National Centre for Radio Astrophysics

Tata Institute of Fundamental Research

Pune University Campus, Pune INDIA

TEMPERATURE MONITORING SYSTEM FOR FRONT END RECEIVER

***Bhalerao Vilas, S Suresh Kumar*.**

Front End Group.

Giant Metrewave Radio Telescope , Narayangaon, Khodad. 410504.

vilas@gmrt.ncra.tifr.res.in

Author : Bhalerao Vilas **Verified by :** ***S Suresh Kumar***	**Date of issue:** **24/02/2015**	**Scope: Temperature Monitoring System for Front End System.**
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Abstract

The purpose of this project is to provide online information of temperature variation in all front end sub band boxes, temperature inside the corresponding Low Noise Amplifier (LNA) and Common Box for Front End Systems of GMRT.

This also useful to study the Noise temperature (T_{LNA}) variation of various LNA used in Front End System.

Acknowledgements

I am thankful to our Senior Engineer and Group Coordinator Mr. S. Sureshkumar , who has assigned me the job to design the temperature monitoring system , testing and installation for the Front End boxes and Common Boxes.

I am very much thankful for his guidance, constant encouragement, supervision, motivation and his support and help in preparing this report.

I am thankful to Prof. Yashwant Gupta (Dean-GMRT) and Prof. S K Ghosh (Center Director of NCRA-TIFR) for giving constant support during this work.

I am very much thankful to Shri.Jitendra Kodilkar who modified online code for temperature monitoring for Front End System.

I wish to express my sincere gratitude to all our front-end colleagues.

Index

1.Overview of GMRT Receiver System

Giant Meter-wave Radio Telescope (GMRT) currently operates at five observing bands centered at 150 MHz, 235 MHz, 327 MHz, 610 MHz and an L-band extending from 1000 to 1450 MHz. The L-band is split into four sub bands centered at 1060MHz, 1170 MHz, 1280 MHz and 1390 MHz, each with a bandwidth of 120 MHz. The L-band receiver also has a bypass mode in which the entire RF band can be brought down to the Antenna Base Receiver (ABR).

The 150 MHz, 235 MHz, 327 MHz bands of GMRT have 40 MHz bandwidth and 610 MHz band has about 60 MHz of bandwidth. Lower frequency bands from 150 to 610 MHz have dual circular polarization which is named as CH1 and CH2 for right hand circular polarization and left hand circular polarization respectively. The higher frequency L-band has dual linear polarization (Vertical and Horizontal polarization) named CH1 and CH2 respectively. At the lower frequencies the polarizer placed before the Low Noise Amplifier (LNA) converts the received linear polarization to circular. At L-band, in order to keep the system temperature low, this element is not inserted into the signal path, and the linear polarized signals are fed directly to the LNA. To calibrate the gain of the receiver chain, it is possible to inject an additional noise signal (of known strength) into the input of the LNA. It is possible to inject noise at any one of four levels. These are called Low cal, Medium cal, High cal and Extra high cal and are of monotonically increasing strength.

To minimize crosstalk between different signals a phase switching facility using separate Walsh functions for each signal path is available at the RF section of the receiver.

At the Common Box the signals go through one additional stage of amplification. The common box has a broad band amplifier which covers the entire frequency range of the GMRT (10 – 1800 MHz).

The band selector in the common box can be configured to take signals from any one of the six RF Front Ends. The common box (and the entire receiver system) has the flexibility to be configured for receiving either both polarizations at a single frequency band or a single polarization at each of two different frequency bands. It is also possible to swap the polarization channels whenever required. For observing strong radio sources like Sun, solar attenuators of 14 dB, 30 dB or 44 dB are available in the common box. In addition there is a power monitor whose output can be continuously monitored to verify the health of the subsystems upstream of the common box.

The first synthesized local oscillator converts the RF band to an IF band centered at 70 MHz. The synthesized local oscillator has a frequency range of 100 MHz to 1795 MHz. The frequency range 100 MHz to 600 MHz is covered by synthesizer-1 and 605 MHz to 1795 MHz is covered by synthesizer-2. The local oscillator frequency from 100 MHz to 354 MHz can be set with a step size of 1 MHz and the frequency range from 355 MHz to 1795 MHz can be set with a step size of 5 MHz. At the IF stage, bandwidth of 5.5 MHz, 16 MHz or a full available RF bandwidth can be selected. The IF at 70 MHz is then translated to a second IF at 130 MHz and 175 MHz for CH1 and CH2 respectively.

The maximum bandwidth available at this stage is 32 MHz for each polarization channel this frequency translation is done so that they can be transported to Central Electronics Building (CEB) over a single fiber optic cable. An Automatic Level Control (ALC) facility is provided at the output stage of IF which can be bypassed whenever required.

The IF signal at 130 MHz and 175 MHz along with telemetry and LO round trip phase carriers directly modulate a laser diode operating at 1300 nm wavelength which is coupled to a single mode fiber-optic link between the receiving antennas and the CEB.

TEMPERATURE SENSOR

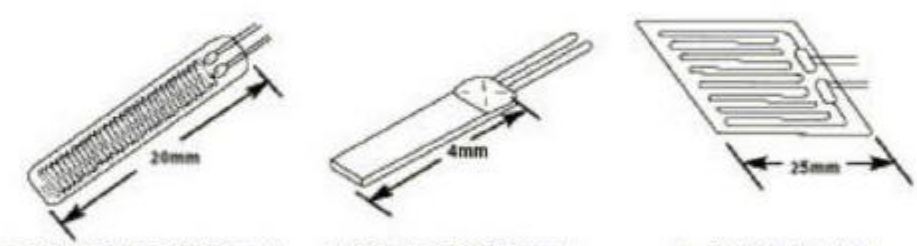
There are a wide variety of temperature sensors on the market today, including Thermocouples, Resistance Temperature Detectors (RTDs), Thermistors, Infrared, and Semiconductor Sensors.
We will discuss three of these alternatives: the RTD, thermistor, and semiconductor sensors.

