

POLITECNICO DI TORINO

ESAME DI STATO PER L'ABILITAZIONE ALLA PROFESSIONE DI INGEGNERE

I SESSIONE ANNO 2001 - RAMO ELETTRONICA - TEMA 2

Si vuole realizzare un sistema di controllo per un impianto di riscaldamento da utilizzarsi in abitazioni private. Il sistema deve rilevare la temperatura di ogni locale dell'abitazione e la temperatura esterna. In base alle informazioni ottenute deve controllare gli elementi riscaldanti di ogni ambiente, per fare in modo che la temperatura segua un profilo prefissato dall'utente, eventualmente diverso da locale a locale.

Il sistema è composto da:

- una centralina di controllo;
- un misuratore di temperatura remoto in ogni locale da controllare;
- un attuatore ON/OFF associato ad ogni elemento riscaldante.

Si richiede al candidato il progetto, il più possibile completo, del misuratore remoto di temperatura, basandosi sulle specifiche seguenti:

- Per facilitare l'installazione, la connessione tra il sensore di temperatura e la centralina di controllo deve essere di tipo *wireless*, utilizzando un modulo trasmettitore a 433 MHz, i cui dati principali sono riportati nel seguito.
- Il sensore di temperatura deve essere di tipo LM35, le cui caratteristiche principali sono allegate.
- Il misuratore deve essere alimentato a batteria.
- La misura della temperatura deve essere effettuata ogni 10÷15s, per il resto del tempo il sistema deve essere in modo "risparmio energia" per prolungare la vita delle batterie.
- Il cuore del sistema può essere costituito o da un dispositivo logico programmabile (FPGA) o da un microcontrollore (μC), a scelta del candidato.
- Ogni misuratore deve avere un identificativo, programmabile per mezzo di jumper (cavallotti), in modo che possano essere utilizzati fino a 15 misuratori diversi per ogni sistema.

Sviluppare in particolare i punti seguenti:

1. Schema a blocchi dell'intero sistema, indicando per ciascun blocco le specifiche interne ed i segnali di interfaccia con gli altri blocchi.
2. Progetto completo del sistema di conversione in digitale del segnale analogico proveniente dal sensore LM35: devono essere previsti due campi di temperatura: $0^{\circ}C \div 25.5^{\circ}C$, con risoluzione di $0.1^{\circ}C$, per i misuratori da porre all'interno dell'abitazione; $-20^{\circ}C \div +40^{\circ}C$, con risoluzione di $0.25^{\circ}C$ per il misuratore della temperatura esterna. Al di fuori dei campi previsti, il sistema deve saturare all'estremo corrispondente del campo ($30^{\circ}C$ sarà letto come $25.5^{\circ}C$ dai sensori interni). Dato che esiste un grande intervallo di tempo tra una misura e la successiva, è possibile utilizzare un convertitore indiretto per l'acquisizione della temperatura, sfruttando le potenzialità della parte digitale del sistema e con costi notevolmente più bassi di quelli di un convertitore classico. Se il candidato è a conoscenza di tecniche di conversione indiretta, le utilizzi. Altrimenti, indichi le specifiche di un convertitore classico adatto.
3. Definizione di un protocollo di comunicazione adeguato per il trasferimento dell'informazione alla centralina. Il sistema di modulazione utilizzato dal modulo di trasmissione è di tipo OOK (on-off keying), con bit-rate di 1.2kbit/s. Devono essere trasferiti i dati seguenti: indirizzo del misuratore, valore di temperatura misurato, codice di controllo per la validazione del dato trasmesso. La trasmissione avviene ad anello aperto (i misuratori non sono dotati di ricevitore, non c'è polling da parte della centralina), quindi non è possibile garantire che non ci siano trasmissioni contemporanee da più misuratori. In questo caso la centralina riceverà dati incomprensibili e deve essere in grado di accorgersi della collisione. E' necessario garantire invece che, se anche avviene una trasmissione parzialmente sovrapposta da parte di due misuratori, questa non si ripeta nel ciclo di misura successivo. Spiegare quali semplici tecniche possono essere utilizzate per garantire questa condizione.
4. Progetto della parte digitale del sistema: in caso di utilizzo di FPGA si definiscano gli schemi elettrici o, a scelta, si fornisca la descrizione VHDL del circuito; se invece si utilizza un μC , si allegino:
 - le specifiche del componente in termini di risorse HW necessarie (I/O, memoria RAM/ROM)
 - le funzionalità software, mediante i flow-chart delle procedure principali. Si sviluppino in linguaggio C alcuni brani del codice corrispondente.
5. Discutere le problematiche derivanti dall'alimentazione a batteria. Non è richiesto un progetto completo dell'alimentatore, ma si richiede di definirne il tipo e le specifiche.



