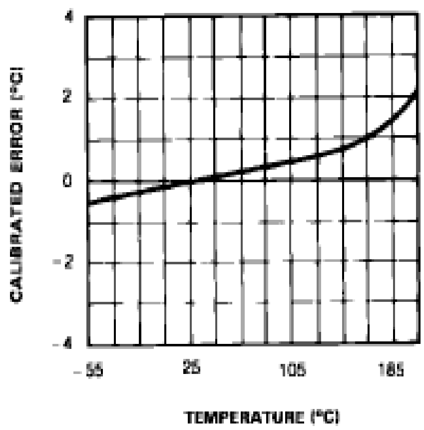
Parameter	LM135 - LM235			LM335,A			Unit
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Operating output voltage change with current 450µA ≤ I_R ≤ 5mA at constant temperature		2.5	10		3	14	mV
Dynamic Impedance (I_R = 1mA)		0.5			0.6		Ω
Output Voltage Temperature Drift		+10			+10		mV/°C
Time Constant Still Air Air 0.5m/s Stirred Oil		80 10 1			80 10 1		s
Time Stability (T_{case} = +125°C)		0.2			0.2		°C/kh

Note : 1. Accuracy measurements are made in a well-stirred oil bath. For other conditions, self heating must be considered.

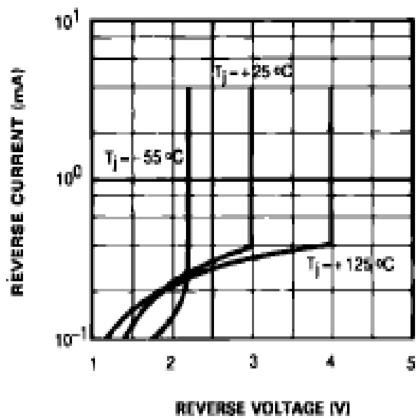
REVERSE VOLTAGE CHANGE



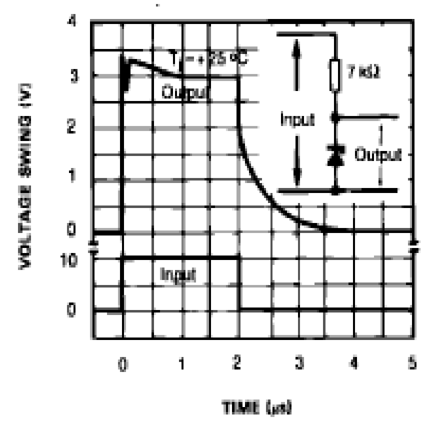
CALIBRATED ERROR



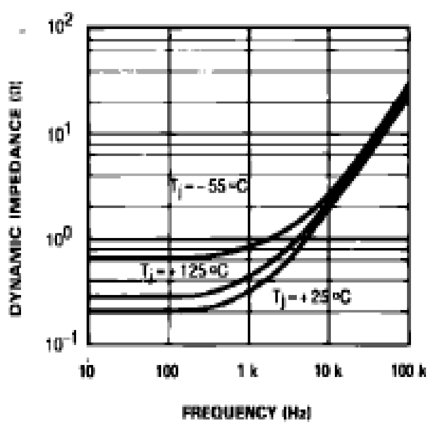
REVERSE CHARACTERISTICS



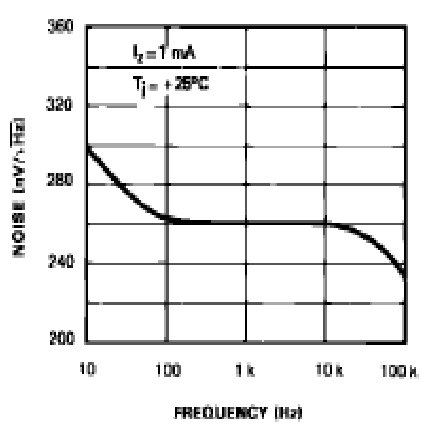
RESPONSE TIME



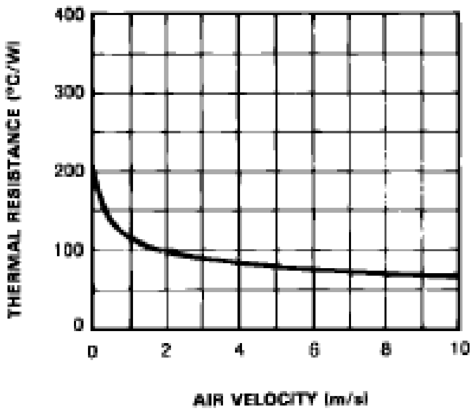
DYNAMIC IMPEDANCE



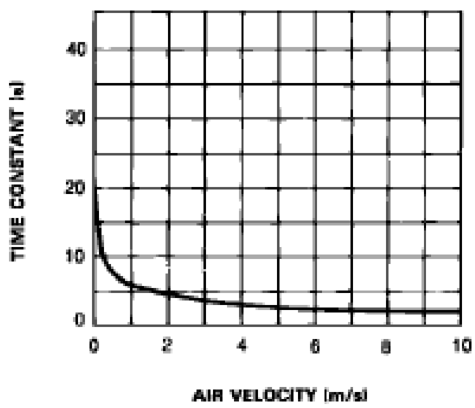
NOISE VOLTAGE



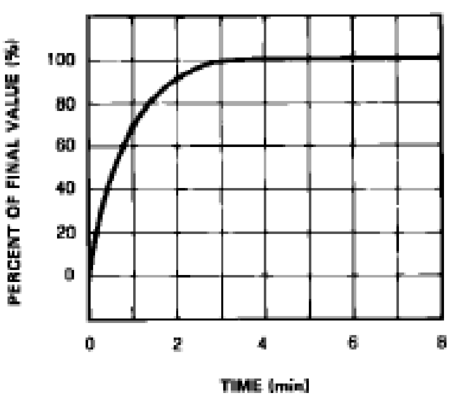
THERMAL RESISTANCE JUNCTION TO AIR



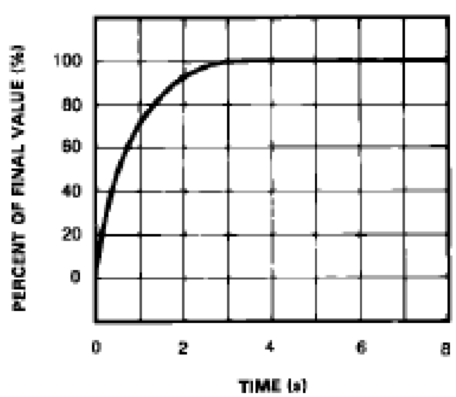
THERMAL TIME CONSTANT



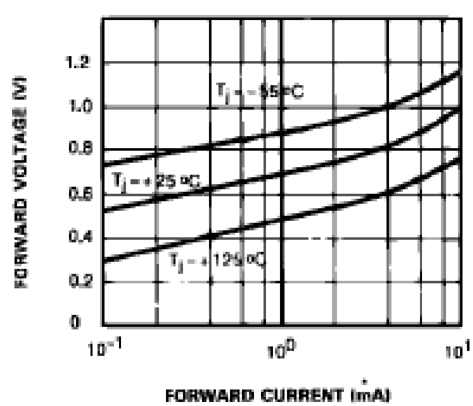
THERMAL RESPONSE IN STILL AIR



THERMAL RESPONSE IN STIRRED OIL BATH



FORWARD CHARACTERICS



APPLICATION HINTS

There is an easy method of calibrating the device for higher accuracies (see typical applications).

The single point calibration works because the output of the LM135, LM235, LM335 is proportional to the absolute temperature with the extrapolated output of sensor going to 0V at 0°K (–273.15°C). Errors in output voltage versus temperature are only slope. Thus a calibration of the slope at one temperature corrects errors at all temperatures.

The output of the circuit (calibrated or not) can be given by the equation : $V_{OT} = VO_{TO} \times \frac{T}{T_o}$

where T is the unknown temperature and T_O is the reference temperature (in °K).

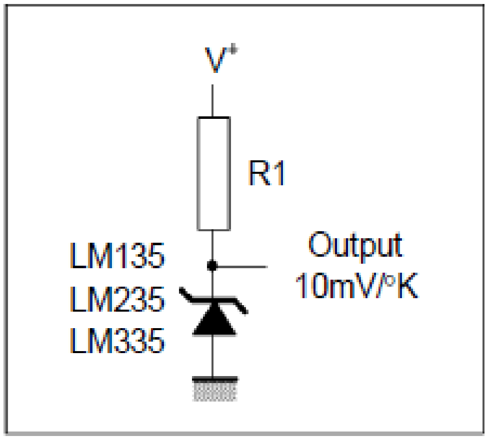
Nominally the output is calibrated at 10mV/°K.

Precautions should be taken to ensure good sensing accuracy. As in the case of all temperatures sensors, self heating can decrease accuracy. The LM135, LM235, LM335 should operate with a low current, but sufficient to drive the sensor and its calibration circuit to their maximum operating temperature.

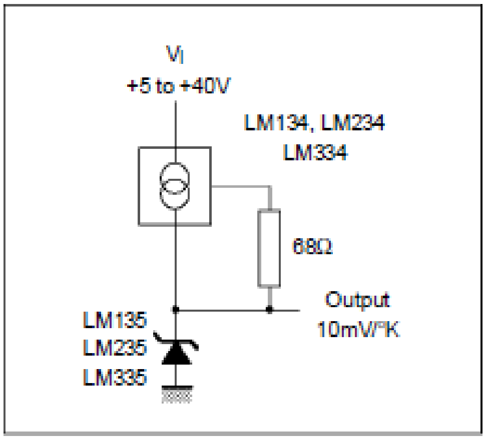
If the sensor is used in surroundings where the thermal resistane is constant, the errors due to self heating can be externally calibrated. This is possible if the circuit is biased with a temperature stable current. Heating will then be proportional to zener voltage and therefore temperature. In this way the error due to self heating is proportional to the absolute temperature as scale factor errors.