1 Resistance Temperature Detectors (RTDs)
2 Thermistors
3 IC Temperature Sensors

Resistance Temperature Detector (RTD)

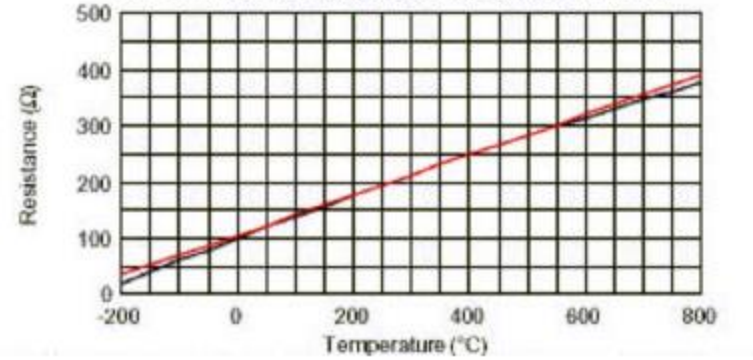
The RTD is a temperature sensing device whose resistance changes with temperature. Typically built from platinum, though devices made from nickel or copper are not uncommon, RTDs can take many different shapes (figure 1). To measure the resistance across an RTD, apply a constant current, measure the resulting voltage, and determine the RTD resistance. We then use a resistance vs. temperature plot to determine the temperature of the surrounding medium (figure 2). RTDs exhibit fairly linear resistance to temperature curves over their operating regions, and any nonlinearities are highly predictable and repeatable.

Figure 1
RTD element styles [2, p.17]



a. Wire-Wound RTD Element
b. Thin film RTD Element
c. Kapton Insulated RTD Element

Figure 2
RTD Resistance vs. Temperature
upper curve is straight line reference [1, p.6]



The RTD requires external current excitation, as well as signal conditioning to account for lead wire effects and self-heating.

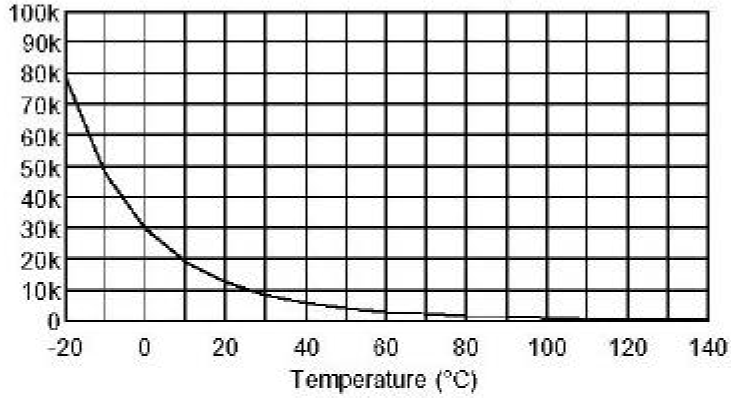
Thermistor

Similar to the RTD, the thermistor is a temperature sensing device whose resistance changes with temperature. Thermistors, however, are made from semiconductor materials (figure 4). Resistance is determined in the same manner as the RTD, but thermistors exhibit a highly nonlinear resistance vs. temperature curve (figure 5). Thus, in the thermistor's operating range we can see a large resistance change for a very small temperature change.

This makes for a highly sensitive device, ideal for set-point applications.

Figure 4
Thermistor element styles [2, p.24]

Figure 5
Thermistor Resistance vs. Temperature [1, p.8]



Like the RTD, thermistors require external current excitation and significant signal conditioning.

IC Temperature Sensors

RTDs and thermistors may be simple devices, but they are likely not suited to any mechatronics application. We need to buy the sensor, purchase a chip or create our own circuitry to apply a constant current and measure the resulting voltage, and run this output through and ADC. All these components need to be matched, for example the ADC needs to have high enough resolution to take advantage of the 10mv/°C change from the LM35. This can end up being quite complicated and costly.

Chips with temperature sensors built into the integrated circuit may be a better alternative.
IC temperature sensors employ the principle that a bipolar junction transistor's (BJT) base-emitter voltage to collector current varies with temperature:

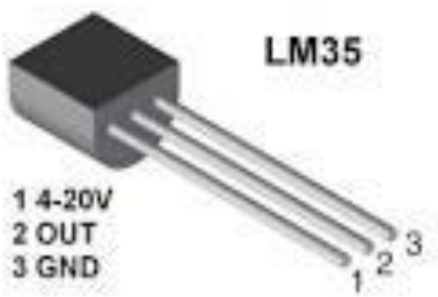
As the temperature sensor is built into the integrated circuit, manufacturers can do all the design for us.

LM35

Precision Centigrade Temperature Sensors

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 ± 1/4°C at room temperature and ± 3/4°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 pack-aged 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-220 package.