UHF LPD RECEIVER AND TRANSMITTER MODULES

BT37 Transmitter

FM Xtal CONTROLLED

DESCRIPTION

The BT37 module is a frequency modulated crystal controlled UHF transmitter. It operates on the 433.05 - 434.79 MHz ISM band with 10 mW output power. Together with the matching BR37 receiver a one way analogue or digital radio link can be achieved on 34 different RF channels. The BT37 needs a single 5 V supply (3 V, 9 V, 12V versions are optional).

- 433.05 - 434.79 ISM BAND
- QUARTZ CONTROLLED ON 34 CHANNELS
- 10 mW RF OUTPUT POWER
- ANALOGUE AND DIGITAL FM MODULATION
- ETS 300 - 220 COMPLIANT

IMPORTANT NOTICE

The CEPT - ERC recommendations prescribe the LPD transmitter user to avoid sending carrier without data or modulation. It is also suggested to avoid continuous transmission applying a system transmission duty cycle of 10% or less.

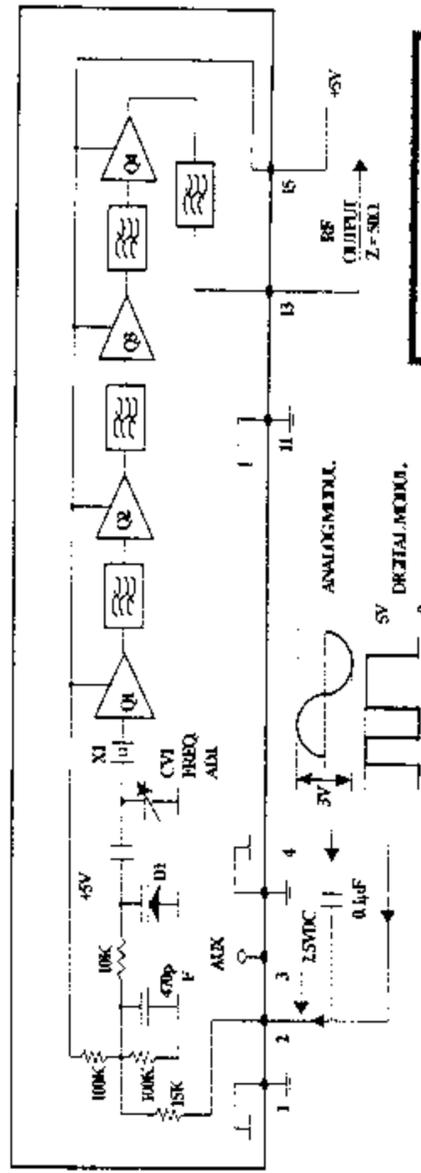


Fig. 1 - Block diagram

Modulation requirements

A digital data signal (0-5 V) must be direct connected to the modulation input terminal. A 1st order low-pass filter is used internally and the resulting frequency deviation is ±7 KHz. NOTE: a DC bias of 2.5 V is present on the modulation input terminal (fig. 1). CVI must be adjusted to obtain the centre channel frequency with the modulation input terminal disconnected. An analogue signal must be coupled to the modulation input with a 0.1 - 0.22μF capacitor (fig. 1).