TYPICAL APPLICATIONS

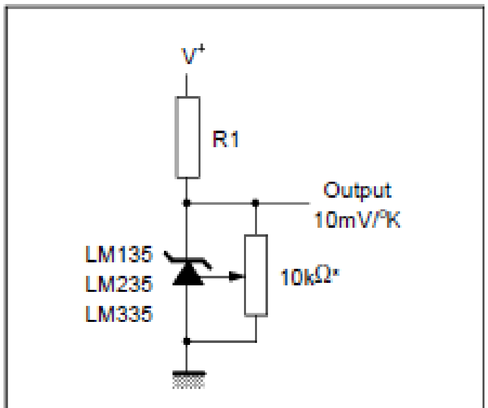
BASIC TEMPERATURE SENSOR



WIDE OPERATING SUPPLY

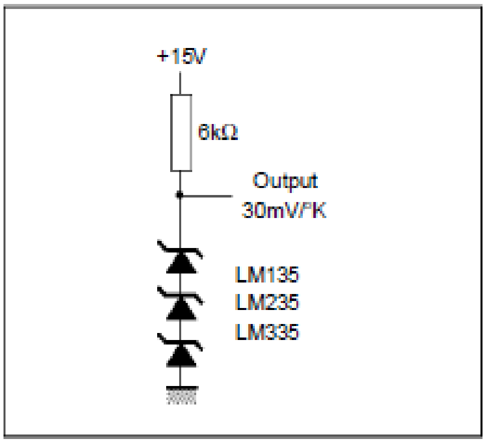


CALIBRATED SENSOR

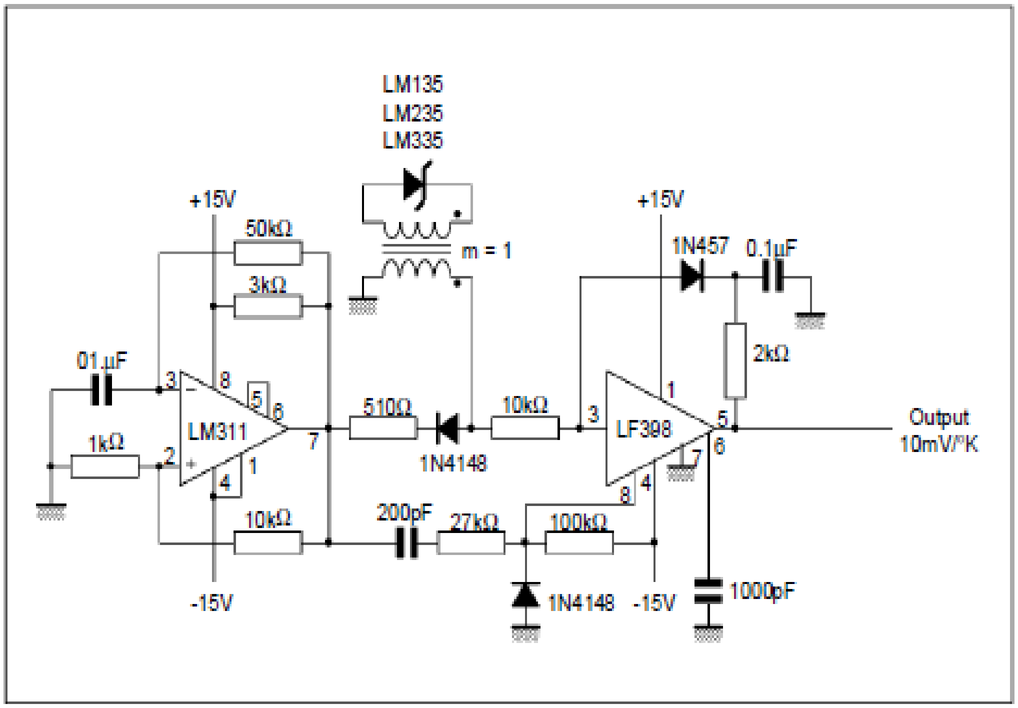


* Calibrate for 2.982V at +25°C

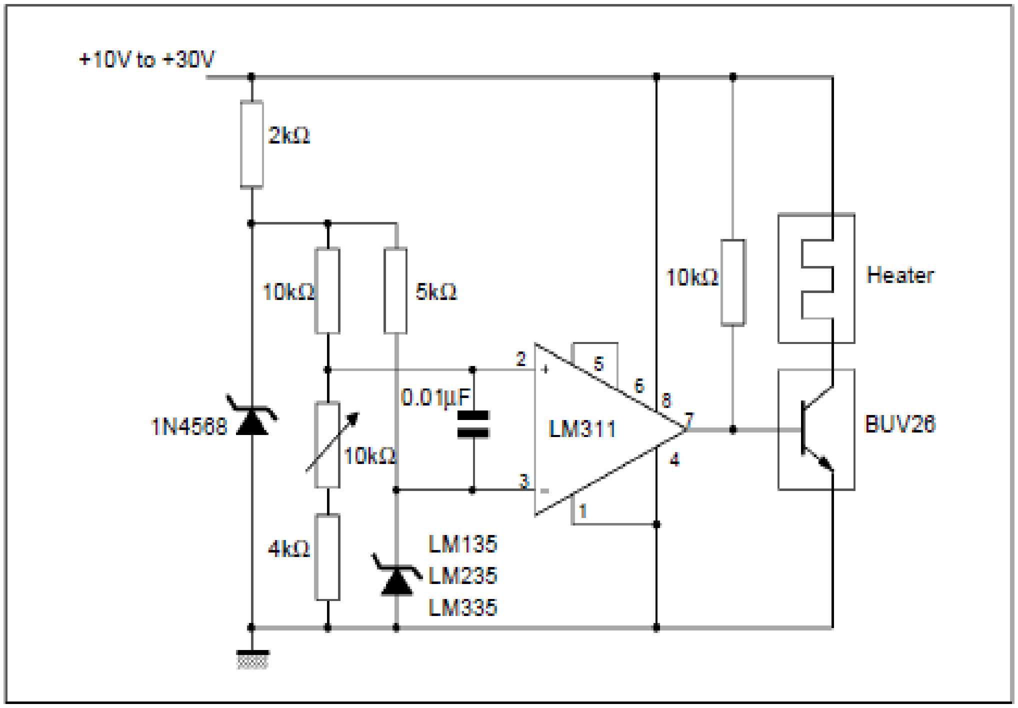
AVERAGE TEMPERATURE SENSING



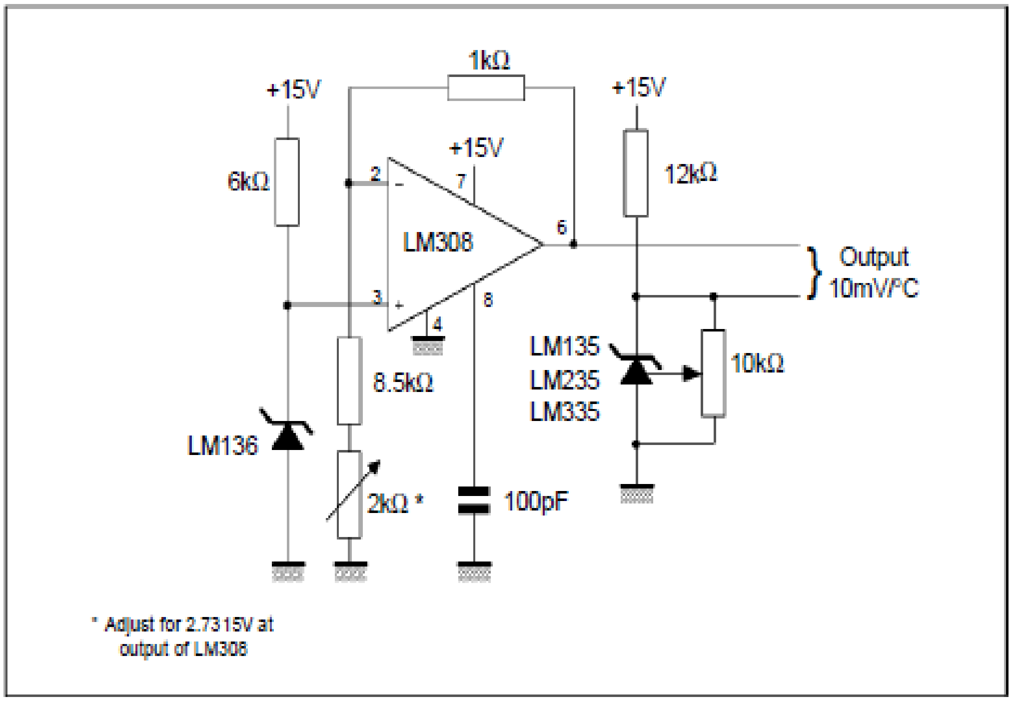
ISOLATED TEMPERATURE SENSOR



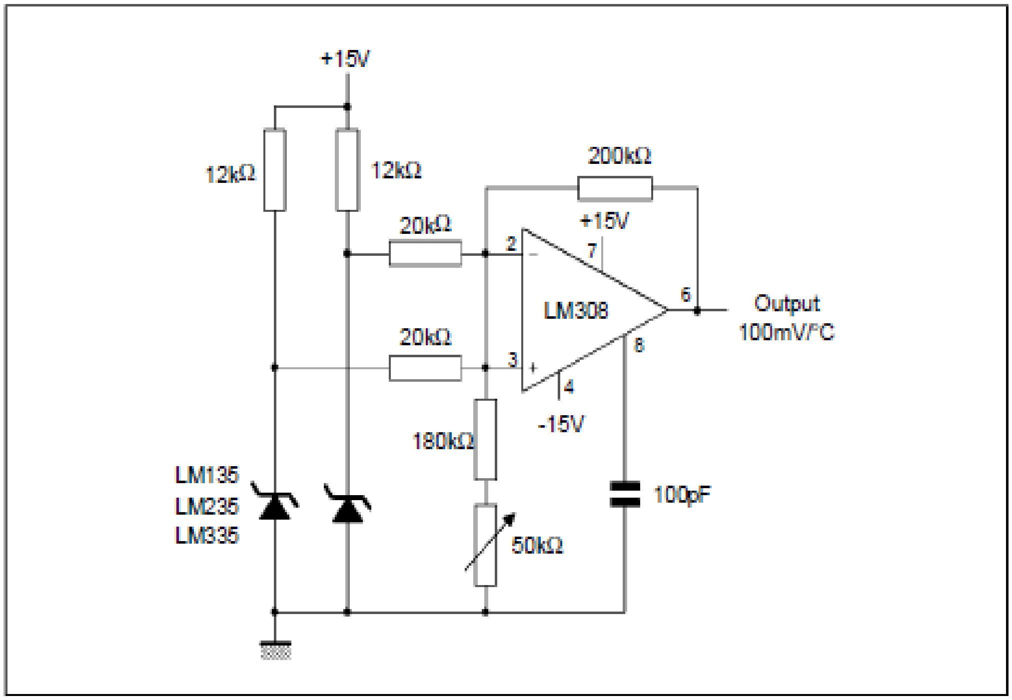
SIMPLE TEMPERATURE CONTROLLER



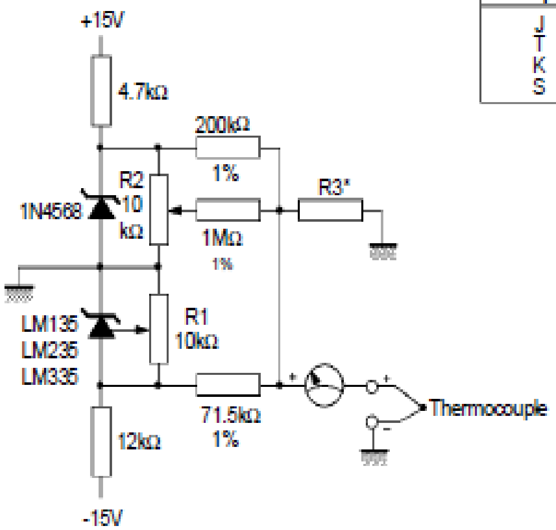
CENTIGRADE THERMOMETER



DIFFERENTIAL TEMPERATURE SENSOR



THERMOCOUPLE COLD JUNCTION COMPENSATION
(compensation for grounded thermocouple)



Thermo-couple	R3	Seebeck Coefficient
J	377Ω	52.3µV/°C
T	308Ω	42.8µV/°C
K	293Ω	40.8µV/°C
S	45.8Ω	6.4µV/°C

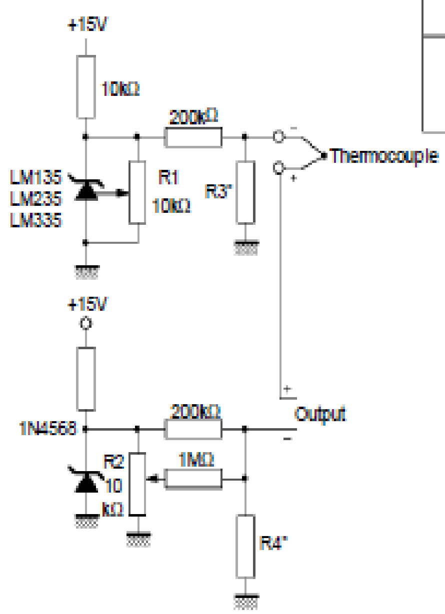
Adjustments : compensates for both sensor and resistor tolerances.

1. Short 1N4568.
2. Adjust R1 for SEEBECK coefficient times ambient temperature (in degrees K) across R3.
3. Short LM135 and adjust R2 for voltage across R3 corresponding to thermocouple type.

J	14.32mV	K	11.17mV
T	11.79mV	S	1.768mV

* Select R3 for proper thermocouple type

SINGLE POWER SUPPLY COLD JUNCTION COMPENSATION



Thermo-couple	R3	R4	Seebeck Coefficient
J	1.05kΩ	385Ω	52.3µV/°C
T	856Ω	315Ω	42.8µV/°C
K	816Ω	300Ω	40.8µV/°C
S	128Ω	46.3Ω	6.4µV/°C

Adjustments :

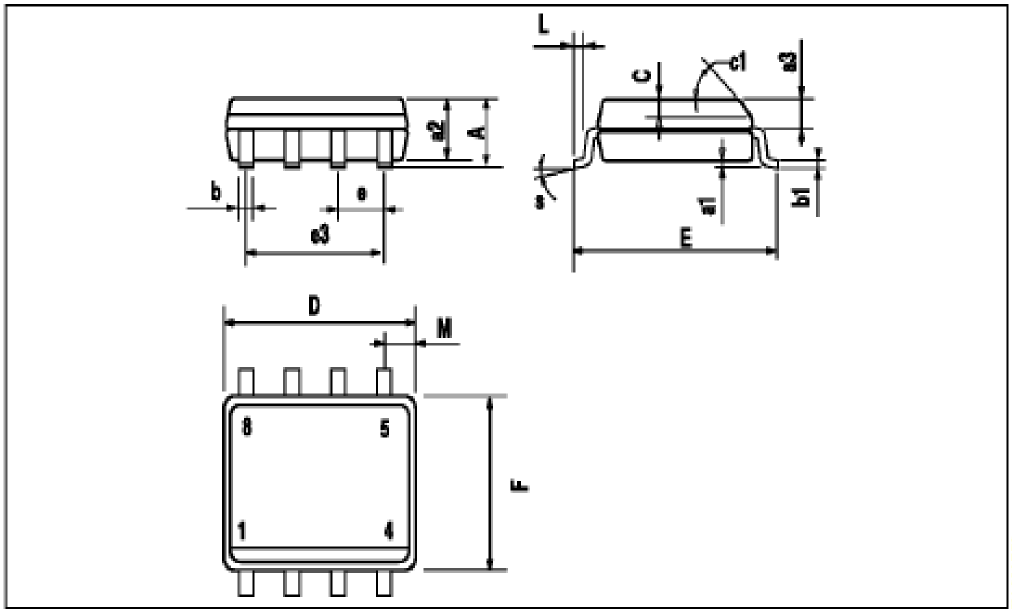
1. Adjust R1 for the voltage across R3 equal to the SEEBECK coefficient times ambient temperature in degrees Kelvin.
2. Adjust R2 for voltage across R4 corresponding to thermocouple.

J	14.32mV	K	11.17mV
T	11.79mV	S	1.768mV

* Select R3 and R4 for proper thermocouple

PACKAGE MECHANICAL DATA

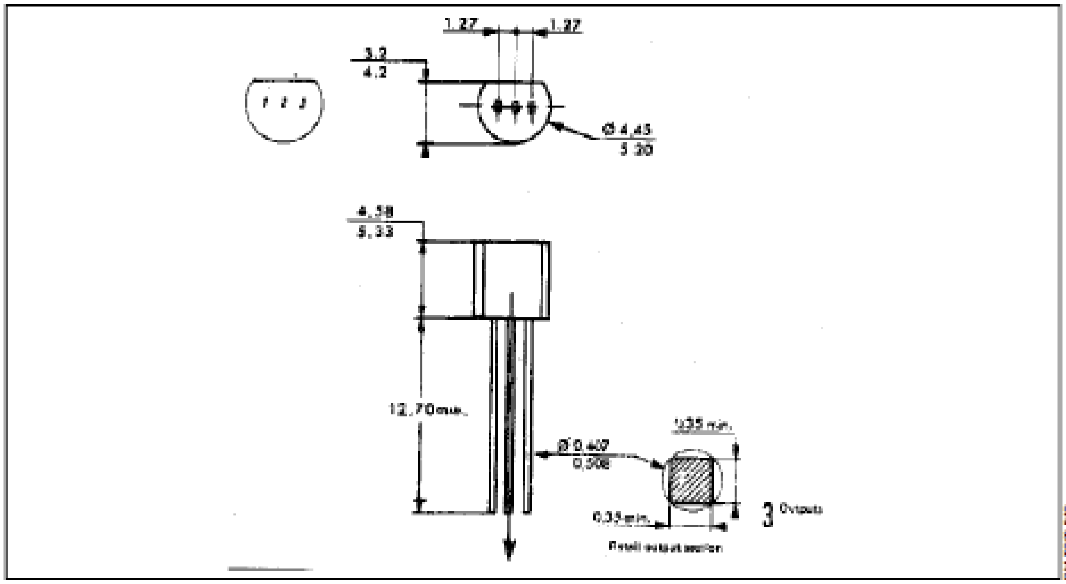
8 PINS - PLASTIC MICROPACKAGE (SO)



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
A			1.75			0.069
a1	0.1		0.25	0.004		0.010
a2			1.65			0.065
a3	0.65		0.85	0.026		0.033
b	0.35		0.48	0.014		0.019
b1	0.19		0.25	0.007		0.010
C	0.25		0.5	0.010		0.020
c1	45° (typ.)					
D	4.8		5.0	0.189		0.197
E	5.8		6.2	0.228		0.244
e		1.27			0.050	
e3		3.81			0.150	
F	3.8		4.0	0.150		0.157
L	0.4		1.27	0.016		0.050
M			0.6			0.024
S	8° (max.)					

PACKAGE MECHANICAL DATA

3 PINS - PLASTIC PACKAGE TO92



Dimensions	Millimeters			Inches		
	Min.	Typ.	Max.	Min.	Typ.	Max.
L		1.27			0.05	
B	3.2	3.7	4.2	0.126	0.1457	0.1654
O1	4.45	5.00	5.2	0.1752	0.1969	0.2047
C	4.58	5.03	5.33	0.1803	0.198	0.2098
K	12.7			0.5		
O2	0.407	0.5	0.508	0.016	0.0197	0.02
a	0.35			0.0138		

ANEXO B: HOJA DE DATOS DEL SENSOR DE TEMPERATURA LM35

National Semiconductor

December 1994

LM35/LM35A/LM35C/LM35CA/LM35D Precision Centigrade Temperature Sensors

General Description

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in ° Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient Centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±¼°C at room temperature and ±¾°C over a full −55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 μA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a −55° to +150°C temperature range, while the LM35C is rated for a −40° to +110°C range (−10° with improved accuracy). The LM35 series is available packaged in hermetic TO-46 transistor packages, while the LM35C, LM35CA, and LM35D are also available in the plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-202 package.

Features

- Calibrated directly in ° Celsius (Centigrade)
- Linear + 10.0 mV/°C scale factor
- 0.5°C accuracy guaranteeable (at +25°C)
- Rated for full −55° to +150°C range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than 60 μA current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only ±¼°C typical
- Low impedance output, 0.1 Ω for 1 mA load

Connection Diagrams

TO-46
Metal Can Package*

TL/H/5516–1

*Case is connected to negative pin (GND)

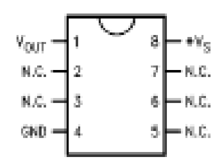
Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

TO-92
Plastic Package

TL/H/5516–2

Order Number LM35CZ, LM35CAZ or LM35DZ
See NS Package Number Z03A

SO-8
Small Outline Molded Package



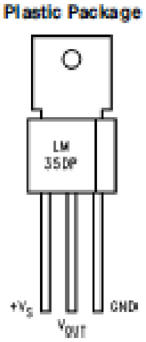
TL/H/5516–21

Top View

N.C. = No Connection

Order Number LM35DM
See NS Package Number M08A

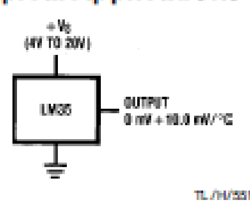
TO-202
Plastic Package



TL/H/5516–24

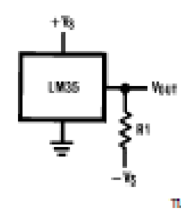
Order Number LM35DP
See NS Package Number P03A

Typical Applications



TL/H/5516–3

FIGURE 1. Basic Centigrade Temperature Sensor (+2°C to +150°C)



TL/H/5516–4

Choose $R_1 = -V_S/50\ \mu A$

$V_{OUT} = +1{,}500$ mV at +150°C
= +250 mV at +25°C
= −550 mV at −55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

Absolute Maximum Ratings (Note 10)

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

Supply Voltage	+35V to −0.2V
Output Voltage	+6V to −1.0V
Output Current	10 mA
Storage Temp., TO-46 Package,	−60°C to +180°C
TO-92 Package,	−60°C to +150°C
SO-8 Package,	−65°C to +150°C
TO-202 Package,	−65°C to +150°C
Lead Temp.:	
TO-46 Package, (Soldering, 10 seconds)	300°C
TO-92 Package, (Soldering, 10 seconds)	260°C
TO-202 Package, (Soldering, 10 seconds)	+230°C
SO Package (Note 12):	
Vapor Phase (60 seconds)	215°C
Infrared (15 seconds)	220°C
ESD Susceptibility (Note 11)	2500V

Specified Operating Temperature Range: T_{MIN} to T_{MAX} (Note 2)

LM35, LM35A	−55°C to +150°C
LM35C, LM35CA	−40°C to +110°C
LM35D	0°C to +100°C

Electrical Characteristics (Note 1) (Note 6)

Parameter	Conditions	LM35A			LM35CA			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy (Note 7)	$T_A = +25°C$	±0.2	±0.5		±0.2	±0.5		°C
	$T_A = -10°C$	±0.3			±0.3		±1.0	°C
	$T_A = T_{MAX}$	±0.4	±1.0		±0.4	±1.0		°C
	$T_A = T_{MIN}$	±0.4	±1.0		±0.4		±1.5	°C
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	**±0.18**		**±0.35**	**±0.15**		**±0.3**	°C
Sensor Gain (Average Slope)	$T_{MIN} \leq T_A \leq T_{MAX}$	**+10.0**	**+9.9, +10.1**		**+10.0**		**+9.9, +10.1**	mV/°C
Load Regulation (Note 3) $0 \leq I_L \leq 1$ mA	$T_A = +25°C$	±0.4	±1.0		±0.4	±1.0		mV/mA
	$T_{MIN} \leq T_A \leq T_{MAX}$	**±0.5**		**±3.0**	**±0.5**		**±3.0**	mV/mA
Line Regulation (Note 3)	$T_A = +25°C$	±0.01	±0.05		±0.01	±0.05		mV/V
	$4V \leq V_S \leq 30V$	**±0.02**		**±0.1**	**±0.02**		**±0.1**	mV/V
Quiescent Current (Note 9)	$V_S = +5V$, +25°C	56	67		56	67		μA
	$V_S = +5V$	**105**		**131**	**91**		**114**	μA
	$V_S = +30V$, +25°C	56.2	68		56.2	68		μA
	$V_S = +30V$	**105.5**		**133**	**91.5**		**116**	μA
Change of Quiescent Current (Note 3)	$4V \leq V_S \leq 30V$, +25°C	0.2	1.0		0.2	1.0		μA
	$4V \leq V_S \leq 30V$	**0.5**		**2.0**	**0.5**		**2.0**	μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.5**	**+0.39**		**+0.5**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, $I_L = 0$	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J = T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Note 1: Unless otherwise noted, these specifications apply: $-55°C \leq T_J \leq +150°C$ for the LM35 and LM35A; $-40° \leq T_J \leq +110°C$ for the LM35C and LM35CA; and $0° \leq T_J \leq +100°C$ for the LM35D. $V_S = +5Vdc$ and $I_{LOAD} = 50$ μA, in the circuit of *Figure 2*. These specifications also apply from +2°C to T_{MAX} in the circuit of *Figure 1*. Specifications in **boldface** apply over the full rated temperature range.