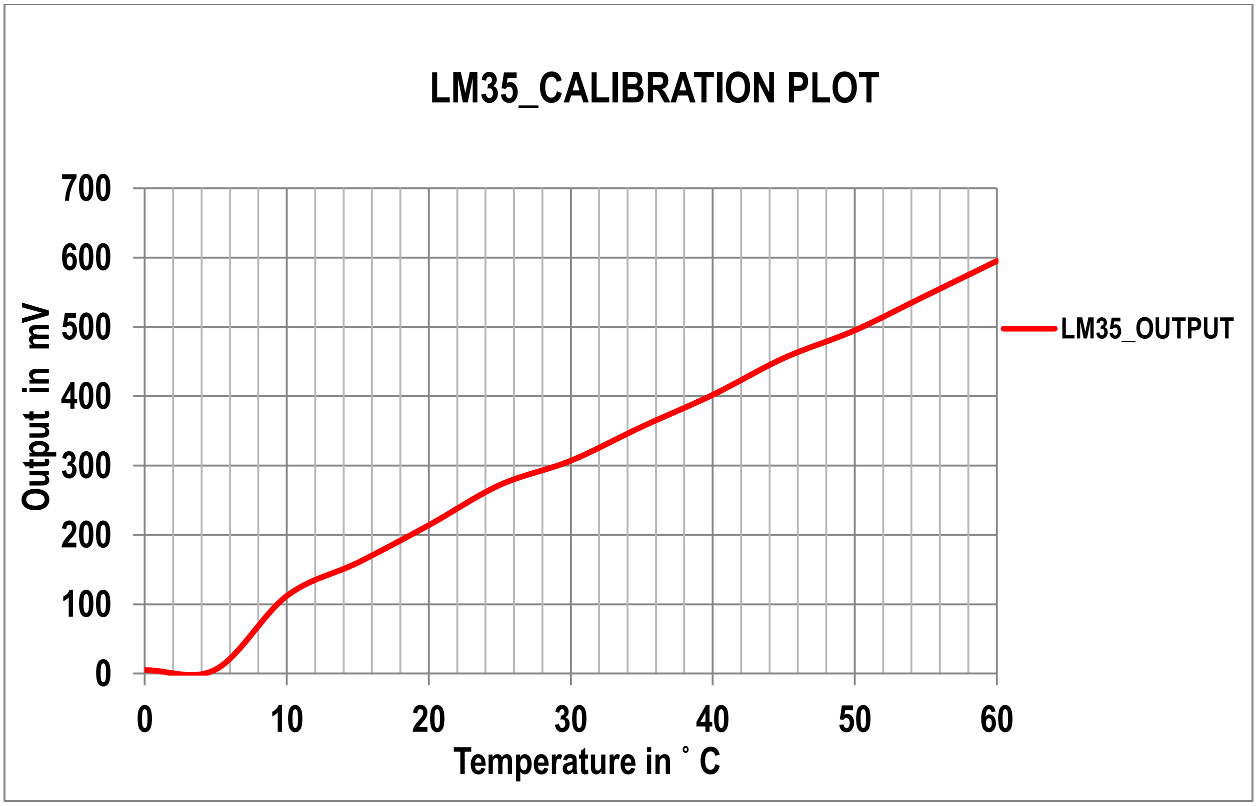
LM 35 Features:



1. Calibrated directly in ° Celsius (Centigrade)
2. Linear + 10.0 mV/°C scale factor
3. 0.5°C accuracy guarantee able (at +25°C)
4. Rated for full -55° to +150°C range
5. Suitable for remote applications
6. Low cost due to wafer-level trimming
7. Operates from 4 to 30 volts
8. Less than 60 µA current drain
9. Low self-heating, 0.08°C in still air
10. Low impedance output, 0.1 Ω for 1 mA load

Observation Table:

Sr.No.	Chamber Temperature in ˚C	LM35 Output voltage in V.
1	00	0.005
2	05	0.060
3	10	0.112
4	15	0.160
5	20	0.214
6	25	0.272
7	30	0.307
8	35	0.356
9	40	0.402
10	45	0.455
11	50	0.495
12	55	0.545
13	60	0.595

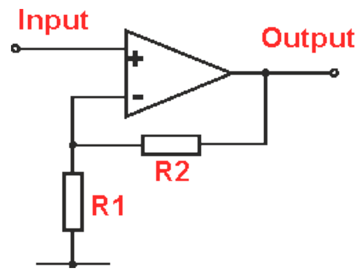


Basic non-inverting operational amplifier :

When an operational amplifier or op-amp is used as a non-inverting amplifier it only requires a few additional components to create a working amplifier circuit.

Non-inverting amplifier circuit

The basic non-inverting amplifier circuit using an op-amp is shown below. In this circuit the signal is applied to the non-inverting input of the amplifier. However the feedback is taken from the output via a resistor to the inverting input of the operational amplifier where another resistor is taken to ground. It is the value of these two resistors that govern the gain of the operational amplifier circuit.



Basic non-inverting operational amplifier circuit

The gain of the non-inverting amplifier circuit for the operational amplifier is easy to determine. The calculation hinges around the fact that the voltage at both inputs is the same. This arises from the fact that the gain of the amplifier is exceedingly high. If the output of the circuit remains within the supply rails of the amplifier, then the output voltage divided by the gain means that there is virtually no difference between the two inputs.

As the input to the op-amp draws no current this means that the current flowing in the resistors R1 and R2 is the same. The voltage at the inverting input is formed from a potential divider consisting of R1 and R2, and as the voltage at both inputs is the same, the voltage at the inverting input must be the same as that at the non-inverting input. This means that Vin = Vout x R1 / (R1 + R2). Hence the voltage gain of the circuit Av can be taken as:

$$\frac{V_{out}}{V_{in}} = A_v = 1 + \frac{R_2}{R_1}$$

Circuit Design :

This is a simple 0-60°C digital thermometer with 0.5°C resolution using MCM

(Monitoring and Control Module ,80535 microcontroller base with in build 8 bit ADC)

MCM is a general purpose Micro-controller based card which provides 16 TTL Control O/Ps and monitors 64 analog signals. Antcom communicates with MCMs thro' RS485 communication link @ 9.6 K baud rate and sets various FE, LO and IF system parameters. MCM card has input voltage range of -5 volt to + 5 volt.

Resolution = Voltage range / (counts - 1)

= 10 V / (2^8 - 1) = 10 V / 255

= 0.0392 V = 39.2 mV

For achieving 0.5 °C resolution we need the voltage gain of 8. This means that for 1°C a 10 mV input to the amplifier will give the out of 80 mV and for 60 °C a 600 mV input to the amplifier will give the out of 4800 mV .

The circuit is based on LM35 analog temperature sensor and dual op-amp LM358 .

LM35 is an analogue temperature sensor IC which can measure a temperature range of -55 to 150°C. Its output voltage varies 10mV per °C change in temperature.

For example, if the temperature is 32°C, the output voltage will be 32 x 10mV = 320mV.

The LM35 is used to convert the temperature into analog output voltage and amplified with gain of 8.