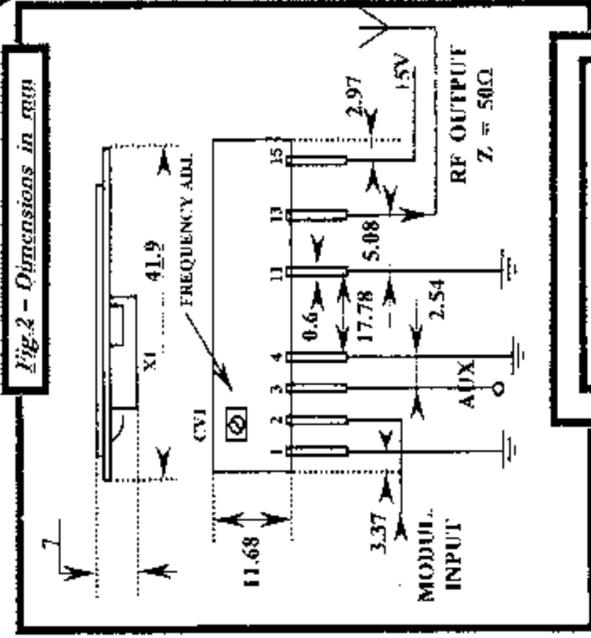
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RF CHANNELS FROM 433.05 TO 434.79 MHz			
CH.	FREQ. MHz	CH.	FREQ. MHz
1	433.075	18	433.925 (1)
2	433.125	19	433.975
3	433.175	20	434.025
4	433.225 (1)	21	434.075 (1)
5	433.275	22	434.125
6	433.325	23	434.175 (1)
7	433.375	24	434.225
8	433.425	25	434.275
9	433.475	26	434.325 (1)
10	433.525	27	434.375
11	433.575	28	434.425
12	433.625	29	434.475
13	433.675	30	434.525 (1)
14	433.725	31	434.575
15	433.775	32	434.625
16	433.825	33	434.675
17	433.875	34	434.725

(1) IN STOCK



XI crystal specifications:
 $F_{XTAL} = \frac{F_T}{16}$
Case = HC49T
Fundamental parallel resonance with 20pF.

PERFORMANCE DATA

PARAMETERS	Min.	Typ.	Max.	Units	Notes
Frequency	433.05	± 4	434.79	MHz	(1)
Freq. Stability		50		KHz	(2)
Channel Separation		12		mW	
RF Output power (Z=50Ω)	8		-36	dBm	
Spurious Emissions	DC		10	KHz	
Modulation Frequency		± 7	5	V	(3)
Frequency Deviation		3	2	Vpp	(4)
Digital Modulation		1		ms	
Analog Modulation		5	5.5	V	
Power Up Time		14		mA	
Operating Supply Range	4.5			°C	
Supply Current	-20		+ 60	mm	
Operating Temp. Range		42 x12x7			
SIZE					

NOTES: (1) -20 + 60 °C
(2) DC Supply = 5V
(3) DC Coupled
(4) AC Coupled

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 $\pm 1/4^\circ\text{C}$ at room temperature and $\pm 1/2^\circ\text{C}$ over a full -55 to $+150^\circ\text{C}$ 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 $60\ \mu\text{A}$ 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 $+150^\circ\text{C}$ temperature range, while the LM35C is rated for a -40° to $+110^\circ\text{C}$ 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.

Features

- Calibrated directly in $^\circ\text{C}$ (Centigrade)
- Linear $+10.0\ \text{mV}/^\circ\text{C}$ scale factor
- 0.5°C accuracy guaranteed (at $+25^\circ\text{C}$)
- Rated for full -55° to $+150^\circ\text{C}$ range
- Suitable for remote applications
- Low cost due to wafer-level trimming
- Operates from 4 to 30 volts
- Less than $60\ \mu\text{A}$ current drain
- Low self-heating, 0.08°C in still air
- Nonlinearity only $\pm 1/2^\circ\text{C}$ typical
- Low impedance output, $0.1\ \Omega$ for 1 mA load

Typical Applications

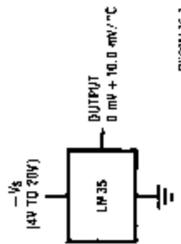
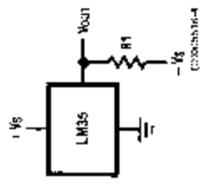