Note 2: Thermal resistance of the TO-46 package is 400°C/W, junction to ambient, and 24°C/W junction to case. Thermal resistance of the TO-92 package is 180°C/W junction to ambient. Thermal resistance of the small outline molded package is 220°C/W junction to ambient. Thermal resistance of the TO-202 package is 85°C/W junction to ambient. For additional thermal resistance information see table in the Applications section.

Electrical Characteristics (Note 1) **(Note 6)** (Continued)

Parameter	Conditions	LM35			LM35C, LM35D			Units (Max.)
		Typical	Tested Limit (Note 4)	Design Limit (Note 5)	Typical	Tested Limit (Note 4)	Design Limit (Note 5)	
Accuracy, LM35, LM35C (Note 7)	$T_A=+25°C$ $T_A=-10°C$ $T_A=T_{MAX}$ $T_A=T_{MIN}$	±0.4 ±0.5 ±0.8 ±0.8	±1.0 ±1.5 	 ±1.5	±0.4 ±0.5 ±0.8 ±0.8	±1.0	 ±1.5 ±1.5 ±2.0	°C °C °C °C
Accuracy, LM35D (Note 7)	$T_A=+25°C$ $T_A=T_{MAX}$ $T_A=T_{MIN}$				±0.6 ±0.9 ±0.9	±1.5	 ±2.0 ±2.0	°C °C °C
Nonlinearity (Note 8)	$T_{MIN}\le T_A\le T_{MAX}$	**±0.3**		**±0.5**	**±0.2**		**±0.5**	°C
Sensor Gain (Average Slope)	$T_{MIN}\le T_A\le T_{MAX}$	**+10.0**	**+9.8, +10.2**		**+10.0**		**+9.8, +10.2**	mV/°C
Load Regulation (Note 3) $0\le I_L\le 1$ mA	$T_A=+25°C$ $T_{MIN}\le T_A\le T_{MAX}$	±0.4 **±0.5**	±2.0	 **±5.0**	±0.4 **±0.5**	±2.0	 **±5.0**	mV/mA mV/mA
Line Regulation (Note 3)	$T_A=+25°C$ $4V\le V_S\le 30V$	±0.01 **±0.02**	±0.1	 **±0.2**	±0.01 **±0.02**	±0.1	 **±0.2**	mV/V mV/V
Quiescent Current (Note 9)	$V_S=+5V$, +25°C $V_S=+5V$ $V_S=+30V$, +25°C $V_S=+30V$	56 **105** 56.2 **105.5**	80 82 	 **158** **161**	56 **91** 56.2 **91.5**	80 82 	 **138** **141**	μA μA μA μA
Change of Quiescent Current (Note 3)	$4V\le V_S\le 30V$, +25°C $4V\le V_S\le 30V$	0.2 **0.5**	2.0	 **3.0**	0.2 **0.5**	2.0	 **3.0**	μA μA
Temperature Coefficient of Quiescent Current		**+0.39**		**+0.7**	**+0.39**		**+0.7**	μA/°C
Minimum Temperature for Rated Accuracy	In circuit of *Figure 1*, $I_L=0$	+1.5		+2.0	+1.5		+2.0	°C
Long Term Stability	$T_J=T_{MAX}$, for 1000 hours	±0.08			±0.08			°C

Note 3: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the internal dissipation by the thermal resistance.

Note 4: Tested Limits are guaranteed and 100% tested in production.

Note 5: Design Limits are guaranteed (but not 100% production tested) over the indicated temperature and supply voltage ranges. These limits are not used to calculate outgoing quality levels.

Note 6: Specifications in **boldface** apply over the full rated temperature range.

Note 7: Accuracy is defined as the error between the output voltage and 10mv/°C times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in °C).

Note 8: Nonlinearity is defined as the deviation of the output-voltage-versus-temperature curve from the best-fit straight line, over the device's rated temperature range.

Note 9: Quiescent current is defined in the circuit of *Figure 1*.

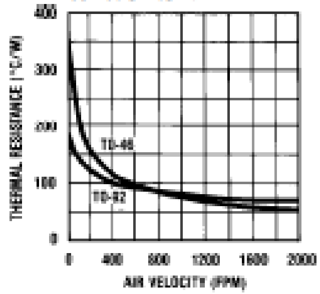
Note 10: Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. DC and AC electrical specifications do not apply when operating the device beyond its rated operating conditions. See Note 1.

Note 11: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

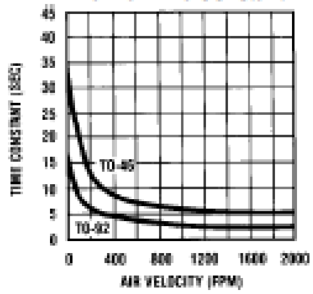
Note 12: See AN-450 "Surface Mounting Methods and Their Effect on Product Reliability" or the section titled "Surface Mount" found in a current National Semiconductor Linear Data Book for other methods of soldering surface mount devices.

Typical Performance Characteristics

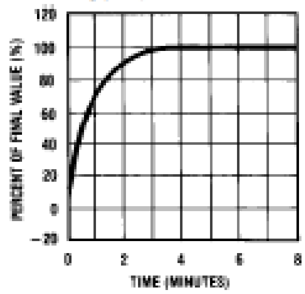
Thermal Resistance Junction to Air



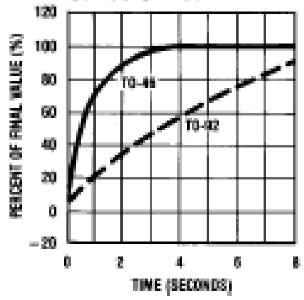
Thermal Time Constant



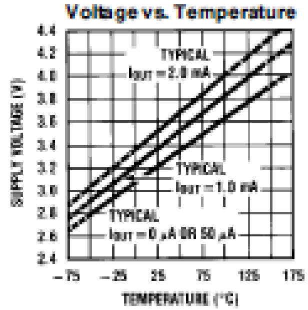
Thermal Response in Still Air



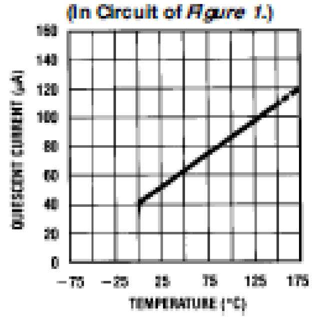
Thermal Response in Stirred Oil Bath



Minimum Supply Voltage vs. Temperature

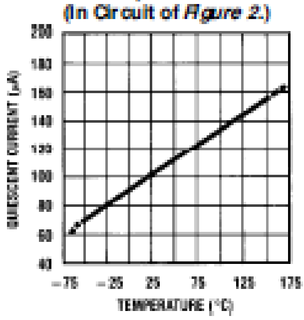


Quiescent Current vs. Temperature (In Circuit of *Figure 1.*)

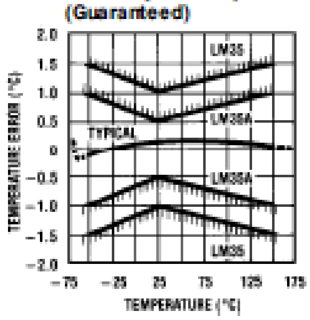


TL/H/5516–17

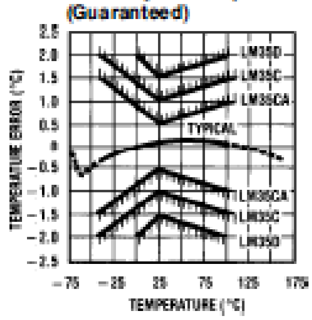
Quiescent Current vs. Temperature (In Circuit of *Figure 2.*)



Accuracy vs. Temperature (Guaranteed)

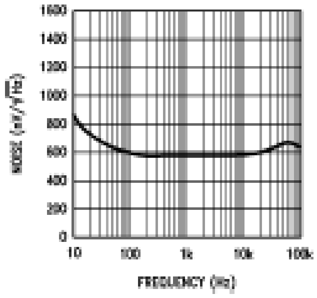


Accuracy vs. Temperature (Guaranteed)

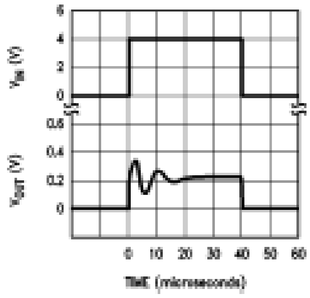


TL/H/5516–18

Noise Voltage



Start-Up Response



TL/H/5516–22

Applications

The LM35 can be applied easily in the same way as other integrated-circuit temperature sensors. It can be glued or cemented to a surface and its temperature will be within about 0.01°C of the surface temperature.

This presumes that the ambient air temperature is almost the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. This is expecially true for the TO-92 plastic package, where the copper leads are the principal thermal path to carry heat into the device, so its temperature might be closer to the air temperature than to the surface temperature.

To minimize this problem, be sure that the wiring to the LM35, as it leaves the device, is held at the same temperature as the surface of interest. The easiest way to do this is to cover up these wires with a bead of epoxy which will insure that the leads and wires are all at the same temperature as the surface, and that the LM35 die's temperature will not be affected by the air temperature.

The TO-46 metal package can also be soldered to a metal surface or pipe without damage. Of course, in that case the V− terminal of the circuit will be grounded to that metal. Alternatively, the LM35 can be mounted inside a sealed-end metal tube, and can then be dipped into a bath or screwed into a threaded hole in a tank. As with any IC, the LM35 and accompanying wiring and circuits must be kept insulated and dry, to avoid leakage and corrosion. This is especially true if the circuit may operate at cold temperatures where condensation can occur. Printed-circuit coatings and varnishes such as Humiseal and epoxy paints or dips are often used to insure that moisture cannot corrode the LM35 or its connections.

These devices are sometimes soldered to a small light-weight heat fin, to decrease the thermal time constant and speed up the response in slowly-moving air. On the other hand, a small thermal mass may be added to the sensor, to give the steadiest reading despite small deviations in the air temperature.

Temperature Rise of LM35 Due To Self-heating (Thermal Resistance)

	TO-46, no heat sink	TO-46, small heat fin*	TO-92, no heat sink	TO-92, small heat fin**	SO-8 no heat sink	SO-8 small heat fin**	TO-202 no heat sink	TO-202*** small heat fin
Still air	400°C/W	100°C/W	180°C/W	140°C/W	220°C/W	110°C/W	85°C/W	60°C/W
Moving air	100°C/W	40°C/W	90°C/W	70°C/W	105°C/W	90°C/W	25°C/W	40°C/W
Still oil	100°C/W	40°C/W	90°C/W	70°C/W				
Stirred oil	50°C/W	30°C/W	45°C/W	40°C/W				
(Clamped to metal, Infinite heat sink)	(24°C/W)				(55°C/W)		(23°C/W)	

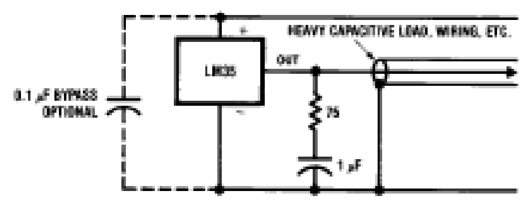
* Wakefield type 201, or 1" disc of 0.020" sheet brass, soldered to case, or similar.

** TO-92 and SO-8 packages glued and leads soldered to 1" square of 1/16" printed circuit board with 2 oz. foil or similar.

Typical Applications (Continued)

TL/H/5516–19

FIGURE 3. LM35 with Decoupling from Capacitive Load



TL/H/5516–20

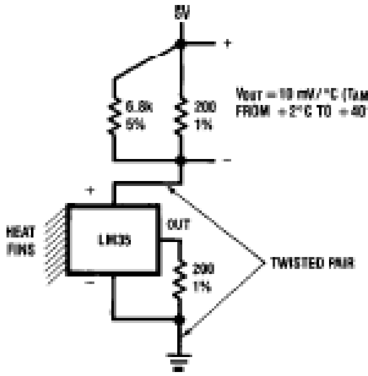
FIGURE 4. LM35 with R-C Damper

CAPACITIVE LOADS

Like most micropower circuits, the LM35 has a limited ability to drive heavy capacitive loads. The LM35 by itself is able to drive 50 pf without special precautions. If heavier loads are anticipated, it is easy to isolate or decouple the load with a resistor; see *Figure 3*. Or you can improve the tolerance of capacitance with a series R-C damper from output to ground; see *Figure 4*.

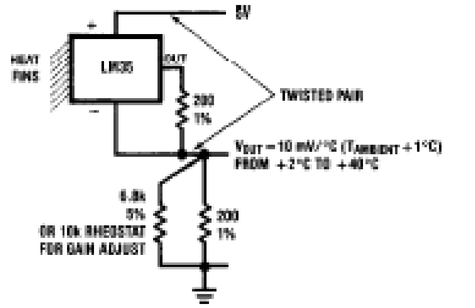
When the LM35 is applied with a 200Ω load resistor as shown in *Figure 5, 6, or 8*, it is relatively immune to wiring capacitance because the capacitance forms a bypass from ground to input, not on the output. However, as with any linear circuit connected to wires in a hostile environment, its performance can be affected adversely by intense electromagnetic sources such as relays, radio transmitters, motors with arcing brushes, SCR transients, etc, as its wiring can act as a receiving antenna and its internal junctions can act as rectifiers. For best results in such cases, a bypass capacitor from V_{IN} to ground and a series R-C damper such as 75Ω in series with 0.2 or 1 μF from output to ground are often useful. These are shown in *Figures 13, 14,* and *16.*

Typical Applications (Continued)



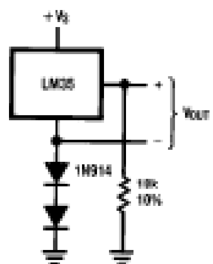
TL/H/5516-5

FIGURE 5. Two-Wire Remote Temperature Sensor (Grounded Sensor)



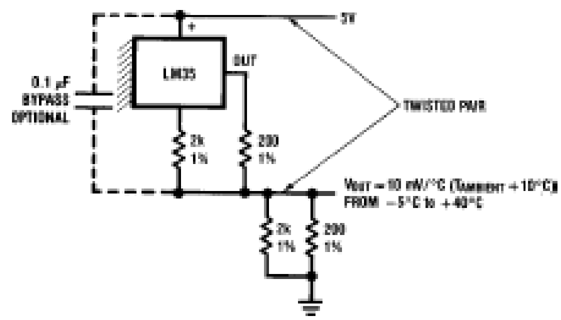
TL/H/5516-6

FIGURE 6. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



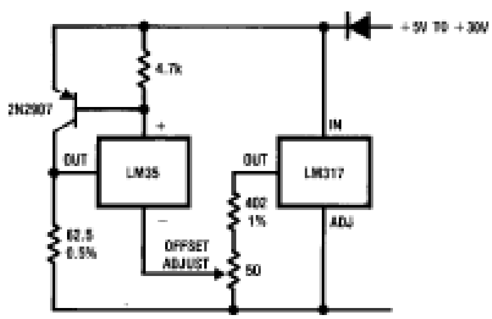
TL/H/5516-7

FIGURE 7. Temperature Sensor, Single Supply, −55° to +150°C



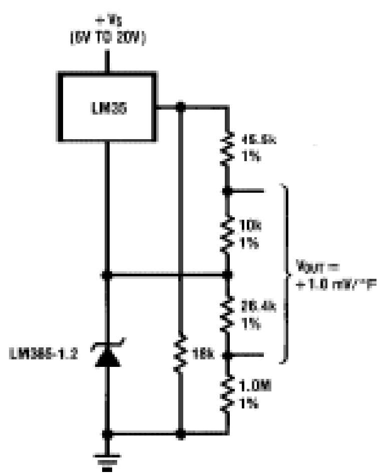
TL/H/5516-8

FIGURE 8. Two-Wire Remote Temperature Sensor (Output Referred to Ground)



TL/H/5516-9

FIGURE 9. 4-To-20 mA Current Source (0°C to + 100°C)



TL/H/5516-10

FIGURE 10. Fahrenheit Thermometer

Typical Applications (Continued)

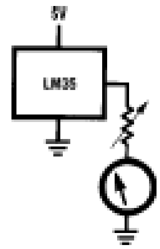


FIGURE 11. Centigrade Thermometer (Analog Meter)

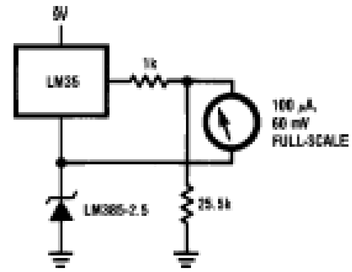


FIGURE 12. Expanded Scale Thermometer (50° to 80° Fahrenheit, for Example Shown)

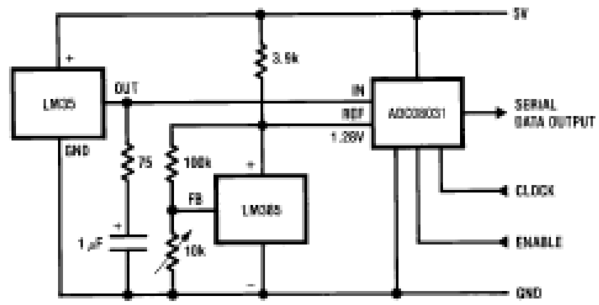


FIGURE 13. Temperature To Digital Converter (Serial Output) (+128°C Full Scale)