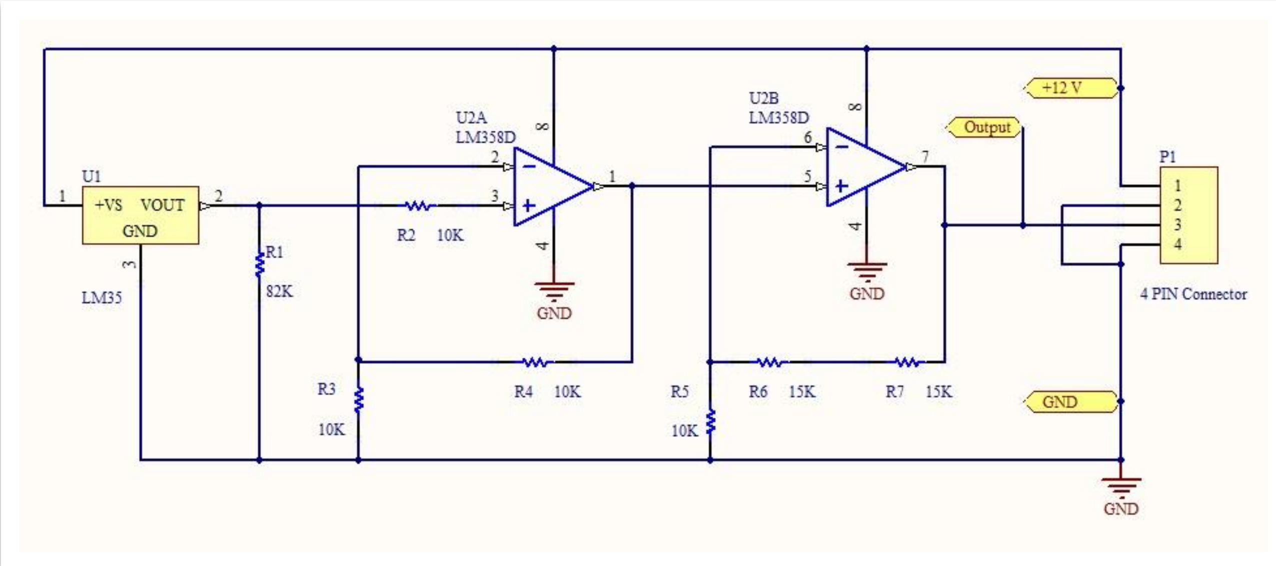


Fig.1 (Schematic diagram of Temperature monitoring with LM35 and LM358.)

The gain of first non-inverting amplifier G1 is

$$G1 = 1 + (R_F/R_1)$$

$$= 1 + (10K/10K)$$

$$= 1 + 1$$

$$= 2$$

The gain of second non-inverting amplifier G2 is

$$G2 = 1 + (R_F/R_1)$$

$$= 1 + (30K/10K)$$

$$= 1 + 3$$

$$= 4$$

Total Gain G = G1 . G2 = 2 . 4 = 8

Bill of material

Sr.No.	Items	Quantity
1	LM 35	1 no.
2	LM358	1 no.
3	10K ohm 1%	4 nos.
5	15 K ohm 1%	2 nos.
6	82K ohm 1%	1 no.
7	4 Pin male-female ralimate connector	1 no.
8	Printed circuit Board	1 no.

The output of the LM35 is connected to the +Vin (pin 3) of the LM358 through 10 K resistor.

The amplified output from (pin 7) of the LM358 is connected to the analog input of MCM card in common box for monitoring the temperature inside the common box.

For monitoring the temperatures inside the LNA (Low Noise Amplifier) LM35 sensor is placed over the surface of LNA device and temperature PCB mounted outside the LNA chassis in Front End box. The output from this card is connected to the analog input of RF-CM card .Another temperature PCB mounted inside the Front End Box is mounted for monitoring the temperature inside the Front End Box.

Connection details:

FE Box monitoring (ADG-506) RFCM Card:

1) Pin no. 10 : LNA temperature. **[MCM CH-24]**
2) Pin no. 11 : FE Box temperature. **[MCM CH-25]**

Common Box monitoring BSCTL CH-1 Card : Pin 25 of FRC (J6) **[MCM CH-57]**

The microcontroller accepts the output of ADC, performs necessary manipulations on it and displays it on Monitor and also write the data into CSV format so that one can easily import into suitable software like MATLAB or Excel to plot entire data.

DC Amplifier observation table for gain of 4 and 8

Sr. nos.	I/P Voltage in (mV)	O/P Voltage in (mV) Gain 4	O/P Voltage In (mV) Gain 8	Sr. nos.	I/P Voltage in (mV)	O/P Voltage in (mV) Gain 4	O/P Voltage in (mV) Gain 8
1	10	44.2	88.4	41	410	1649	3298
2	20	79.2	158.4	42	420	1688	3376
3	30	118.1	236.2	43	430	1731	3462
4	40	157.7	315.4	44	440	1772	3544
5	50	202.2	404.4	45	450	1828	3656
6	60	241.9	483.8	46	460	1851	3702
7	70	281.6	563.2	47	470	1893	3786
8	80	324	648	48	480	1935	3870
9	90	362.9	725.8	49	490	1975	3950
10	100	405	810	50	500	2012	4024
11	110	444.7	889.4	51	510	2052	4104
12	120	482	964	52	520	2093	4186
13	130	522.8	1045.6	53	530	2134	4268
14	140	562	1124	54	540	2173	4346
15	150	604	1208	55	550	2217	4434
16	160	640.9	1281.8	56	560	2255	4510
17	170	684	1368	57	570	2292	4584
18	180	724	1448	58	580	2333	4666
19	190	764	1528	59	590	2374	4748
20	200	809	1618	60	600	2416	4832
21	210	839	1678	61	610	2453	4906
22	220	883	1766	62	620	2497	4994
23	230	927.7	1855.4	63	630	2535	5070
24	240	967	1934	64	640	2574	5148
25	250	1000	2000	65	650	2614	5228
26	260	1048	2096	66	660	2655	5310
27	270	1086	2172	67	670	2695	5390
28	280	1127	2254	68	680	2736	5472
29	290	1166	2332	69	690	2777	5554
30	300	1207	2414	70	700	2816	5632
31	310	1248	2496	71	710	2856	5712
32	320	1289	2578	72	720	2897	5794
33	330	1329	2658	73	730	2936	5872
34	340	1370	2740	74	740	2975	5950
35	350	1407	2814	75	750	3019	6038
36	360	1448	2896	76	760	3057	6114
37	370	1490	2980	77	770	3097	6194
38	380	1531	3062	78	780	3137	6274
39	390	1569	3138	79	790	3177	6354
40	400	1611	3222	80	800	3217	6434