FIGURE 1. Basic Centigrade Temperature Sensor ($+2^\circ\text{C}$ to $+150^\circ\text{C}$)



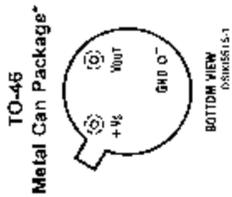
Choose $R_1 = -V_{S,50}\ \mu\text{A}$
 $V_{\text{OUT}} = +1.500\ \text{mV}$ at $+150^\circ\text{C}$
 $= +250\ \text{mV}$ at $+25^\circ\text{C}$
 $= -550\ \text{mV}$ at -55°C

FIGURE 2. Full-Range Centigrade Temperature Sensor

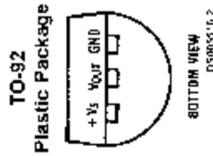
LM35 Precision Centigrade Temperature Sensors

November 2000

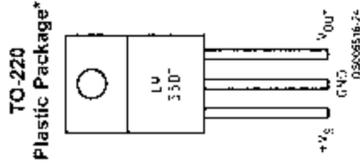
Connection Diagrams



*Case is connected to negative pin (GND).
 Order Number LM35H, LM35AH, LM35CH, LM35CAH or LM35DH
 See NS Package Number H03H



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



*Tab is connected to the negative pin (GND).
 Note: The LM35D1 pinout is different than the discontinued LM35DP.

Order Number LM35DT
 See NS Package Number TA03F

LM35

LM35

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	+36V to -0.2V	TO-92 and TO-220 Package, (Soldering, 10 seconds)	260°C
Output Voltage	+6V to -1.0V	SO Package (Note 12)	215°C
Output Current	10 mA	Vapor Phase (60 seconds)	220°C
Storage Temp.		Infrared (15 seconds)	2500V
TO-46 Package,	-60°C to +180°C	ESD Susceptibility (Note 11)	
TO-92 Package,	-60°C to +150°C	Specified Operating Temperature Range: T_{MIN} to T_{MAX}	
SO-8 Package,	-65°C to +150°C		
TO-220 Package,	-65°C to +150°C		
Lead Temp.: TO-46 Package, (Soldering, 10 seconds)	300°C		

Electrical Characteristics
(Notes 1, 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)	$T_A = +25^\circ\text{C}$ $T_A = -10^\circ\text{C}$ $T_A = T_{MAX}$ $T_A = T_{MIN}$	± 0.2 ± 0.3 ± 0.4 ± 0.4	± 0.5 ± 1.0 ± 1.0	± 1.0 ± 1.5 ± 1.5	± 0.2 ± 0.3 ± 0.4 ± 0.4	± 0.5 ± 1.0 ± 1.0	± 1.0 ± 1.5 ± 1.5	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	± 0.18		± 0.35	± 0.15	± 0.3	$^\circ\text{C}$	
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/ $^\circ\text{C}$	
Load Regulation (Note 3), $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$ $T_{MIN} \leq T_A \leq T_{MAX}$	± 0.4 ± 0.5	± 1.0	± 3.0	± 0.4 ± 0.5	± 1.0 ± 3.0	mV/mA mV/mA	
Line Regulation (Note 3)	$T_A = +25^\circ\text{C}$ $4V \leq V_S \leq 30V$	± 0.01 ± 0.02	± 0.05	± 0.1	± 0.01 ± 0.02	± 0.05 ± 0.1	mV/V mV/V	
Quiescent Current (Note 9)	$V_S = +5V, +25^\circ\text{C}$ $V_S = +5V$ $V_S = +30V, +25^\circ\text{C}$ $V_S = +30V$	56 105 56.2 105.5	67 68	131 133	56 91 56.2 91.5	67 68 114 116	μA μA μA μA	
Change of Quiescent Current (Note 3)	$4V \leq V_S \leq 30V, +25^\circ\text{C}$ $4V \leq V_S \leq 30V$	0.2 0.5	1.0	2.0	0.2 0.5	1.0 2.0	μA μA	
Temperature Coefficient of Quiescent Current		+0.39		+0.5	+0.39	+0.5	$\mu\text{A}/^\circ\text{C}$	
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_L = 0$	+1.5		+2.0	+1.5	+2.0	$^\circ\text{C}$	
Long Term Stability	$T_J = T_{MAX}$, for 1000 hours	± 0.08			± 0.08		$^\circ\text{C}$	