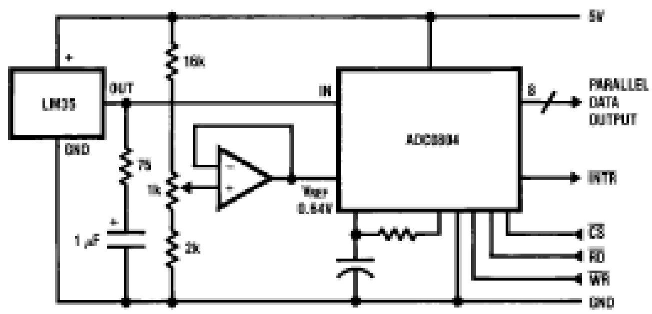
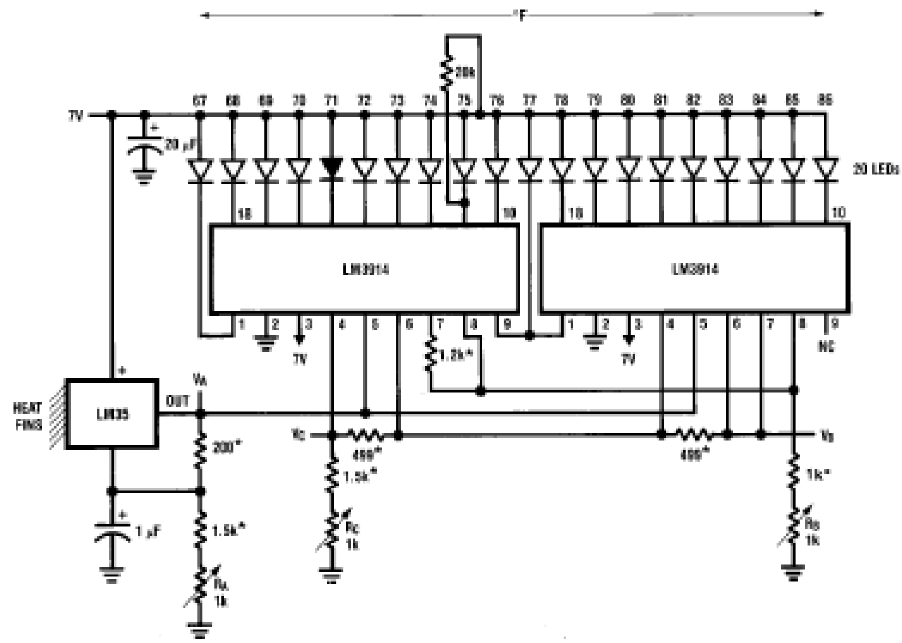


FIGURE 14. Temperature To Digital Converter (Parallel TRI-STATE® Outputs for Standard Data Bus to μP Interface) (128°C Full Scale)

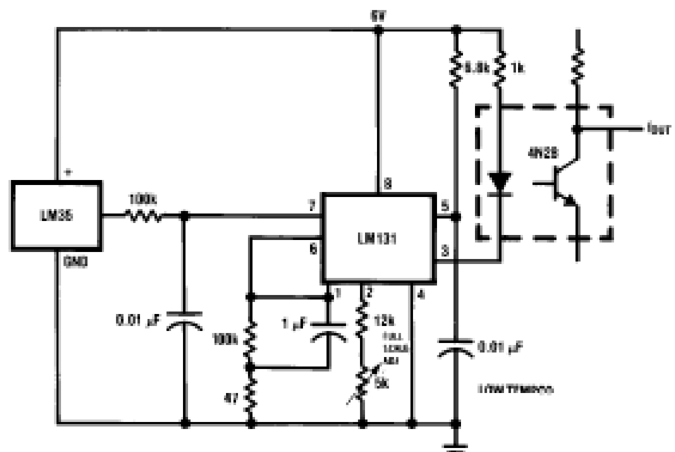
Typical Applications (Continued)



TL/H/5516–16

* = 1% or 2% film resistor
-Trim R_B for $V_B = 3.075V$
-Trim R_C for $V_C = 1.955V$
-Trim R_A for $V_A = 0.075V + 100mV/°C \times T_{ambient}$
-Example, $V_A = 2.275V$ at 22°C

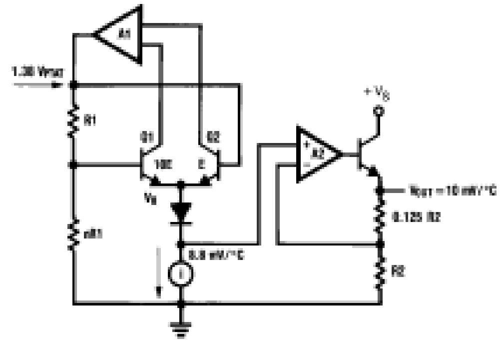
FIGURE 15. Bar-Graph Temperature Display (Dot Mode)



TL/H/5516–15

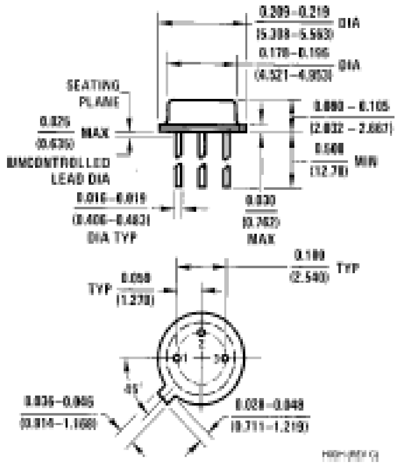
FIGURE 16. LM35 With Voltage-To-Frequency Converter And Isolated Output (2°C to + 150°C; 20 Hz to 1500 Hz)

Block Diagram

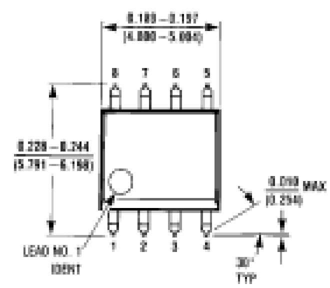


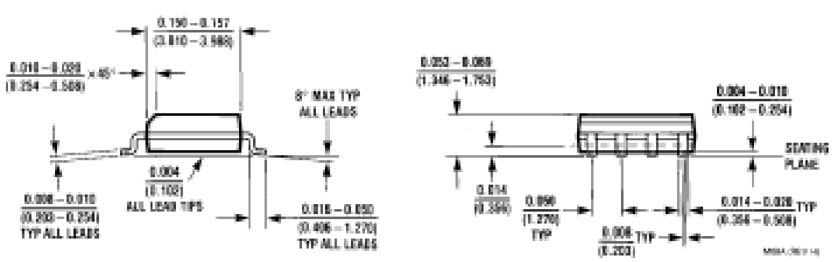
TL/H/5516–20

Physical Dimensions inches (millimeters)



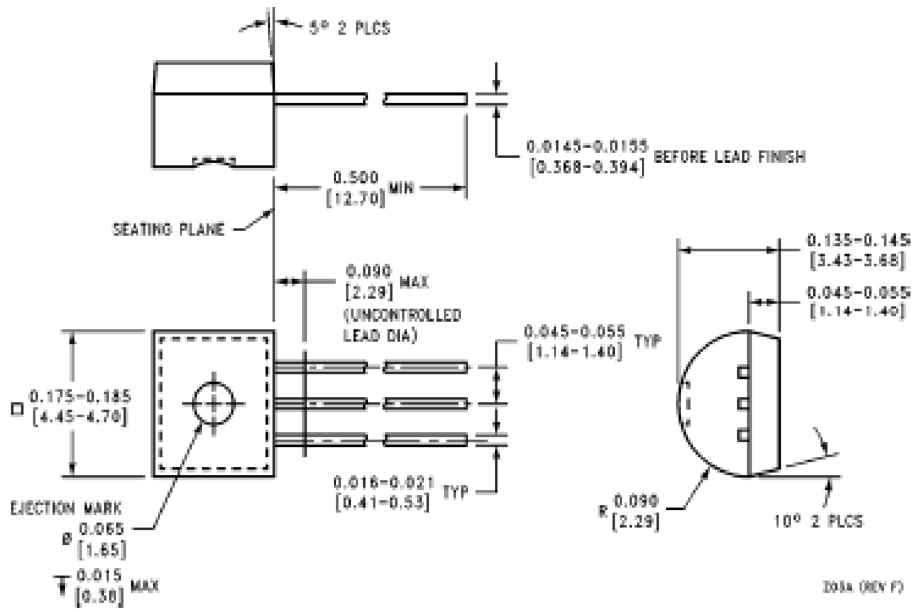
TO-46 Metal Can Package (H)
Order Number LM35H, LM35AH, LM35CH, LM35CAH, or LM35DH
NS Package Number H03H





SO-8 Molded Small Outline Package (M)
Order Number LM35DM
NS Package Number M08A

Physical Dimensions inches (millimeters) (Continued)



TO-92 Plastic Package (Z)
Order Number LM35CZ, LM35CAZ or LM35DZ
NS Package Number Z03A

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 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
2900 Semiconductor Drive
P.O. Box 58090
Santa Clara, CA 95052-8090
Tel: 1(800) 272-9959
TWX: (910) 339-9240

National Semiconductor GmbH
Livry-Gargan-Str. 10
D-82256 Fürstenfeldbruck
Germany
Tel: (81-41) 35-0
Telex: 527649
Fax: (81-41) 35-1

National Semiconductor Japan Ltd.
Sumitomo Chemical Engineering Center
Bldg. 7F
1-7-1, Nakase, Mihama-Ku
Chiba-City,
Ciba Prefecture 261
Tel: (043) 299-2300
Fax: (043) 299-2500

National Semiconductor Hong Kong Ltd.
13th Floor, Straight Block,
Ocean Centre, 5 Canton Rd.
Tsimshatsui, Kowloon
Hong Kong
Tel: (852) 2737-1600
Fax: (852) 2736-9960

National Semiconductores Do Brazil Ltda.
Rue Deputado Lacorda Franco 120-3A
Sao Paulo-SP
Brazil 05418-000
Tel: (55-11) 212-5066
Telex: 391-1131931 NSBR BR
Fax: (55-11) 212-1181

National Semiconductor (Australia) Pty, Ltd.
Building 16
Business Park Drive
Monash Business Park
Nottinghill, Melbourne
Victoria 3168 Australia
Tel: (3) 558-9999
Fax: (3) 558-9998

ANEXO C: HOJA DE DATOS DEL SENSOR DE TEMPERATURA MCP9701

MICROCHIP

MCP9700/9700A MCP9701/9701A

Low-Power Linear Active Thermistor™ ICs

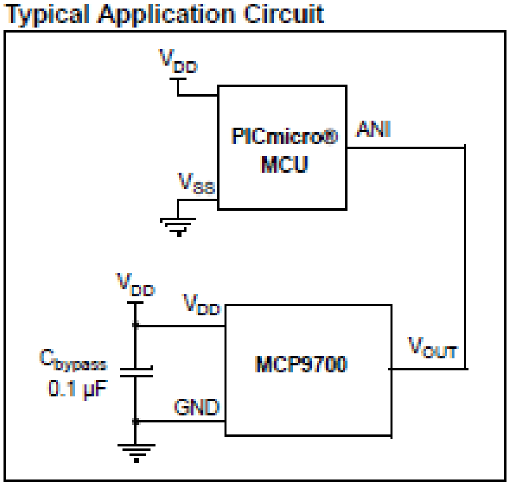
Features

- Tiny Analog Temperature Sensor
- Available Packages: SC-70-5, TO-92-3
- Wide Temperature Measurement Range:
  - -40°C to +125°C
- Accuracy:
  - ±2°C (max.), 0°C to +70°C (**MCP9700A/9701A**)
  - ±4°C (max.), 0°C to +70°C (**MCP9700/9701**)
- Optimized for Analog-to-Digital Converters (ADCs):
  - 10.0 mV/°C (typ.) **MCP9700/9700A**
  - 19.5 mV/°C (typ.) **MCP9701/9701A**
- Wide Operating Voltage Range:
  - V_{DD} = 2.3V to 5.5V **MCP9700/9700A**
  - V_{DD} = 3.1V to 5.5V **MCP9701/9701A**
- Low Operating Current: 6 µA (typ.)
- Optimized to Drive Large Capacitive Loads

Typical Applications

- Hard Disk Drives and Other PC Peripherals
- Entertainment Systems
- Home Appliance
- Office Equipment
- Battery Packs and Portable Equipment
- General Purpose Temperature Monitoring

Typical Application Circuit



Description

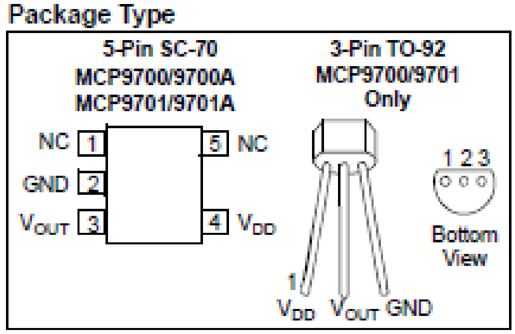
The MCP9700/9700A and MCP9701/9701A family of Linear Active Thermistor™ Intergrated Circuit (IC) is an analog temperature sensor that converts temperature to analog voltage. It's a low-cost, low-power sensor with an accuracy of ±2°C from 0°C to +70°C (MCP9700A/9701A) ±4°C from 0°C to +70°C (MCP9700/9701) while consuming 6 µA (typ.) of operating current.

Unlike resistive sensors (such as thermistors), the Linear Active Thermistor IC does not require an additional signal-conditioning circuit. Therefore, the biasing circuit development overhead for thermistor solutions can be avoided by implementing this low-cost device. The voltage output pin (V_{OUT}) can be directly connected to the ADC input of a microcontroller. The MCP9700/9700A and MCP9701/9701A temperature coefficients are scaled to provide a 1°C/bit resolution for an 8-bit ADC with a reference voltage of 2.5V and 5V, respectively.

The MCP9700/9700A and MCP9701/9701A provide a low-cost solution for applications that require measurement of a relative change of temperature. When measuring relative change in temperature from +25°C, an accuracy of ±1°C (typ.) can be realized from 0°C to +70°C. This accuracy can also be achieved by applying system calibration at +25°C.

In addition, this family is immune to the effects of parasitic capacitance and can drive large capacitive loads. This provides Printed Circuit Board (PCB) layout design flexibility by enabling the device to be remotely located from the microcontroller. Adding some capacitance at the output also helps the output transient response by reducing overshoots or undershoots. However, capacitive load is not required for sensor output stability.

Package Type



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{DD}:.. 6.0V
Storage temperature: .... -65°C to +150°C
Ambient Temp. with Power Applied:.. -40°C to +125°C
Junction Temperature (T_J):................................ 150°C
ESD Protection On All Pins (HBM:MM):.... (4 kV:200V)
Latch-Up Current at Each Pin: .... ±200 mA

†Notice: Stresses above those listed under "Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not implied. Exposure to maximum rating conditions for extended periods may affect device reliability.

DC ELECTRICAL CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameter	Sym	Min	Typ	Max	Unit	Conditions
Power Supply						
Operating Voltage Range	V_{DD} V_{DD}	2.3 3.1	— —	5.5 5.5	V V	**MCP9700/9700A** **MCP9701/9701A**
Operating Current	I_{DD}	—	6	12	µA	
Power Supply Rejection	$\Delta°C/\Delta V_{DD}$	—	0.1	—	°C/V	
Sensor Accuracy (Notes 1, 2)						
T_A = +25°C	T_{ACY}	—	±1	—	°C	
T_A = 0°C to +70°C	T_{ACY}	-2.0	—	+2.0	°C	**MCP9700A/9701A**
T_A = -40°C to +125°C	T_{ACY}	-2.0	—	+4.0	°C	**MCP9700A**
T_A = -10°C to +125°C	T_{ACY}	-2.0	—	+4.0	°C	**MCP9701A**
T_A = 0°C to +70°C	T_{ACY}	-4.0	—	+4.0	°C	**MCP9700/9701**
T_A = -40°C to +125°C	T_{ACY}	-4.0	—	+6.0	°C	**MCP9700**
T_A = -10°C to +125°C	T_{ACY}	-4.0	—	+6.0	°C	**MCP9701**
Sensor Output						
Output Voltage, T_A = 0°C	$V_{0°C}$	—	500	—	mV	**MCP9700/9700A**
Output Voltage, T_A = 0°C	$V_{0°C}$	—	400	—	mV	**MCP9701/9701A**
Temperature Coefficient	T_C	—	10.0	—	mV/°C	**MCP9700/9700A**
	T_C	—	19.5	—	mV/°C	**MCP9701/9701A**
Output Non-linearity	V_{ONL}	—	±0.5	—	°C	T_A = 0°C to +70°C **(Note 2)**
Output Current	I_{OUT}	—	—	100	µA	
Output Impedance	Z_{OUT}	—	20	—	Ω	I_{OUT} = 100 µA, f = 500 Hz
Output Load Regulation	$\Delta V_{OUT}/\Delta I_{OUT}$	—	1	—	Ω	T_A = 0°C to +70°C, I_{OUT} = 100 µA

Note 1: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.

2: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2.

3: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.

4: SC-70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

DC ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameter	Sym	Min	Typ	Max	Unit	Conditions
Turn-on Time	t_{ON}	—	800	—	µs	
Typical Load Capacitance (Note 3)	C_{LOAD}	—	—	1000	pF	
SC-70 Thermal Response to 63%	t_{RES}	—	1.3	—	s	30°C (Air) to +125°C (Fluid Bath) (Note 4)
TO-92 Thermal Response to 63%	t_{RES}	—	1.65	—	s	

Note 1: The MCP9700/9700A family accuracy is tested with V_{DD} = 3.3V, while the MCP9701/9701A accuracy is tested with V_{DD} = 5.0V.

2: The MCP9700/9700A and MCP9701/9701A family is characterized using the first-order or linear equation, as shown in Equation 4-2.

3: The MCP9700/9700A and MCP9701/9701A family is characterized and production tested with a capacitive load of 1000 pF.