Temperature sensor LM35 with DC Amplifier observation table for gain of 4 and 8

Sr. nos.	Chamber Temp. in ˚C	O/P Voltage in (mV) Gain 4	O/P Voltage In (mV) Gain 8	Sr. nos.	Chamber Temp. in ˚C	O/P Voltage in (mV) Gain 4	O/P Voltage In (mV) Gain 8
1	21	800	1600	21	41	1578	3156
2	22	850	1700	22	42	1618	3236
3	23	896	1792	23	43	1659	3318
4	24	932	1864	24	44	1698	3396
5	25	966	1932	25	45	1736	3472
6	26	1002	2004	26	46	1776	3552
7	27	1032	2064	27	47	1817	3634
8	28	1059	2118	28	48	1859	3718
9	29	1090	2180	29	49	1899	3798
10	30	1146	2292	30	50	1940	3880
11	31	1192	2384	31	51	1980	3960
12	32	1242	2484	32	52	2020	4040
13	33	1267	2534	33	53	2060	4120
14	34	1304	2608	34	54	2100	4200
15	35	1338	2676	35	55	2140	4280
16	36	1373	2746	36	56	2180	4360
17	37	1415	2830	37	57	2219	4438
18	38	1457	2914	38	58	2255	4510
19	39	1500	3000	39	59	2300	4600
20	40	1540	3080	40	60	2334	4668

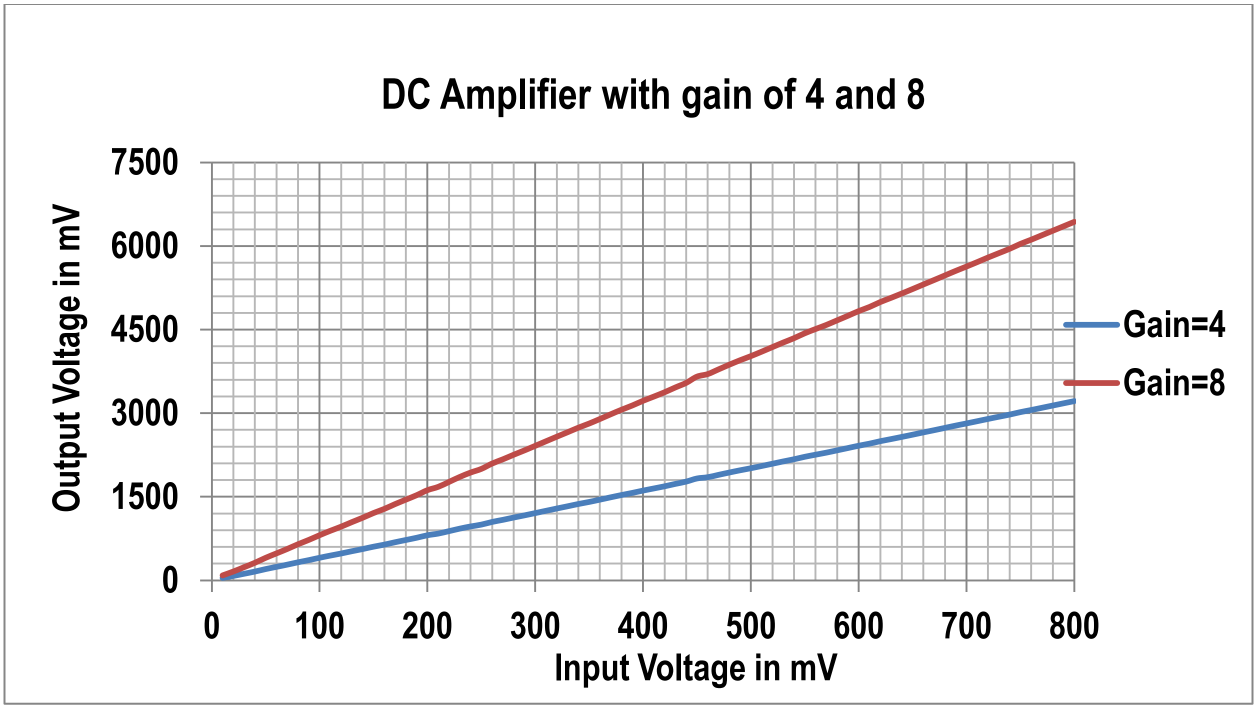


Fig.2 (Non-inverting DC amplifier with voltage gain of 4 and 8 when DC input voltage is given)