LM35

Electrical Characteristics
(Notes 1, 6)

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)	$T_A = +25^\circ\text{C}$ $T_A = -10^\circ\text{C}$ $T_A = T_{MAX}$ $T_A = T_{MIN}$	± 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 ± 1.5 ± 2.0 ± 2.0	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$
Accuracy, LM35D (Note 7)	$T_A = +25^\circ\text{C}$ $T_A = T_{MAX}$ $T_A = T_{MIN}$				± 0.6 ± 0.9 ± 0.9	± 1.5	± 2.0 ± 2.0 ± 2.0	$^\circ\text{C}$ $^\circ\text{C}$ $^\circ\text{C}$
Nonlinearity (Note 8)	$T_{MIN} \leq T_A \leq T_{MAX}$	± 0.3		± 0.5	± 0.2		± 0.5	$^\circ\text{C}$
Sensor Gain (Average Slope)	$T_{MIN} \leq T_A \leq T_{MAX}$	+10.0	+9.8, +10.2		+10.0		+9.8, +10.2	mV/ $^\circ\text{C}$
Load Regulation (Note 3), $0 \leq I_L \leq 1 \text{ mA}$	$T_A = +25^\circ\text{C}$ $T_{MIN} \leq T_A \leq T_{MAX}$	± 0.4 ± 0.5	± 2.0	± 5.0	± 0.4 ± 0.5	± 2.0	± 5.0 ± 5.0	mV/mA mV/mA
Line Regulation (Note 3)	$T_A = +25^\circ\text{C}$ $4V \leq V_S \leq 30V$	± 0.01 ± 0.02	± 0.1	± 0.2	± 0.01 ± 0.02	± 0.1	± 0.2 ± 0.2	mV/V mV/V
Quiescent Current (Note 9)	$V_S = +5V, +25^\circ\text{C}$ $V_S = +5V$ $V_S = +30V, +25^\circ\text{C}$ $V_S = +30V$	56 105 56.2 105.5	80 82	158 161	56 91 56.2 91.5	80 82 141	μA μA μA μA	
Change of Quiescent Current (Note 3)	$4V \leq V_S \leq 30V, +25^\circ\text{C}$ $4V \leq V_S \leq 30V$	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	$\mu\text{A}/^\circ\text{C}$
Minimum Temperature for Rated Accuracy	In circuit of Figure 1, $I_L = 0$	+1.5		+2.0	+1.5		+2.0	$^\circ\text{C}$
Long Term Stability	$T_J = T_{MAX}$, for 1000 hours	± 0.08			± 0.08			$^\circ\text{C}$

Note 1: Unless otherwise noted, these specifications apply: $-55 \leq T_{ST} \leq +150^\circ\text{C}$ for the LM35 and LM35A; $-40 \leq T_{ST} \leq +110^\circ\text{C}$ for the LM35C and LM35CA; and $0 \leq T_{ST} \leq +100^\circ\text{C}$ for the LM35D, $V_S = +5\text{Vdc}$ and $I_{LOAD} = 50 \mu\text{A}$, in the circuit of Figure 2. These specifications also apply from $+2^\circ\text{C}$ 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 140°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-220 package is 90°C/W junction to ambient. For additional thermal resistance information, see Table 1 in the Applications section.

Note 3: Regulation is measured at constant junction temperature, using pulsed loading with a low duty cycle. Changes in output due to heating effects can be computed by multiplying the inboard 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 $10\text{mV}/^\circ\text{C}$ times the device's case temperature, at specified conditions of voltage, current, and temperature (expressed in $^\circ\text{C}$).

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, 150 pF discharged through a $1.5 \text{ k}\Omega$ 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.

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