4: SC-70-5 package thermal response with 1x1 inch, dual-sided copper clad, TO-92-3 package thermal response without PCB (leaded).

TEMPERATURE CHARACTERISTICS

Electrical Specifications: Unless otherwise indicated:
MCP9700/9700A: V_{DD} = 2.3V to 5.5V, GND = Ground, T_A = -40°C to +125°C and No load.
MCP9701/9701A: V_{DD} = 3.1V to 5.5V, GND = Ground, T_A = -10°C to +125°C and No load.

Parameters	Sym	Min	Typ	Max	Units	Conditions
Temperature Ranges						
Specified Temperature Range	T_A	-40	—	+125	°C	**MCP9700/9700A (Note)**
	T_A	-10	—	+125	°C	**MCP9701/9701A (Note)**
Operating Temperature Range	T_A	-40	—	+125	°C	
Storage Temperature Range	T_A	-65	—	+150	°C	
Thermal Package Resistances						
Thermal Resistance, SC-70-5	θ_{JA}	—	331	—	°C/W	
Thermal Resistance, TO-92-3	θ_{JA}	—	131.9	—	°C/W	

Note: Operation in this range must not cause T_J to exceed Maximum Junction Temperature (+150°C).

2.0 TYPICAL PERFORMANCE CURVES

> **Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

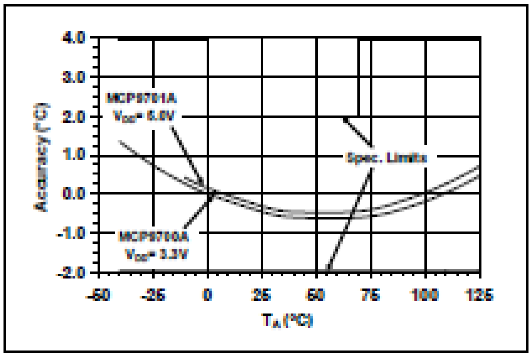


FIGURE 2-1: Accuracy vs. Ambient Temperature (MCP9700A/9701A).

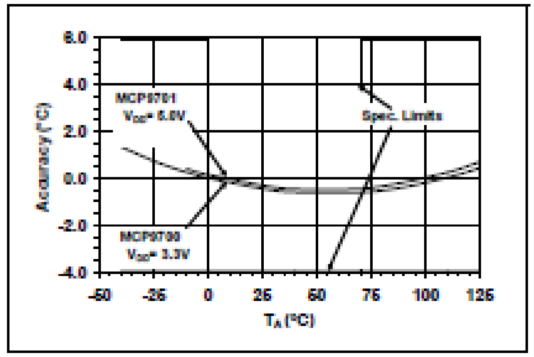


FIGURE 2-4: Accuracy vs. Ambient Temperature (MCP9700/9701).

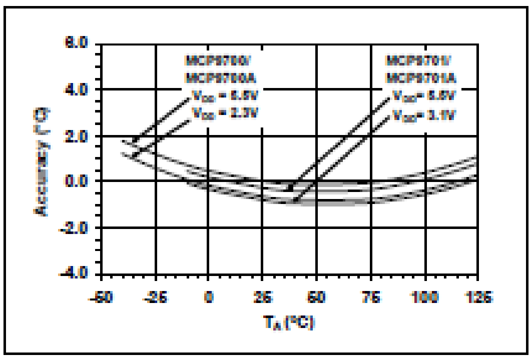


FIGURE 2-2: Accuracy vs. Ambient Temperature, with V_{DD}.

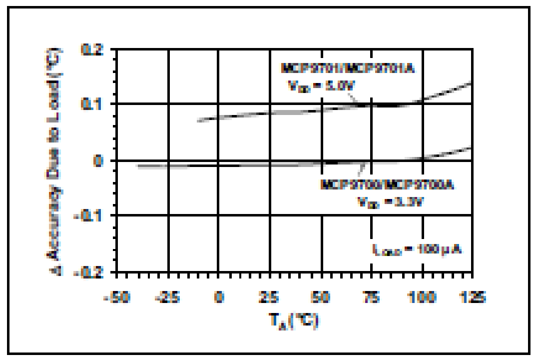


FIGURE 2-5: Changes in Accuracy vs. Ambient Temperature (Due to Load).

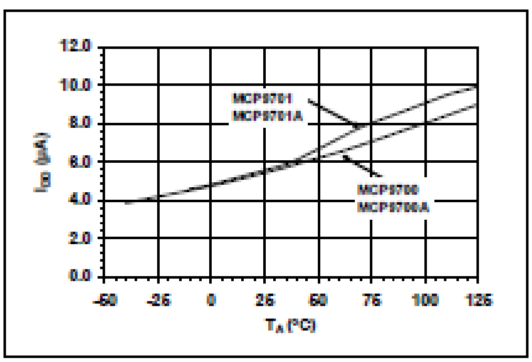


FIGURE 2-3: Supply Current vs. Temperature.

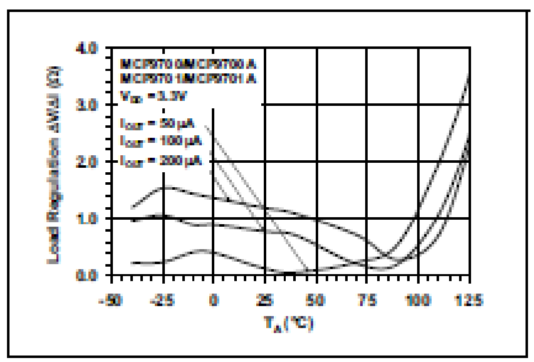


FIGURE 2-6: Load Regulation vs. Ambient Temperature.

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

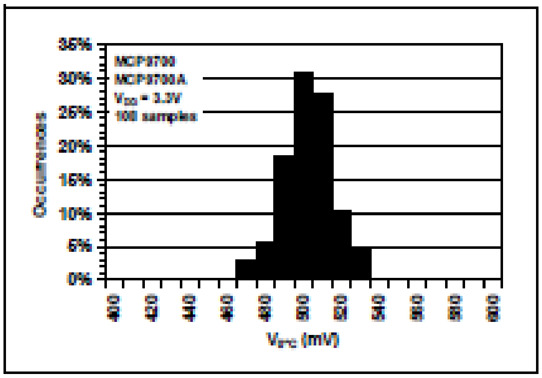


FIGURE 2-7: Output Voltage at 0°C (MCP9700/9700A).

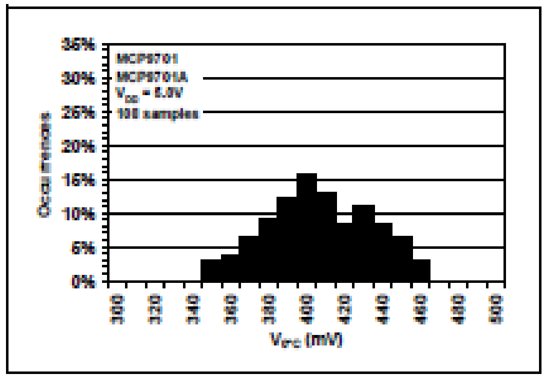


FIGURE 2-10: Output Voltage at 0°C (MCP9701/9701A).

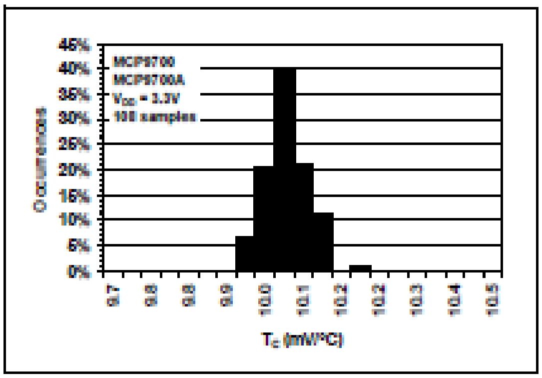


FIGURE 2-8: Occurrences vs. Temperature Coefficient (MCP9700/9700A).

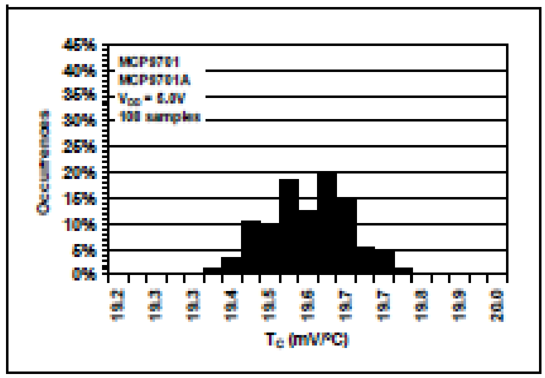


FIGURE 2-11: Occurrences vs. Temperature Coefficient (MCP9701/9701A).

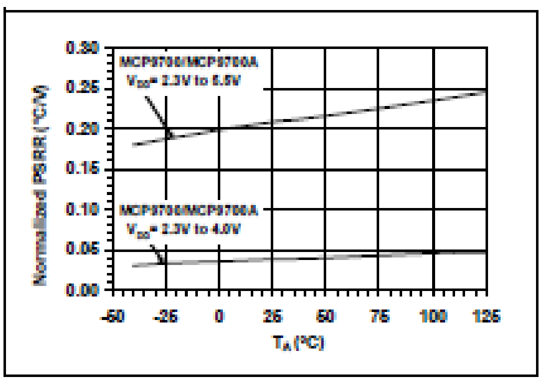


FIGURE 2-9: Power Supply Rejection (Δ°C/ΔV_{DD}) vs. Ambient Temperature.

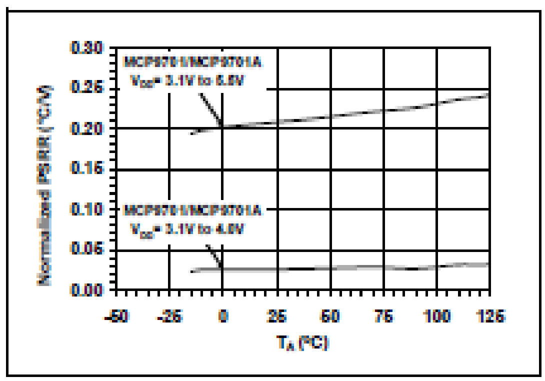


FIGURE 2-12: Power Supply Rejection (Δ°C/ΔV_{DD}) vs. Temperature.

Note: Unless otherwise indicated, **MCP9700/9700A**: V_{DD} = 2.3V to 5.5V; **MCP9701/9701A**: V_{DD} = 3.1V to 5.5V; GND = Ground, C_{bypass} = 0.1 µF.

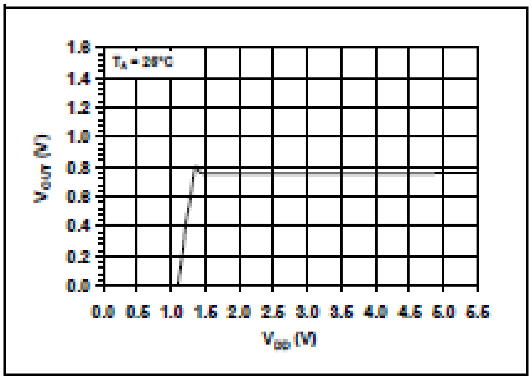


FIGURE 2-13: Output Voltage vs. Power Supply.

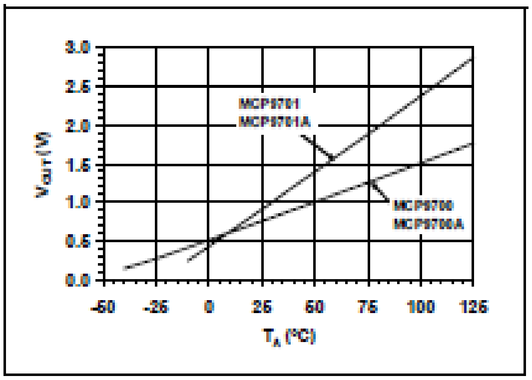


FIGURE 2-16: Output Voltage vs. Ambient Temperature.

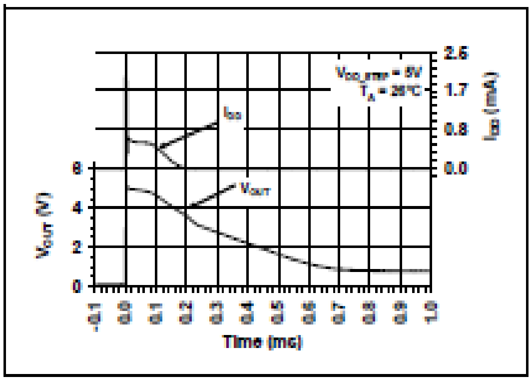


FIGURE 2-14: Output vs. Settling Time to step V_{DD}.

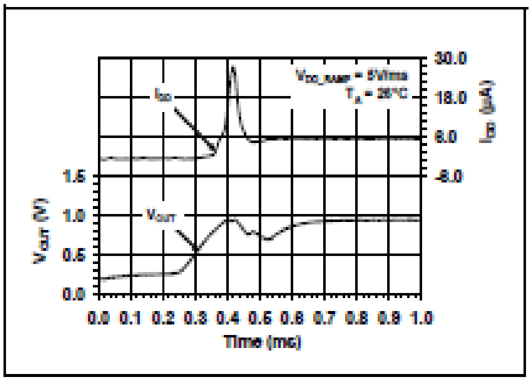


FIGURE 2-17: Output vs. Settling Time to Ramp V_{DD}.

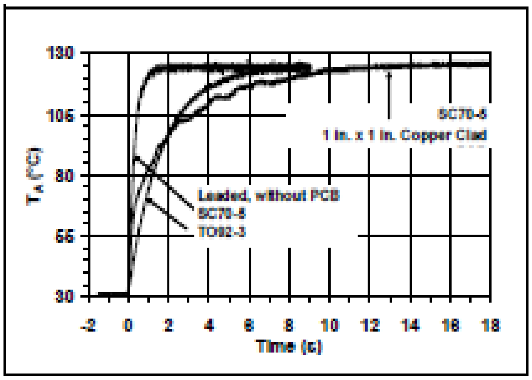


FIGURE 2-15: Thermal Response (Air to Fluid Bath).

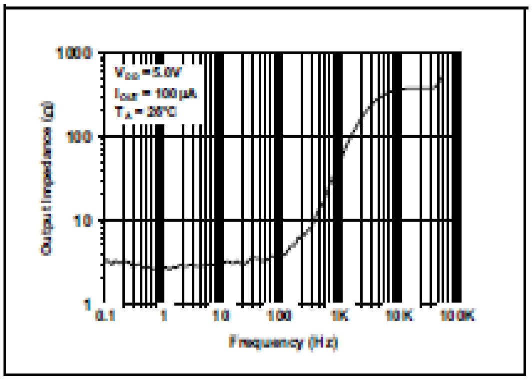


FIGURE 2-18: Output Impedance vs. Frequency.

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin No. SC-70	Pin No. TO-92	Symbol	Function
1	—	NC	No Connect
2	3	GND	Power Ground Pin
3	2	V_{OUT}	Output Voltage Pin
4	1	V_{DD}	Power Supply Input
5	—	NC	No Connect

3.1 Power Ground Pin (GND)

GND is the system ground pin.

3.2 Output Voltage Pin (V_{OUT})

The sensor output can be measured at V_{OUT}. The voltage range over the operating temperature range for the MCP9700/9700A is 100 mV to 1.75V and for the MCP9701/9701A, 200 mV to 3V .

3.3 Power Supply Input (V_{DD})

The operating voltage as specified in the "DC Electrical Characteristics" table is applied to V_{DD}.

4.0 APPLICATIONS INFORMATION

The Linear Active Thermistor™ IC uses an internal diode to measure temperature. The diode electrical characteristics have a temperature coefficient that provides a change in voltage based on the relative ambient temperature from -40°C to 125°C. The change in voltage is scaled to a temperature coefficient of 10.0 mV/°C (typ.) for the MCP9700/9700A and 19.5 mV/°C (typ.) for the MCP9701/9701A. The output voltage at 0°C is also scaled to 500 mV (typ.) and 400 mV (typ.) for the MCP9700/9700A and MCP9701/9701A, respectively. This linear scale is described in the first-order transfer function shown in Equation 4-1.

EQUATION 4-1: SENSOR TRANSFER FUNCTION

$$V_{OUT} = T_C \bullet T_A + V_{0°C}$$

Where:

T_A = Ambient Temperature

V_{OUT} = Sensor Output Voltage

$V_{0°C}$ = Sensor Output Voltage at 0°C

T_C = Temperature Coefficient

4.1 Improving Accuracy

The MCP9700/9700A and MCP9701/9701A accuracy can be improved by performing a system calibration at a specific temperature. For example, calibrating the system at +25°C ambient improves the measurement accuracy to a ±0.5°C (typ.) from 0°C to +70°C, as shown in Figure 4-1. Therefore, when measuring relative temperature change, this family measures temperature with higher accuracy.

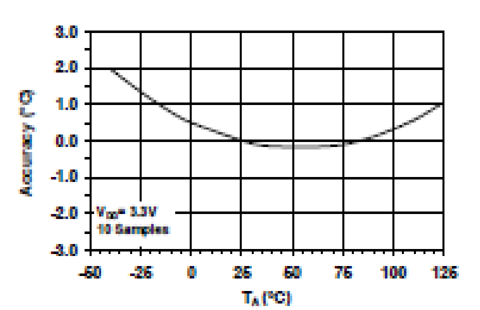


FIGURE 4-1: Relative Accuracy to +25°C vs. Temperature.

The change in accuracy from the calibration temperature is due to the output non-linearity from the first-order equation, as specified in Equation 4-2. The accuracy can be further improved by compensating for the output non-linearity.