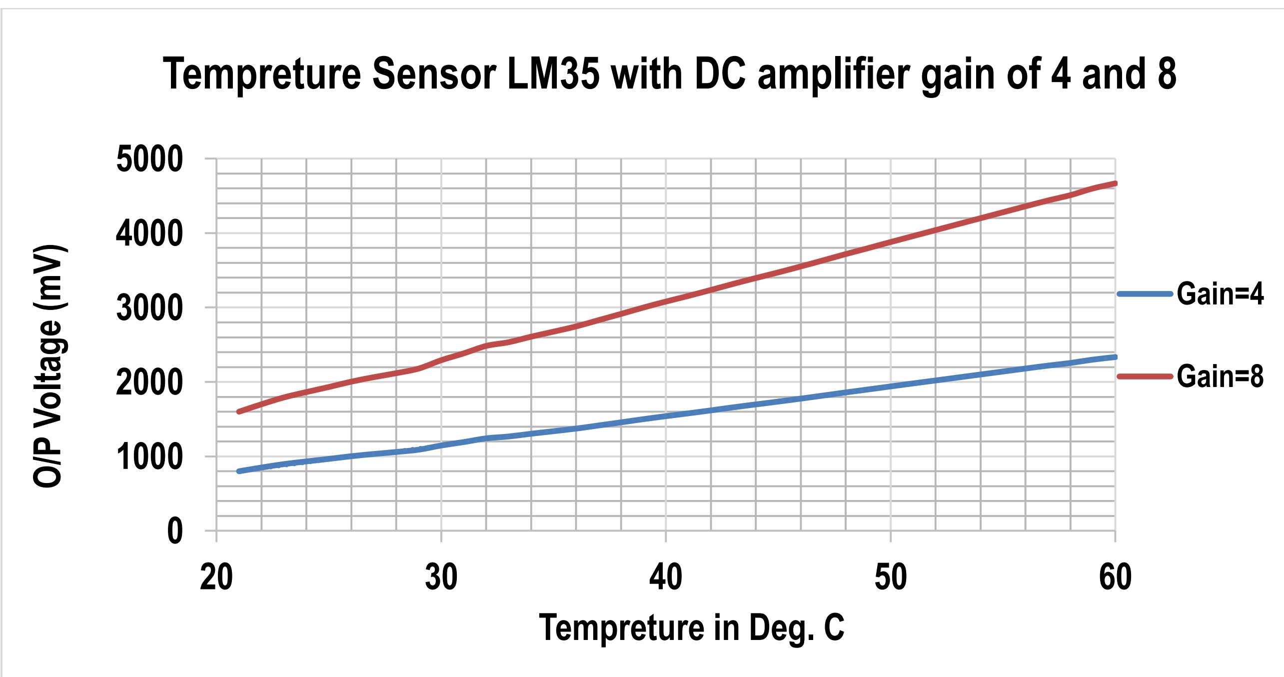


Fig.3 (Non-inverting DC amplifier with voltage gain of 4 and 8 when LM35 output is given)

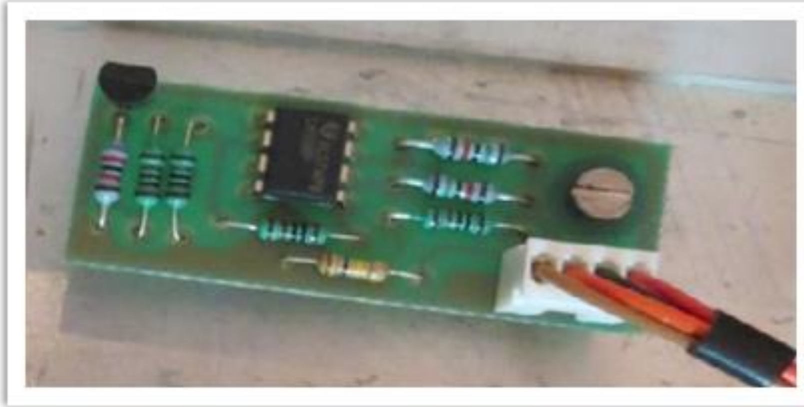


Fig.4 (Temperature monitoring Card with LM35)

Fig.5 (Temperature sensor LM35 inside LNA chassis)

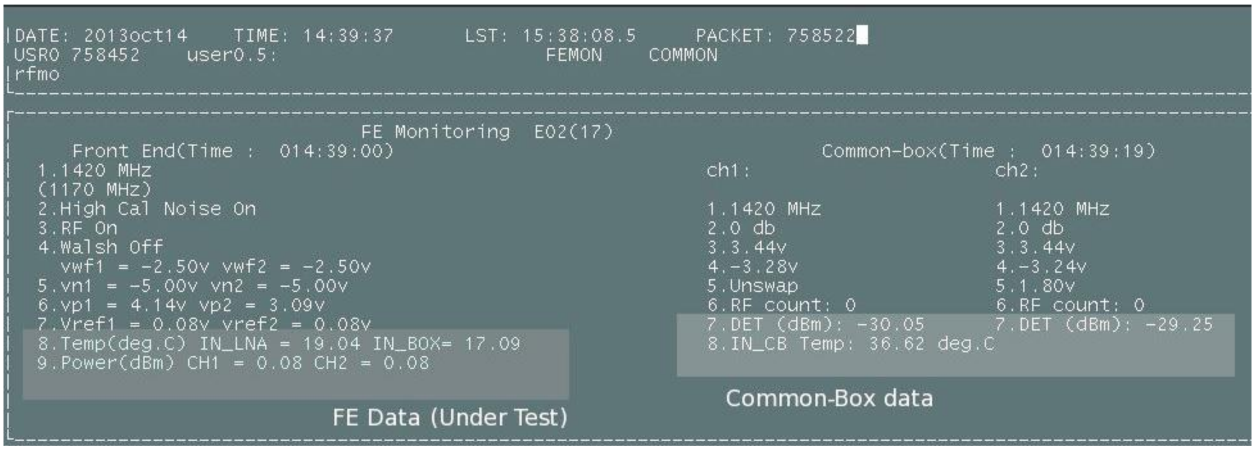


Fig.6 (Temperature monitoring window from control room)