For higher accuracy using a sensor compensation technique, refer to AN1001 *"IC Temperature Sensor Accuracy Compensation with a PICmicro® Microcontroller"* (DS01001). The application note shows that if the MCP9700 is compensated in addition to room temperature calibration, the sensor accuracy can be improved to ±0.5°C (typ.) accuracy over the operating temperature (Figure 4-2).

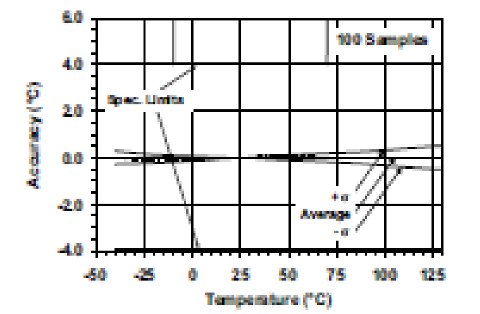


FIGURE 4-2: MCP9700/9700A Calibrated Sensor Accuracy.

The compensation technique provides a linear temperature reading. A firmware look-up table can be generated to compensate for the sensor error.

4.2 Shutdown Using Microcontroller I/O Pin

The MCP9700/9700A and MCP9701/9701A family of low operating current of 6 µA (typ.) makes it ideal for battery-powered applications. However, for applications that require tighter current budget, this device can be powered using a microcontroller Input/Output (I/O) pin. The I/O pin can be toggled to shut down the device. In such applications, the microcontroller internal digital switching noise is emitted to the MCP9700/9700A and MCP9701/9701A as power supply noise. This switching noise compromises measurement accuracy. Therefore, a decoupling capacitor and series resistor will be necessary to filter out the system noise.

4.3 Layout Considerations

The MCP9700/9700A and MCP9701/9701A family does not require any additional components to operate. However, it is recommended that a decoupling capacitor of 0.1 µF to 1 µF be used between the V_{DD} and GND pins. In high-noise applications, connect the power supply voltage to the V_{DD} pin using a 200Ω resistor with a 1 µF decoupling capacitor. A high frequency ceramic capacitor is recommended. It is necessary for the capacitor to be located as close as possible to the V_{DD} and GND pins in order to provide effective noise protection. In addition, avoid tracing digital lines in close proximity to the sensor.

4.4 Thermal Considerations

The MCP9700/9700A and MCP9701/9701A family measures temperature by monitoring the voltage of a diode located in the die. A low-impedance thermal path between the die and the PCB is provided by the pins. Therefore, the sensor effectively monitors the temperature of the PCB. However, the thermal path for the ambient air is not as efficient because the plastic device package functions as a thermal insulator from the die. However, the plastic device package insulates the die and restricts device thermal response. This limitation applies to plastic-packaged silicon temperature sensors. If the application requires measuring ambient air, the PCB needs to be designed with proper thermal conduction to the sensor pins.

The MCP9700/9700A and MCP9701/9701A is designed to source/sink 100 µA (max.). The power dissipation due to the output current is relatively insignificant. The effect of the output current can be described using Equation 4-2.

EQUATION 4-2: EFFECT OF SELF-HEATING

$$T_J - T_A = \theta_{JA}(V_{DD}I_{DD} + (V_{DD} - V_{OUT})I_{OUT})$$

Where:

T_J = Junction Temperature

T_A = Ambient Temperature

θ_{JA} = Package Thermal Resistance (331°C/W)

V_{OUT} = Sensor Output Voltage

I_{OUT} = Sensor Output Current

I_{DD} = Operating Current

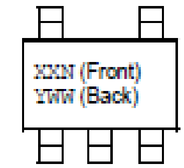
V_{DD} = Operating Voltage

At T_A = +25°C (V_{OUT} = 0.75V) and maximum specification of I_{DD} = 12 µA, V_{DD} = 5.5V and I_{OUT} = +100 µA, the self-heating due to power dissipation ($T_J - T_A$) is 0.179°C.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

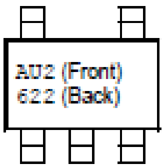
5-Lead SC-70 (**MCP9700/MCP9700A**)



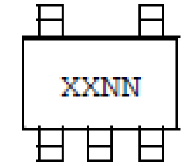
Device	Code
MCP9700/9700A	AUN
MCP9701/9701A	AVN

Note: Applies to 5-Lead SC-70.

Example:



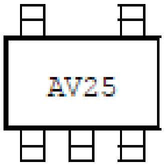
5-Lead SC-70 (**MCP9701/MCP9701A**)



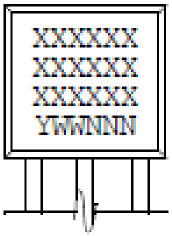
Device	Code
MCP9700/9700A	AUNN
MCP9701/9701A	AVNN

Note: Applies to 5-Lead SC-70.

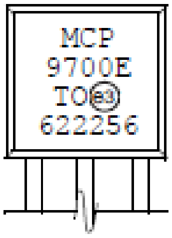
Example:



3-Lead TO-92 (**MCP9700/MCP9701**)



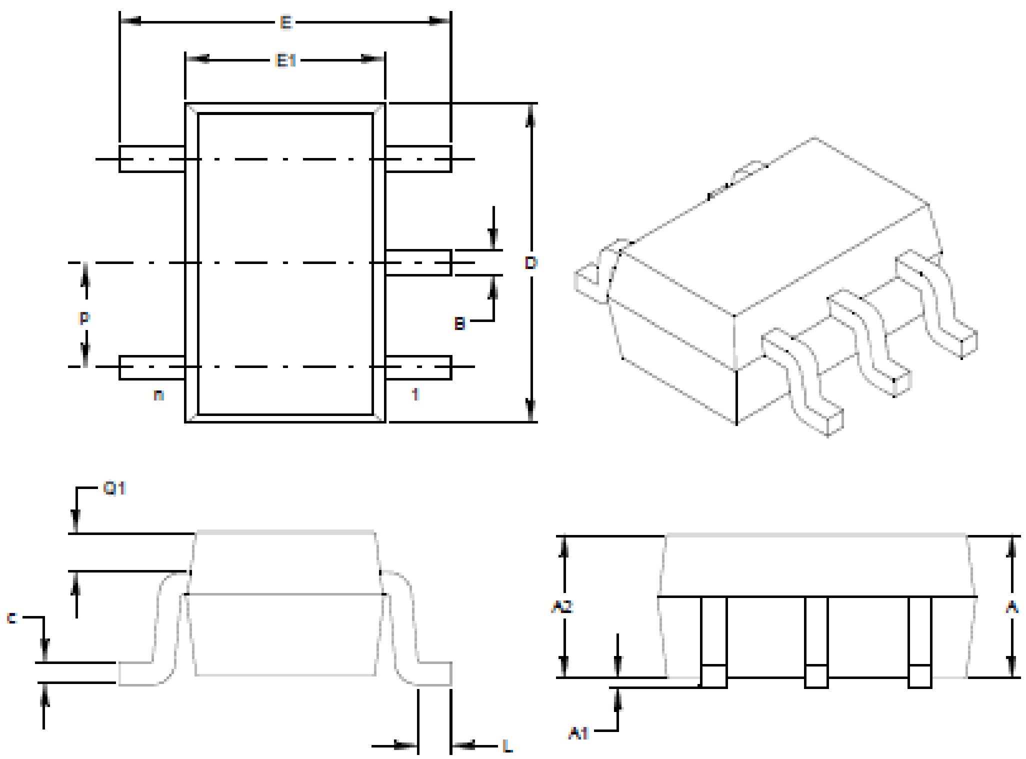
Example



Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

5-Lead Plastic Small Outline Transistor (LT) (SC-70)



Units		INCHES			MILLIMETERS*		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		5			5	
Pitch	p		.026 (BSC)			0.65 (BSC)	
Overall Height	A	.031		.043	0.80		1.10
Molded Package Thickness	A2	.031		.039	0.80		1.00
Standoff	A1	.000		.004	0.00		0.10
Overall Width	E	.071		.094	1.80		2.40
Molded Package Width	E1	.045		.053	1.15		1.35
Overall Length	D	.071		.087	1.80		2.20
Foot Length	L	.004		.012	0.10		0.30
Top of Molded Pkg to Lead Shoulder	Q1	.004		.016	0.10		0.40
Lead Thickness	c	.004		.007	0.10		0.18
Lead Width	B	.006		.012	0.15		0.30

* Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .005" (0.127mm) per side.

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

See ASME Y14.5M

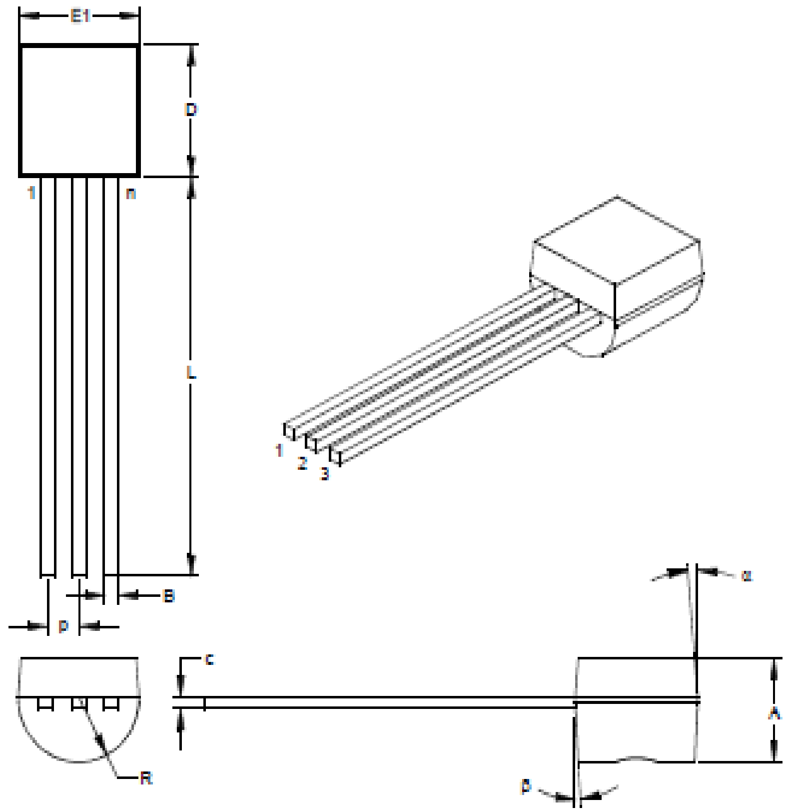
JEITA (EIAJ) Standard: SC-70

Drawing No. C04-061

Revised 07-19-05

MCP9700/9700A and MCP9701/9701A

3-Lead Plastic Transistor Outline (TO) (TO-92)



Units		INCHES*			MILLIMETERS		
Dimension Limits		MIN	NOM	MAX	MIN	NOM	MAX
Number of Pins	n		3			3	
Pitch	p		.050			1.27	
Bottom to Package Flat	A	.130	.143	.155	3.30	3.62	3.94
Overall Width	E1	.175	.186	.195	4.45	4.71	4.95
Overall Length	D	.170	.183	.195	4.32	4.64	4.95
Molded Package Radius	R	.085	.090	.095	2.16	2.29	2.41
Tip to Seating Plane	L	.500	.555	.610	12.70	14.10	15.49
Lead Thickness	c	.014	.017	.020	0.36	0.43	0.51
Lead Width	B	.016	.019	.022	0.41	0.48	0.56
Mold Draft Angle Top	α	4	5	6	4	5	6
Mold Draft Angle Bottom	β	2	3	4	2	3	4

* Controlling Parameter

Notes:

Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed .010" (0.254mm) per side.

JEDEC Equivalent: TO-92

Drawing No. C04-101

APPENDIX A: REVISION HISTORY

Revision C (June 2006)

- Added the MCP9700A and MCP9701A devices to data sheet
- Added TO92 package for the MCP9700/MCP9701

Revision B (October 2005)

The following is the list of modifications:

- Added **Section 3.0 "Pin Descriptions"**
- Added the Linear Active Thermistor™ IC trademark
- Removed the 2^{nd} order temperature equation and the temperature coeficient histogram
- Added a reference to AN1001 and corresponding verbiage
- Added Figure 4-2 and corresponding verbiage

Revision A (November 2005)

- Original Release of this Document.

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO. – X /XX

Device – Temperature Range – Package

Device:	MCP9700T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9700AT:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9701T:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
	MCP9701AT:	Linear Active Thermistor™ IC, Tape and Reel, Pb free
Temperature Range:	E	= -40°C to +125°C
Package:	LT	= Plastic Small Outline Transistor, 5-lead
	TO	= Plastic Plastic Transistor Outline, 3-lead (MCP9700, MCP9701 only)

Examples:

a) MCP9700T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

b) MCP9700-E/TO: Linear Active Thermistor™ IC, 3LD TO-92 package.

c) MCP9700AT-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

a) MCP9701T-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

b) MCP9701-E/TO: Linear Active Thermistor™ IC, 3LD TO-92 package.

c) MCP9701AT-E/LT: Linear Active Thermistor™ IC, Tape and Reel, 5LD SC-70 package.

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
ISO/TS 16949:2002

Microchip received ISO/TS-16949:2002 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona, Gresham, Oregon and Mountain View, California. The Company's quality system processes and procedures are for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