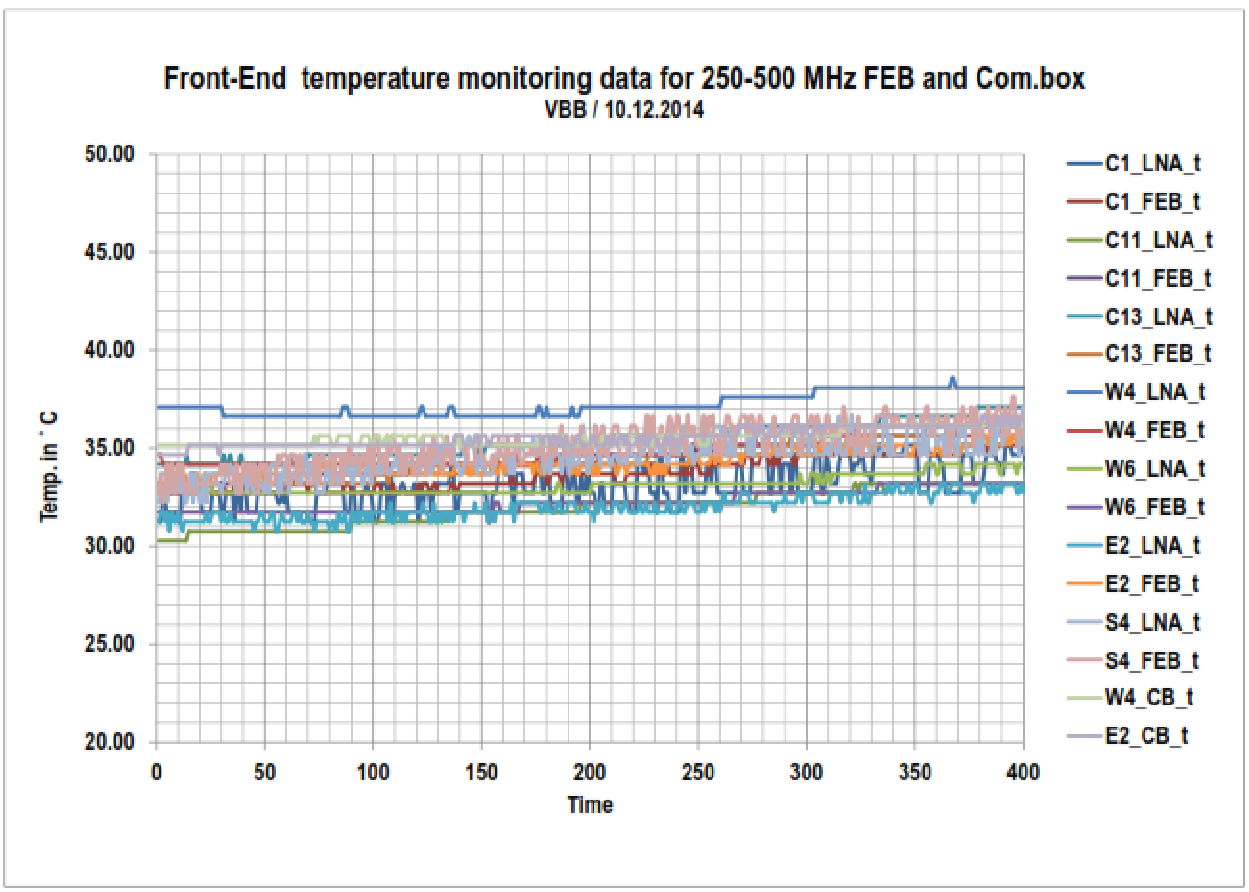
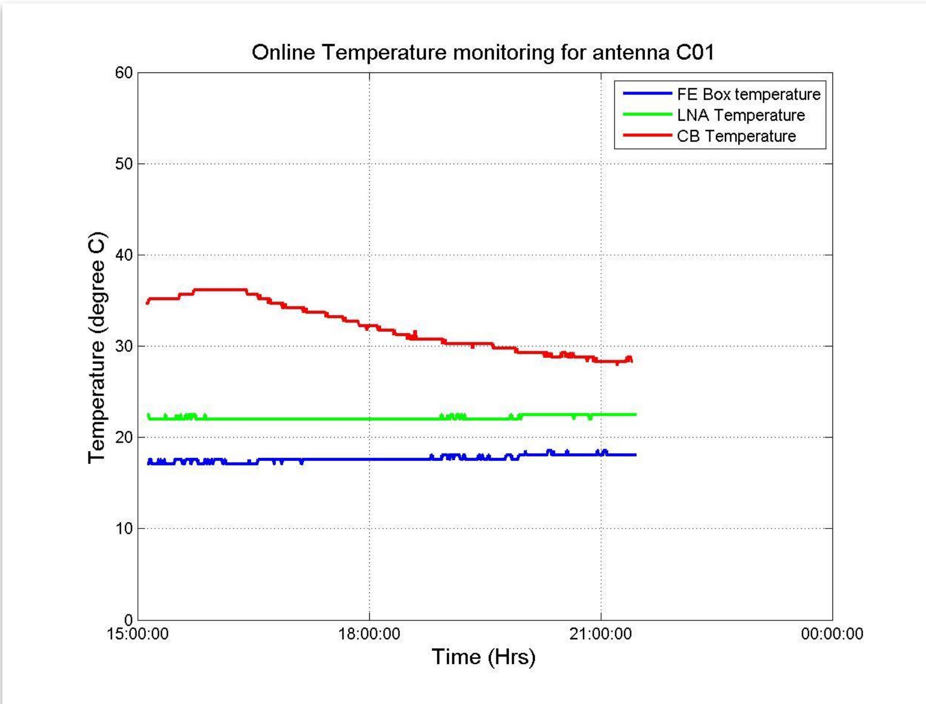
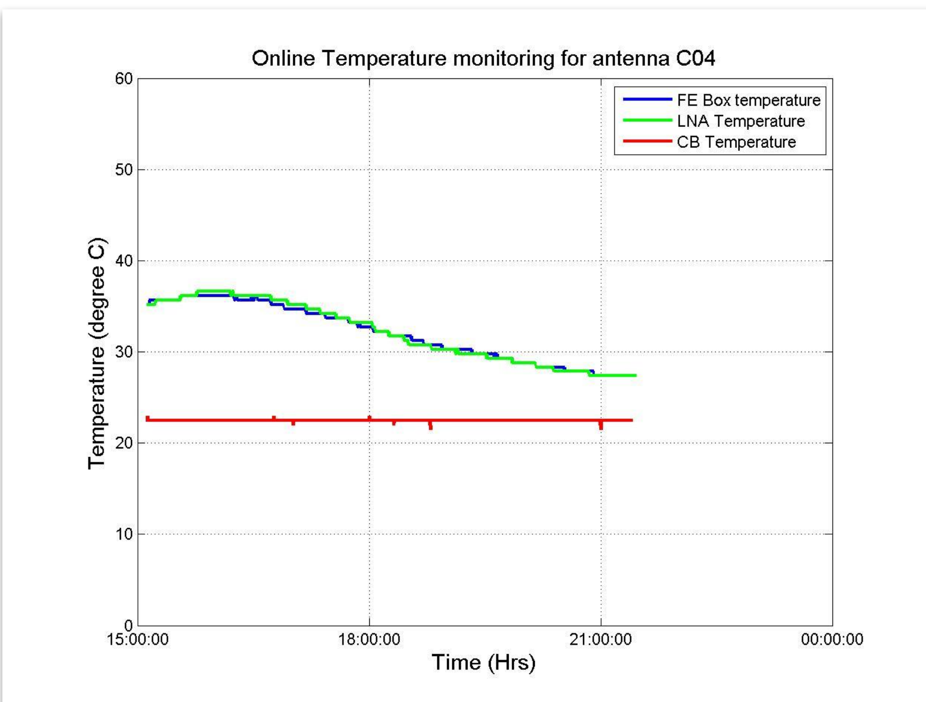
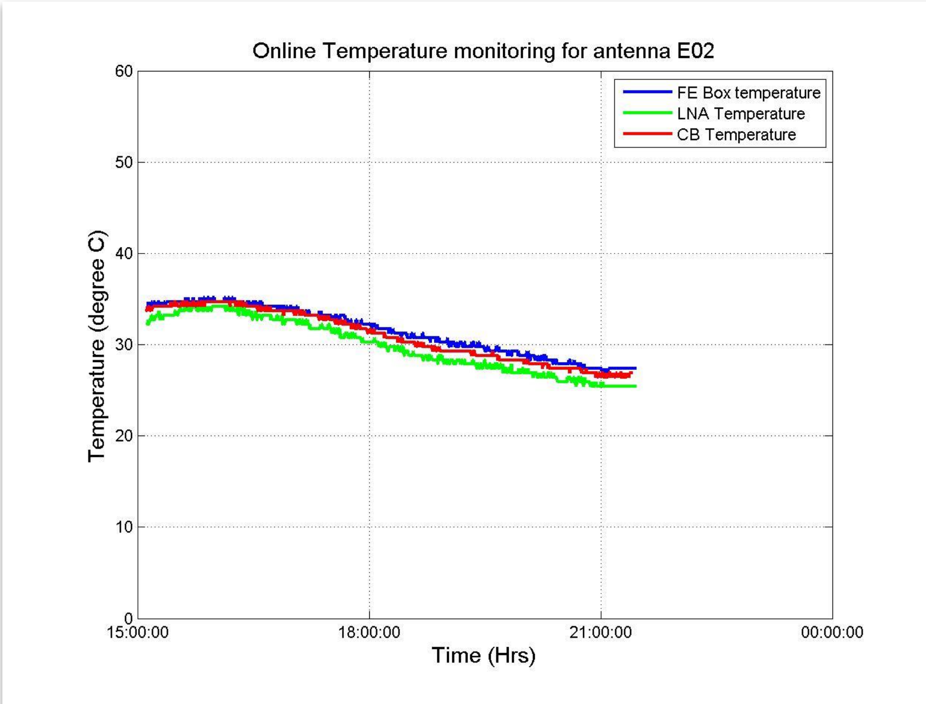