ANEXO D: PROGRAMA COMENTADO DEL ATMEGA16

```
; ******************************************************

; BASIC .ASM template file for AVR

; ******************************************************


.include "C:\VMLAB\include\m16def.inc"


; Define here the variables

;

.def contseg = r20

.def contmin = r21


.def tiempo_des = r22

.def rpm_des = r23

.def temp_des = r24


.def se_acabo = r3


.def cont_int = r4


.def primera_vez = r5


.def fin = r6


.def  temp  =r16
```

```
; Define here Reset and interrupt vectors, if any
;
reset:
   rjmp Inicio
   reti      ; Addr $01
   .org $02
   rjmp INT_0 ; Interrupcion externa calcula rpm
   reti      ; Addr $03
   reti      ; Addr $04
   reti      ; Addr $05
   reti      ; Addr $06        Use 'rjmp myVector'
   reti      ; Addr $07        to define a interrupt vector
   reti      ; Addr $08
   reti      ; Addr $09
   reti      ; Addr $0A
   reti      ; Addr $0B                         This is just an example
   .org $0c
   rjmp INT_TMR1; interrupcion de timer 1, se activa cada segundo     Not all MCUs
have the same
   reti      ; Addr $0D                         number of interrupt vectors
   reti      ; Addr $0E
   reti      ; Addr $0F
   reti      ; Addr $10
   .org $26
   rjmp int_tmr0


msgPantallaIngreseVelocidad:
```

```
.db "INGRESE VELOCIDAD [100-255] RPM:",0,0
msgPantallaIngreseTemperatura:
.db "INGRESE TEMPERATURA [20-65] C:",0,0
msgPantallaIngreseTiempo:
.db "INGRESE TIEMPO [1-9] min:",0,0
msgPantallaFinDelProceso:
.db "FIN DEL PROCESO",0,0

msgtact:
.db "Tact",0,0
msgrpm:
.db "RPM",0,0
; Programa empieza aca después de Reset

Inicio:
ldi r16,high(ramend); inicio pila
out sph,r16
ldi r16,low(ramend)
out spl,r16

rcall configpuertos
rcall configADC
rcall configINT_TMR0
rcall configINT_TMR1
rcall configLCD
;rcall configPWM
```

```
rcall configInterrupcionExterna

clr contseg ; Inicializacion de contadores y banderas
clr contmin
clr temp_des
clr tiempo_des
clr rpm_des
clr se_acabo
clr cont_int
clr primera_vez
clr fin

sbi portd,4; prendo ventiladores

PantallaIngreseVelocidad:
ldi r16,$01
rcall comandoLCD; pantalla en blanco cursor en posicion $00
ldi zh,high(msgPantallaIngreseVelocidad*2)
ldi zl,low(msgPantallaIngreseVelocidad*2)
rcall escribeLCD
rcall retardo10ms
rcall teclado
rcall retardo10ms
```

```
mov r0,r25
rcall conversion_centenas
mov rpm_des,r25


rcall retardo50ms

ldi r16,$A1
rcall comandolcd

ldi r17,'0'
add r0, r17
mov r16, r0
rcall escribech
rcall retardo10ms
rcall teclado
rcall retardo10ms
mov r1,r25
rcall conversion_decenas
add rpm_des,r25

rcall retardo50ms
ldi r16,$A2
rcall comandolcd
ldi r17,'0'
add r1,r17
```

```
mov r16,r1
rcall escribech

rcall retardo10ms
rcall teclado
rcall retardo10ms
mov r2,r25
add rpm_des,r25

mov r16,rpm_des
ldi r16,$A3
rcall comandolcd
ldi r17,'0'
add r2,r17
mov r16,r2
rcall escribech


okrpm:
rcall retardo50ms
rcall retardo10ms
rcall teclado
rcall retardo10ms
cpi r25,0b1011
brne okrpm
```

```
;*************************************************************
pantallaIngreseTemperatura:
ldi r16,$01
rcall comandoLCD; pantalla en blanco cursor en posicion $00
ldi zh,high(msgPantallaIngreseTemperatura*2)
ldi zl,low(msgPantallaIngreseTemperatura*2)
rcall escribeLCD

;********INGRESO DE LA TEMPERATURA DESEADA************

rcall teclado
mov r1,r25
rcall conversion_decenas
mov temp_des,r25


;rcall retardo50ms

ldi r16,$A0
rcall comandolcd

ldi r17,'0'
add r1, r17
mov r16, r1
rcall escribech
```

```
rcall teclado
mov r2,r25

add temp_des,r25

rcall retardo50ms
ldi r16,$A1
rcall comandolcd
ldi r17,'0'
add r2,r17
mov r16,r2
rcall escribech

oktemp:
rcall retardo50ms
rcall teclado
cpi r25,0b1011
brne oktemp

;*********************************************
pantallaIngreseTiempo:
ldi r16,$01
rcall comandoLCD; pantalla en blanco cursor en posicion $00
ldi zh,high(msgPantallaIngreseTiempo*2)
ldi zl,low(msgPantallaIngreseTiempo*2)
rcall escribeLCD
```

```
;********INGRESO DEL TIEMPO DESEADO************

rcall teclado
add tiempo_des,r25
mov r16,tiempo_des

rcall obtiene_ascii

ldi r16,$A0
rcall comandolcd
mov r16,r2
rcall escribech

oktiempo:
rcall retardo50ms
rcall teclado
cpi r25,0b1011
brne oktiempo

clr r25



rcall configPWM

sei ; SE ACTIVAN INTERRUPCIONES
```

```
cbi portd, 0   ; prendo motor!!!!!!!!!!!!!!

pregunta_acabo:
mov r16,se_acabo
cpi r16,1
brne pregunta_acabo


;*********************************************
pantallaFinDelProceso:
ldi r16,$01
rcall comandoLCD; pantalla en blanco cursor en posicion $00
ldi zh,high(msgPantallaFinDelProceso*2)
ldi zl,low(msgPantallaFinDelProceso*2)
rcall escribeLCD

in r16, sreg
andi r16, 0b01111111
out sreg, r16
;rjmp inicio

FIN:
cbi portd,5    ; apago resistencias calefactoras
cbi portd,4    ; apago ventiladores
sbi portd,0    ; apago motor!!!!!!!!!!!!!!!
```

```
RJMP FIN

;////////////////////////

configpuertos:

;////////////////////////

push r16

ldi r16,0b11100000  ; PA7=RS  PA6=E PA5=R/W PA1 y PA0= Sensores de Temperatura

out DDRA,r16

ldi r16,0b11111111  ; PB0..PB7=LCD

out DDRB,r16

ldi r16,0b00001111  ; PC0..PC3=Columnas  PC4..PC7=Filas

out DDRC,r16

ldi r16,0b10110001  ; PD7=PWM  PD5=Calefactores  PD4=Ventilador  PD2=Encoder PD0=Motor

out DDRD,r16

pop r16

ret ; Retorna al programa principal

;////////////////////////
```

```
;//////////////////////////
configPWM:; PWM rápido, PWM no invertido, Pre escalador N=32
;//////////////////////////

            push r16
            ldi r16, 0x6B       ; PWM rápido, no invertido, N=32
            out TCCR2, r16
            ldi r16, 0x7F
            out OCR2, r16       ; inicialmente duty cycle 50%
            pop r16
            ret
;//////////////////////////

;/////////////////////////////////////////
configADC:;configuracion del ADC (PA0)
;modo: una sola conversion
;factor de division, preescalador=64 (frec ADC=156.25Khz)
;ajuste de resultado: izquierdo
;Voltaje de referencia: AVCC
;/////////////////////////////////////////

    push r16
    ldi R16,(0<<REFS1 | 1<<REFS0 | 1<<ADLAR | 0<<MUX3 | 0<<MUX2 | 0<<MUX1 |
0<<MUX0)
    out ADMUX,R16
    ldi R16,(1<<ADEN |0<<ADSC | 1<<ADPS2 | 1<<ADPS1 | 0<<ADPS0)
    out ADCSR, R16
```

```
	pop r16

ret
;/////////////////////////////////////

;/////////////////////////////////////
configInterrupcionExterna:

push r16

ldi r16,(1<<ISC01 | 0<<ISC00) ; Flanco de bajada en INT0 solicita interrupcion
out MCUCR, R16
ldi r16,(1<<INT0)		; Interrupcion Externa 0 habilitada
out GICR,R16

pop r16
ret
;/////////////////////////////////////

;/////////////////////////
configINT_TMR0:

push r16
push r17

ldi r16,0
```

```
out TCCR0,r16   ;sin generador de señal, modo CTC, Prescalador = 64
ldi r16,(1<<WGM01 |0<<WGM00 |1<<CS02 |0<<CS01 |0<<CS00)
out TCCR0,r16

ldi r16,92          ;OCR0 = 92, T =2.4mseg, Fosc = 10Mhz;
;ldi r17,low(92)
;out OCR1AH,r16
out OCR0,r16

ldi r16,0b00010010     ; habilito interrupcion TIMER 0 COMPA
out TIMSK,r16

pop r17
pop r16

ret
;/////////////////////////


;/////////////////////////
configINT_TMR1:
;/////////////////////////

push r16
push r17
```

```
ldi r16,0
out TCCR1A,r16   ;sin generador de señal, modo CTC, Prescalador = 256
ldi r16,(0<<WGM13 |1<<WGM12 |1<<CS12 |0<<CS11 |0<<CS10)
out TCCR1B,r16

ldi r16,high(39063)       ;OCR1A = 39063, T =1seg, Fosc = 10Mhz;
ldi r17,low(39063)
out OCR1AH,r16
out OCR1AL,r17

ldi r16,0b00010010     ; habilito interrupcion TIMER 1 COMPA
out TIMSK,r16

pop r17
pop r16

ret
;////////////////////////


;////////////////////////
configLCD:
;///////////////////////

push r16
push r17
```

```
ldi r16,$3c; instruccion a enviar: Function set command

rcall retardo50ms

;caracteres de 8 bit, 2 lineas y caracter de 5*10puntos. realizar comando sin chequear BF

        ldi R17,0b000           ;RW=0, RS=0 y E=0

        out PORTA,R17

        ldi R17,0b01000000          ;RW=0, RS=0 y E=1    RS  E  RW

        out PORTA,R17


        out PORTB,r16           ;se envia la instruccion almacenada en R16


        ldi R17,0b000           ;RW=0, RS=0 y E=0    RS  E  RW

        out PORTA,R17

        ldi R17,0b00100000          ;RW=1, RS=0 y E=0    RS  E  RW

        out PORTA,R17


rcall retardo50ms

;caracteres de 8 bit, 2 lineas y caracter de 5*10puntos. realizar comando sin chequear BF

        ldi R17,0b000           ;RW=0, RS=0 y E=0

        out PORTA,R17

        ldi R17,0b01000000          ;RW=0, RS=0 y E=1     RS  E  RW

        out PORTA,R17


        out PORTB,r16           ;se envia la instruccion almacenada en R16
```

```
        ldi R17,0b000           ;RW=0, RS=0 y E=0
        out PORTA,R17
        ldi R17,0b00100000          ;RW=1, RS=0 y E=0       RS  E  RW
        out PORTA,R17

rcall retardo50ms
;despues de este comando ya se puede chequear BF (usar comandoLCD)
        ldi R17,0b000           ;RW=0, RS=0 y E=0
        out PORTA,R17
        ldi R17,0b01000000          ;RW=0, RS=0 y E=1
        out PORTA,R17

        out PORTB,r16           ;se envia la instruccion almacenada en R16

        ldi R17,0b000           ;RW=0, RS=0 y E=0
        out PORTA,R17
        ldi R17,0b00100000          ;RW=1, RS=0 y E=0
        out PORTA,R17

rcall retardo50ms

ldi r16,$3c
rcall comandoLCD; Function Set: caracteres de 8 bit, 2 lineas y caracter de 5*7puntos.
ldi r16,$08
rcall comandoLCD; Display Off
ldi r16,$01
```

```
rcall comandoLCD; Clear display

ldi r16,$06

rcall comandoLCD; Entry Mode Set: cursor de mueve a la derecha, pantalla sin desplazamiento.

ldi r16,$0c

rcall comandoLCD; Display ON sin cursor


pop r17

pop r16

ret



;////////////////////////////////

comandoLCD:;ejecuta el comandoLCD cuyo codigo se encuentra en r16

;////////////////////////////////

push r16

push r17

rcall checkBF


WriteIR:

        ldi R17,0b000           ;RW=0, RS=0 y E=0

        out PORTA,R17

        ldi R17,0b01000000            ;RW=0, RS=0 y E=1

        out PORTA,R17


        out PORTB,r16          ;se envia la instruccion almacenada en R16

rcall retardo10ms
```

```
        ldi R17,0b000           ;RW=0, RS=0 y E=0
;problema al usar 10mhz en frec de uC
        out PORTA,R17
        ldi R17,0b00100000          ;RW=1, RS=0 y E=0
        out PORTA,R17

pop r17
pop r16
ret

;///////////////////////////////
CheckBF:;espera a que la busy flag del LCD este libre (DB7='0')
;///////////////////////////////

        push R16
        push R17

        ldi R16,0               ;Bus de datos: entrada
        out DDRB,R16

LecturaBF1:
        ldi R16,0b00100000          ;RW=1, RS=0 y E=0
        out PORTA,R16
        ldi R16,0b01100000          ;RW=1, RS=0 y E=1           RS  E  RW
        out PORTA,R16
```

```
        nop
        nop
        nop
        nop
        in R17,PINB             ;Analiza bit BF (DB7)

        ldi R16,0b00100000              ;RW=1, RS=0 y E=0
        out PORTA,R16

        andi R17,0b10000000
        cpi R17,0
        brne LecturaBF1                 ;Si LCD esta ocupado => espera

        ldi R16,$FF             ;Bus de datos: salida
        out DDRB,R16

        pop R17
        pop R16

        ret

;/////////////////////////


;//////////////////
escribeLCD:;escribe el mensaje que esta siendo apuntado por Z hasta encontrar un caracter NULL
;ENTRADAS: puntero Z
```

```
;SALIDAS:ninguna

;REGISTROS MODIFICADOS: ninguno

;//////////////////

push r16

push r17


lazoescribe:

lpm r17,z

cpi r17,0

breq salirlazoescribe


rcall checkbf; espera hasta que el Busy Flag este libre para transmitir dato

ldi r16,0b10000000; RW=0,  RS=1,  E=0            RS  E  RW

out portA,r16

ldi r16,0b11000000

out portA,r16; RW=0,  RS=1,  E=1


lpm r17,z+

out portb,r17


ldi R16,0b10000000              ;RW=0, RS=1 y E=0

;rcall retardo10ms

out PORTA,R16

ldi R16,0b00100000              ;RW=1, RS=0 y E=0

out PORTA,R16
```

```
rjmp lazoEscribe


salirlazoescribe:
adiw zl,1;incrementa puntero Z para que apunte a la siguiente cadena
lpm r17,z
cpi r17,0;si el siguiente carater es un segundo NULL, apuntará al siguiente caracter
brne salirEscribeLCD


adiw zl,1


salirEscribeLCD:
pop r17
pop r16
ret


;//////////////////////


;/////////////////////////////
retardo50ms:;retardo de 50ms
;/////////////////////////////
push r16


ldi r16,5
lazoR50ms:
rcall retardo10ms
dec r16
```

```
brne lazoR50ms

pop r16
ret
;//////////////////////
retardo10ms:
;//////////////////////
push R16;2us

ldi r16,20
lazoR10ms:
rcall retardo500us
dec r16
brne lazoR10ms

pop r16
ret;4us

;///////////////////////
retardo500us:
;///////////////////////
push R16
push R17
push r18

ldi r17,18
```

```
lazo2R500us:
ldi r16,91
lazo1R500us:
dec r16; 1 clock
brne lazo1R500us; 1 o 2 clock
dec r17
nop
brne lazo2R500us
nop
nop

pop r18
pop R17;2us
pop R16;2us
ret;4us

;///////////////
INT_TMR1:
;///////////////
sei

push r16
push r17
push r18    ;*****
in  r16,sreg
push r16
```

```
inc contseg

cpi contseg,60

breq un_minuto

rjmp fin_int1



un_minuto:

inc contmin

clr contseg


fin_int1:


rcall medir_adc


;ldi r25, 204; SACAR RPM DE INT EXTERNA   r25=RPM SOLO PARA PRUEBA

;SOLO PARA PRUEBA

;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA

;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA;SOLO PARA PRUEBA


; sacar temperatura de tabla

;clr r16

;ldi zh,high(temperaturas*2)
```

```
;ldi zl,low(temperaturas*2)

;add zl,r18
;adc zh,r16
;lpm r19,z          ;guarda temperatura en r19


mov r16,r18
;mov r16, r19
;ldi r16,234   ;solo para probar
rcall obtiene_ascii

; mostrar pantalla

pantalla_tact:
ldi r16,$01
rcall comandoLCD; pantalla en blanco cursor en posicion $00
ldi zh,high(msgtact*2)
ldi zl,low(msgtact*2)
rcall escribeLCD


ldi r16,$87
rcall comandolcd
mov r16,r1
```

```
rcall escribech
ldi r16,$88
rcall comandolcd
mov r16,r2
rcall escribech


pantalla_rpm:
ldi r16,$8C
rcall comandoLCD; pantalla se mantiene cursor en posicion $0c
ldi zh,high(msgrpm*2)
ldi zl,low(msgrpm*2)
rcall escribeLCD

mov r16,r25
rcall obtiene_ascii
ldi r16,$91
rcall comandolcd
mov r16,r0
rcall escribech
ldi r16,$92
rcall comandolcd
mov r16,r1
rcall escribech
ldi r16,$93
rcall comandolcd
```

```
mov r16,r2
rcall escribech


;escribir tiempo en pantalla
mov r16,contmin
rcall obtiene_ascii
ldi r16,$A2
rcall comandolcd
mov r16,r1
rcall escribech
ldi r16,$A3
rcall comandolcd
mov r16,r2
rcall escribech

ldi r16,$A4
rcall comandolcd
ldi r16,':'
rcall escribech

mov r16,contseg
rcall obtiene_ascii
ldi r16,$A5
rcall comandolcd
mov r16,r1
```

```
rcall escribech
ldi r16,$A6
rcall comandolcd
mov r16,r2
rcall escribech



;verificacion de tiempo transcurrido
cp contmin,tiempo_des
brne no_completo_tiempo
ldi r16,1
mov r3,r16

pop r16
out sreg,r16
pop r18    ;*******
pop r17
pop r16

reti
; verificacion de temperatura actual con temperatura deseada
; temperatura actual en r19
no_completo_tiempo:
cp r18,temp_des
brlo prender_resistencia
```

```
cbi portd,5
rjmp fin_temp
prender_resistencia:
sbi portd,5

fin_temp:
; verificacion de RPM con RPM_deseado
; RPM esta en R25
cp rpm_des,r25
brlo disminuir_PWM
aumentar_PWM:
in r16,OCR2
cpi r16,0xFF
breq fin_rpm
inc r16
out OCR2,r16                    ;FALTA COMPLETAR AUMENTAR PWM
rjmp fin_rpm

disminuir_PWM:          ; FALTA COMPLETAR DISMINUIR PWM
in r16, OCR2
cpi r16,0
breq fin_rpm
dec r16
out OCR2, r16
fin_rpm:
```

```
pop r16
out sreg,r16
pop r18        ;**********
pop r17
pop r16


reti


;///////////////////////////
medir_adc:
;ENTRADA: ninguna
;SALIDA: r18
;///////////////////////////
push r16
push r17
push r19
push r20
push r24
push r25

clr r18
cbi admux,0       ; se escoge temperatura 1 en adc0
ldi r20,30
```

```
clr r24

clr r25


medida1:


in r16,ADCSR

ori r16,$40;bit de inicio de conversion en 1

out ADCSR,r16


ldi r17,8

lazoesperaa:

ldi r16,200;espera 25*64=1600 ciclos de reloj del uC (prescalador adc=64)

lazoespera:

dec r16

brne lazoespera;tiempo que demora la lectura del ADC

dec r17

brne lazoesperaa


;in r16,ADCL; leo parte alta y baja de medicion del ADC

in r16,ADCH           ; temperatura 1 en r18


ldi zh,high(temperaturas*2)

ldi zl,low(temperaturas*2)


add zl,r16

adc zh,r18
```

```
lpm r16,z

add r24, r16
adc r25, r18
dec r20
brne medida1

rcall div30
mov r18,r16


clr r24
clr r25
clr r19
sbi admux,0      ; se escoge temperatura 2 en adc1
ldi r20, 30

medida2:

in r16,ADCSR
ori r16,$40;bit de inicio de conversion en 1
out ADCSR,r16

ldi r17,8
lazoesperaa2:
ldi r16,200;espera 25*64=1600 ciclos de reloj del uC (prescalador adc=64)
```

```
lazoespera2:
dec r16
brne lazoespera2;tiempo que demora la lectura del ADC
dec r17
brne lazoesperaa2

;in r16,ADCL; leo parte alta y baja de medicion del ADC
in r16,ADCH       ;temperatura2 en r19

ldi zh,high(temperaturas*2)
ldi zl,low(temperaturas*2)

add zl,r16
adc zh,r19
lpm r16,z

add r24, r16
adc r25, r19
dec r20
brne medida2

rcall div30
mov r19,r16
```

```
lsr r18
lsr r19
add r18,r19          ;promedio de temperauras en r18


pop r25
pop r24
pop r20
pop r19
pop r17
pop r16
ret

;///////////////////



;///////////////////
obtiene_ascii:
;RUTINA QUE OBTIENE LOS ASCII DE UN NUMERO GUARDADO EN R16 Y LOS DEVUELVE EN R0 R1 y R2

push r17
push r18
push r19
push r20
clr r17
```

```
mov r0,r17
mov r1,r17
mov r2,r17


tiene_centenas:
cpi r16,100
brlo tiene_solo_decenas
subi r16,100
inc r0
rjmp tiene_centenas


tiene_solo_decenas:
cpi r16,10
brlo tiene_solo_unidades
subi r16,10
inc r1
rjmp tiene_solo_decenas

tiene_solo_unidades:

mov r2,r16

ldi r17,'0'
add r0,r17
```

```
add r1,r17
add r2,r17



pop r20
pop r19
pop r18
pop r17
ret

;////////////////////////

;////////////////////////
EscribeCh:;escribe 1 solo caracter, almacenado en r16
;ENTRADAS: r16
;SALIDAS:ninguna
;REGISTROS MODIFICADOS: ninguno
;////////////////////////
push r16
push r17

cpi r16,0
breq salirEscribeCh

rcall checkbf; espera hasta que el Busy Flag este libre para transmitir dato
```

```
ldi r17,0b10000000; RW=0,  RS=1,  E=0             RS  E  RW
out portA,r17
ldi r17,0b11000000
out portA,r17; RW=0,  RS=1,  E=1

out portb,r16

ldi R17,0b10000000          ;RW=0, RS=1 y E=0
out PORTA,R17
ldi R17,0b00100000          ;RW=1, RS=0 y E=0
out PORTA,R17

salirEscribeCh:
pop r17
pop r16
ret

;////////////////////////

;//////////////////rutina de interrupcion por timer 0
int_tmr0:
push r16
push r17
in  r16,sreg
```

```
push r16



mov r16,cont_int
inc r16
mov cont_int,r16



pop r16
out sreg, r16
pop r17
pop r16

reti

;////////////////////////

;////////////////////////////////////
teclado:  ; Registro modificado R25
;////////////////////////////////////
push r16
push r17
push r18
push r19
in  r16,sreg
push r16
```

```
vuelve:
 clr r18

;*** Lectura del teclado
ExploraTeclado:
      ldi R19,0b1110 ;Se habilita columna seleccionada (1110)
colum:
      out PORTC,R19 ;(nibble bajo)

      nop ;Retardo para la lectura
            nop ;
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
                  nop
```

```
        ; rcall retardo500us

    in R16,PINC ;Se leen las filas
    andi R16,$F0 ;(nibble alto)

    cpi R16,0b11110000 ;Si filas = 1111, analizar si finalizo exploracion
breq mueve_columna

;*** Se presiono tecla!
    cpi R16,0b11100000 ;Se explora primera fila (filas = 1110)
    brne SegundaFila

    ldi R17,0 ;bloque <- 0
    rjmp LecturaTablaTecla

SegundaFila:
    cpi R16,0b11010000 ;Se explora segunda fila (filas = 1101)
    brne TerceraFila
    ldi R17,1 ;bloque <- 1
    rjmp LecturaTablaTecla

TerceraFila:
     cpi R16,0b10110000 ;Se explora tercera fila (filas = 1011)
     brne CuartaFila

     ldi R17,2 ;bloque <- 2
```

```
	rjmp LecturaTablaTecla

CuartaFila: ;(filas = 0111)
	ldi R17,3 ;bloque <- 3
	rjmp LecturaTablaTecla

LecturaTablaTecla:
	mov r16,r17
	add R16,R16
	add R16,R16
	add R16,R18

;*** Se lee de la tabla
ldi ZH,high(TablaTecla*2) ;Z apunta al inicio de la tabla
ldi ZL,low(TablaTecla*2)
add ZL,R16 ;Se suma desplazamiento
clr R16
adc ZH,R16
lpm R16,Z ;Se obtiene tecla leida: Fin de exploracion
mov r25,r16 ; ******GUARDO TECLA PRESIONADA EN R25*********
		;***********************************************
rcall retardo50ms
rcall retardo50ms
rcall retardo50ms
rcall retardo50ms
```

```
pop r16
out sreg, r16
pop r19
pop r18
pop r17
pop r16

ret

mueve_columna:
    inc r18
    cpi r18,0b1
    breq paso_columna2
    cpi r18,0b10
    breq paso_columna3
    cpi r18,0b11
    breq paso_columna4
    rjmp vuelve

paso_columna2:
    ldi r19,0b1101
    rjmp colum
paso_columna3:
    ldi r19,0b1011
    rjmp colum
```

```
paso_columna4:
      ldi r19,0b0111
      rjmp colum

;/////////////////////////////////


;/////////////////////////////////
conversion_centenas:
;/////////////////////////////////
rcall conversion_decenas
rcall conversion_decenas

  ret

;//////////////////////////////////
conversion_decenas:
;//////////////////////////////////
  push r16
  push r17

  mov r16,r25
  mov r17,r16

  add r25,r25
  add r25,r25
  add r16,r16
```

```
  add r16,r16
  add r25,r16
  add r25,r17
  add r25,r17


  pop r17
  pop r16
  ret
;////////////////////////////////


;*********************************************************************************
;div30: divide R25:R24 entre 30  (el numero a dividir debe ser como máximo 7650)
;solo guarda el cociente en r16.
;entradas: R25:R25 numero a dividir entre 30
;salidas: R16  cociente de la division
;registros modificados: r16, sreg
;revisión: 1.2
div30:
                        push    r25
                        push    r24
        clr     r16
        cpi     r25,0       ;analiza si el byte mas significativo es cero
        breq    analiza_r24
dividiendo:
                        inc     r16     ;efectúa divisiones sucesivas para determinar el
cociente de la división
                        sbiw    r24, 30
```

```
                cpi     r25,0
                breq    analiza_r24
                rjmp    dividiendo
analiza_r24:
                cpi     r24, 30
                brlo    terminar
                rjmp    dividiendo   ; termina la división cuando el residuo es
menor que el divisor = 30, o si el
                                                        ; número a dividir es
menor que 30

terminar:
                pop     r24
                pop     r25
                ret

;*********************************************************************************
;*********************************
;////////////////////////////////
INT_0:

push r16
push r17
push r18
in  r16,sreg
push r16
```

```
mov r16, primera_vez
cpi r16, 1
brne es_primera_vez

ldi r16, 0
mov primera_vez, r16

mov fin, cont_int
mov r16, fin
clr r18
;****sacar de FIN tabla RPM *****

ldi ZH,high(TablaRPM*2) ;Z apunta al inicio de la tabla
ldi ZL,low(TablaRPM*2)
add zl,r16
adc zh,r18
lpm r25,z

pop r16
out sreg,r16
pop r18
pop r17
pop r16

;rcall retardo500us
;rcall retardo500us
```

```
reti

es_primera_vez:
ldi r17, 0
mov cont_int, r17
ldi r16, 1
mov primera_vez, r16

pop r16
out sreg,r16
pop r18
pop r17
pop r16

;rcall retardo500us
;rcall retardo500us

reti

;*********************************
;*********************************
;TABLAS:
;*********************************
;*********************************
TablaTecla:
```

```
;.DB 9, 3, 3, 4, 3, 3, 3, 5, 3, 3, 3, 6, 7, 3, 8, 9
;.DB 1, 2, 3, 11, 4, 5, 6, 11, 7, 8, 9, 11, 11, 0, 11, 11
.DB 1, 4, 7, 11, 2, 5, 8, 0, 3, 6, 9, 11, 11, 11, 11, 11
TablaRPM:
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
```

```
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
.DB 255,255
```

.DB 255,255

.DB 254,253

.DB 250,248

.DB 245,243

.DB 240,238

.DB 236,234

.DB 231,229

.DB 227,225

.DB 223,221

.DB 219,217

.DB 216,214

.DB 212,210

.DB 208,207

.DB 205,203

.DB 202,200

.DB 198,197

.DB 195,194

.DB 192,191

.DB 189,188

.DB 187,185

.DB 184,182

.DB 181,180

.DB 179,177

.DB 176,175

.DB 174,172

.DB 171,170

.DB 169,168

.DB 167,166

.DB 164,163

.DB 162,161

.DB 160,159

.DB 158,157

.DB 156,155

.DB 154,153

.DB 152,152

.DB 151,150

.DB 149,148

.DB 147,146

.DB 145,145

.DB 144,143

.DB 142,141

.DB 140,140

.DB 139,138

.DB 137,137

.DB 136,135

.DB 134,134

.DB 133,132

.DB 132,131

.DB 130,130

.DB 129,128

.DB 128,127

.DB 126,126

.DB 125,124

.DB 124,123

.DB 123,122

.DB 121,121

.DB 120,120

.DB 119,118

.DB 118,117

.DB 117,116

.DB 116,115

.DB 115,114

.DB 114,113

.DB 113,112

.DB 112,111

.DB 111,110

.DB 110,109

.DB 109,108

.DB 108,107

.DB 107,106

.DB 106,105

.DB 105,105

.DB 104,104

.DB 103,103

.DB 102,102

.DB 102,101

.DB 101,100

temperaturas:

.db 0,0

.db 1,1

.db 1,1

.db 2,2

.db 2,2

.db 3,3

.db 3,3

.db 4,4

.db 4,4

.db 5,5

.db 5,5

.db 6,6

.db 6,6

.db 7,7

.db 7,7

.db 8,8

.db 8,8

.db 9,9

.db 9,9

.db 10,10

.db 10,10

.db 11,11

.db 11,11

.db 12,12

.db 12,12

.db 13,13

.db 13,14

.db 14,14

.db 14,15

.db 15,15

.db 15,16

.db 16,16

.db 16,17

.db 17,17

.db 17,18

.db 18,18

.db 18,19

.db 19,19

.db 19,20

.db 20,20

.db 20,21

.db 21,21

.db 21,22

.db 22,22

.db 22,23

.db 23,23

.db 23,24

.db 24,24

.db 24,25

.db 25,25

.db 25,26

.db 26,26

.db 27,27

.db 27,27

.db 28,28

.db 28,28

.db 29,29

.db 29,29

.db 30,30

.db 30,30

.db 31,31

.db 31,31

.db 32,32

.db 32,32

.db 33,33

.db 33,33

.db 34,34

.db 34,34

.db 35,35

.db 35,35

.db 36,36

.db 36,36

.db 37,37

.db 37,37

.db 38,38

.db 38,38

.db 39,39

.db 39,40

.db 40,40

.db 40,41

.db 41,41

.db 41,42

.db 42,42

.db 42,43

.db 43,43

.db 43,44

.db 44,44

.db 44,45

.db 45,45

.db 45,46

.db 46,46

.db 46,47

.db 47,47

.db 47,48

.db 48,48

.db 48,49

.db 49,49

.db 49,50

.db 50,50

.db 50,51

.db 51,51

.db 51,52

.db 52,52

.db 53,53

.db 53,53

.db 54,54

.db 54,54

.db 55,55

.db 55,55

.db 56,56

.db 56,56

.db 57,57

.db 57,57

.db 58,58

.db 58,58

.db 59,59

.db 59,59

.db 60,60

.db 60,60

.db 61,61

.db 61,61

.db 62,62

.db 62,62

.db 63,63

.db 63,63

.db 64,64

.db 64,64

.db 65,65

ANEXO E: DATOS OBTENIDOS EN LAS PRUEBAS DE VELOCIDAD DEL MOTOR

Ensayo para 1 minuto y 120 Rpm

Tiempo (s)	Temperatura Desada (°C)	Temperatura Medida Termocupla (°C)	Tempetaruta Medida Agitador (°C)
0	120	114	114
1	120	118	118
2	120	121	121
3	120	120	120
4	120	119	119
5	120	121	121
6	120	120	120
7	120	120	120
8	120	119	119
9	120	120	120
10	120	120	120
11	120	121	121
12	120	121	121
13	120	121	121
14	120	120	120
15	120	119	119
16	120	119	119
17	120	120	120
18	120	120	120
19	120	120	120
20	120	120	120
21	120	121	121
22	120	120	120
23	120	119	119
24	120	121	121
25	120	121	121
26	120	121	121
27	120	119	119
28	120	120	120
29	120	121	121
30	120	121	121
31	120	120	120
32	120	119	119
33	120	119	119
34	120	120	120

35	120	120	120
36	120	121	121
37	120	121	121
38	120	119	119
39	120	119	119
40	120	120	120
41	120	120	120
42	120	121	121
43	120	121	121
44	120	120	120
45	120	120	120
46	120	120	120
47	120	119	119
48	120	120	120
49	120	120	120
50	120	121	121
51	120	121	121
52	120	120	120
53	120	120	120
54	120	119	119
55	120	119	119
56	120	120	120
57	120	121	121
58	120	120	120
59	120	119	119
60	120	120	120

Ensayo para 4 minutos y 130 Rpm

Tiempo (s)	Velocidad Deseada (RPM)	Velocidad Medida Tacómetro (RPM)	Velocidad Medida Agitador (RPM)
0	130	114	114
4	130	118	118
8	130	121	121
12	130	126	126
16	130	130	130
20	130	129	129
24	130	131	131
28	130	131	131

32	130	131	131
36	130	130	130
40	130	131	131
44	130	129	129
48	130	129	129
52	130	129	129
56	130	130	130
60	130	130	130
64	130	131	131
68	130	131	131
72	130	129	129
76	130	129	129
80	130	130	130
84	130	130	130
88	130	129	129
92	130	129	129
96	130	130	130
100	130	130	130
104	130	129	129
108	130	131	131
112	130	130	130
116	130	131	131
120	130	131	131
124	130	131	131
128	130	129	129
132	130	130	130
136	130	131	131
140	130	130	130
144	130	130	130
148	130	131	131
152	130	129	129
156	130	129	129
160	130	130	130
164	130	131	131
168	130	131	131
172	130	130	130
176	130	131	131
180	130	129	129
184	130	129	129
188	130	130	130
192	130	129	129

196	130	131	131
200	130	131	131
204	130	131	131
208	130	129	129
212	130	130	130
216	130	130	130
220	130	129	129
224	130	131	131
228	130	131	131
232	130	129	129
236	130	130	130
240	130	131	131

ANEXO F: DATOS OBTENIDOS EN LAS PRUEBAS DE TEMPERATURA

Ensayo para 1 minuto y 27°C

Tiempo (s)	Temperatura Desada (°C)	Temperatura Medida Termocupla (°C)	Tempetaruta Medida Agitador (°C)
0	27	23	23
1	27	23	23
2	27	24	23
3	27	25	24
4	27	26	24
5	27	27	25
6	27	28	26
7	27	29	26
8	27	28	28
9	27	27	27
10	27	26	27
11	27	27	26
12	27	27	26
13	27	29	27
14	27	28	28
15	27	26	27
16	27	27	26
17	27	28	29
18	27	26	28
19	27	25	26
20	27	25	27

21	27	27	29
22	27	27	29
23	27	29	28
24	27	28	27
25	27	26	27
26	27	25	26
27	27	26	25
28	27	28	26
29	27	29	27
30	27	29	28
31	27	28	29
32	27	27	28
33	27	27	27
34	27	26	27
35	27	25	26
36	27	26	26
37	27	27	26
38	27	28	26
39	27	29	28
40	27	28	29
41	27	25	27
42	27	26	28
43	27	27	29
44	27	26	28
45	27	25	27
46	27	25	26
47	27	27	26
48	27	28	27
49	27	29	28
50	27	27	29
51	27	27	28
52	27	26	28
53	27	25	27
54	27	25	25
55	27	26	26
56	27	26	27
57	27	27	28
58	27	27	29
59	27	29	29
60	27	28	28

Ensayo para 2 minutos y 35°C

Tiempo (s)	Temperatura Desada (°C)	Temperatura Medida Termocupla (°C)	Tempetaruta Medida Agitador (°C)
0	35	23	23
2	35	24	24
4	35	26	26
6	35	28	27
8	35	30	28
10	35	32	30
12	35	34	31
14	35	36	33
16	35	37	35
18	35	37	36
20	35	36	38
22	35	36	37
24	35	35	37
26	35	34	36
28	35	33	35
30	35	33	34
32	35	34	33
34	35	35	34
36	35	36	36
38	35	36	37
40	35	37	36
42	35	39	38
44	35	36	38
46	35	37	37
48	35	36	37
50	35	35	36
52	35	34	35
54	35	33	35
56	35	33	34
58	35	34	33
60	35	35	34
62	35	35	36
64	35	36	36
66	35	36	37
68	35	37	37
70	35	36	34
72	35	36	34

74	35	35	36
76	35	33	35
78	35	34	33
80	35	37	35
82	35	36	37
84	35	34	36
86	35	33	34
88	35	35	34
90	35	37	36
92	35	36	38
94	35	35	37
96	35	34	36
98	35	34	34
100	35	33	34
102	35	34	33
104	35	36	34
106	35	37	36
108	35	38	35
110	35	36	34
112	35	35	34
114	35	35	33
116	35	34	33
118	35	33	35
120	35	34	36

Ensayo para 4 minutos y 40°C

Tiempo (s)	Temperatura Desada (°C)	Temperatura Medida Termocupla (°C)	Tempetaruta Medida Agitador (°C)
0	40	23	23
4	40	26	25
8	40	29	27
12	40	33	30
16	40	36	33
20	40	38	36
24	40	40	39
28	40	42	40
32	40	43	41
36	40	43	41
40	40	42	43

44	40	41	43
48	40	39	41
52	40	38	39
56	40	40	40
60	40	42	41
64	40	42	39
68	40	41	37
72	40	39	38
76	40	40	39
80	40	43	41
84	40	42	42
88	40	41	43
92	40	39	42
96	40	38	39
100	40	38	38
104	40	40	39
108	40	42	41
112	40	42	42
116	40	41	42
120	40	40	41
124	40	38	39
128	40	37	38
132	40	38	38
136	40	40	39
140	40	42	41
144	40	43	42
148	40	42	43
152	40	40	41
156	40	38	39
160	40	37	38
164	40	39	38
168	40	41	39
172	40	42	39
176	40	43	40
180	40	43	41
184	40	42	42
188	40	41	42
192	40	40	41
196	40	38	41
200	40	38	40
204	40	37	39

208	40	38	38
212	40	40	38
216	40	41	37
220	40	42	39
224	40	43	42
228	40	41	43
232	40	40	42
236	40	38	39
240	40	39	38