Fig.7 (Temperature data plot of installed temperature monitoring card at various antenna)


Online Temperature monitoring for antenna C01
FE Box temperature
LNA Temperature
CB Temperature
Temperature (degree C)
0
10
20
30
40
50
60
15:00:00
18:00:00
21:00:00
00:00:00
Time (Hrs)


Online Temperature monitoring for antenna C04
FE Box temperature
LNA Temperature
CB Temperature
Temperature (degree C)
0
10
20
30
40
50
60
15:00:00
18:00:00
21:00:00
00:00:00
Time (Hrs)



Conclusion and future scope :

a) Overall temperature monitoring is working for both FE, LNA and CB satisfactorily.

b) Online monitoring was tested and verified.

c) Higher bit ADC will give good resolution.

d) Suitable GUI will be of use to the monitoring system.

e) Currently MCM-5 is turn OFF during observation and the monitoring facility will be available only with new rabbit card based MCM which will be kept ON during observation.

f) Calibration of MCM-5 ADC ref. is needed to get correct temperature .

References :

a) Datasheet of National Semiconductor LM35 and datasheet of LM358

b) Tool used Altium designer for PCB design.

Datasheet :

National Semiconductor

December 1994

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

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)

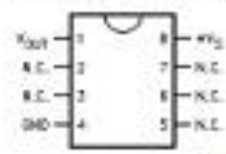
Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
See NS Package Number H03H

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



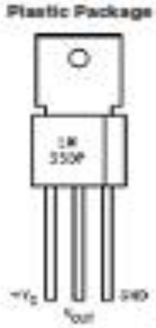
TL/H/5516–21

Top View

N.C. = No Connection

Order Number LM35DM
See NS Package Number M08A

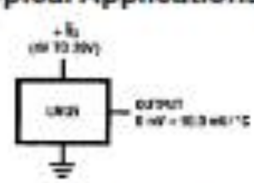
TO-202
Plastic Package



TL/H/5516–24

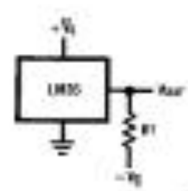
Order Number LM35DP
See NS Package Number P03A

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

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RRD-B30M75/Printed in U. S. A.

LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

Single Supply Dual Operational Amplifiers

Utilizing the circuit designs perfected for Quad Operational Amplifiers, these dual operational amplifiers feature low power drain, a common mode input voltage range extending to ground/V_{EE}, and single supply or split supply operation. The LM358 series is equivalent to one–half of an LM324.

These amplifiers have several distinct advantages over standard operational amplifier types in single supply applications. They can operate at supply voltages as low as 3.0 V or as high as 32 V, with quiescent currents about one–fifth of those associated with the MC1741 (on a per amplifier basis). The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features

- Short Circuit Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation
- NCV Prefix for Automotive and Other Applications Requiring Unique Site and Control Change Requirements; AEC–Q100 Qualified and PPAP Capable
- These Devices are Pb–Free, Halogen Free/BFR Free and are RoHS Compliant

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http://onsemi.com

PDIP–8
N, AN, VN SUFFIX
CASE 626

SOIC–8
D, VD SUFFIX
CASE 751

Micro8™
DMR2 SUFFIX
CASE 846A

PIN CONNECTIONS

(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 11 of this data sheet.