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SL6609

DIRECT CONVERSION FSK DATA RECEIVER

This device is an advanced direct conversion receiver for operation up to 470MHz. The device integrates all functions to translate a binary FSK modulated RF signal into a demodulated data stream. Adjacent channel rejection is provided using tuneable gyrator filters. To assist operation in the presence of large interfering signals both RF and audio AGC functions are provided.

The device also includes a 1 volt regulator capable of sourcing up to 5mA, a battery flag and the facility of incorporating a more complex post detection filter off-chip. Both battery flag and data outputs have open collector outputs to ease their interface with other devices.

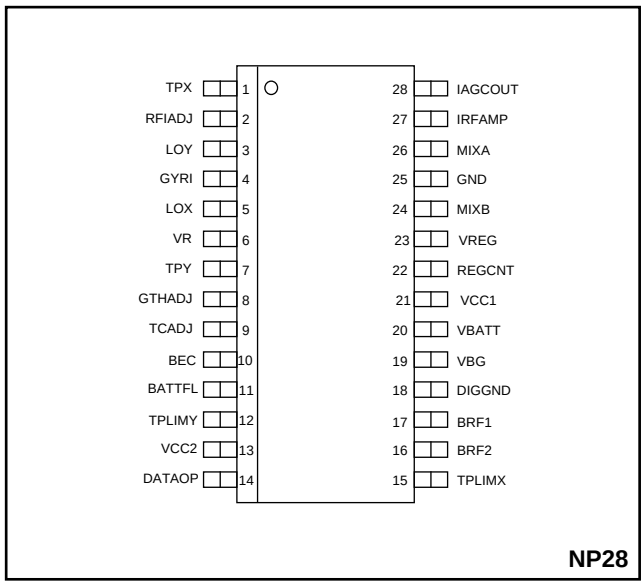


Fig.1 Pin connections

FEATURES

- Very low power operation - typ 3.0mW
- Single cell operation for most of the device. Limited functional blocks operating via an inverter
- Superior sensitivity of -130dBm
- Operation at wide range of paging data rates 512, 1200, 2400 baud
- On chip 1 volt regulator
- Small package offering SSOP

APPLICATIONS

- Credit card pagers
- Watch pagers
- Small form factor pagers i.e. PCMCIA
- Low data rate data receivers i.e. Security/remote control

ABSOLUTE MAXIMUM RATINGS

Supply voltage	6V
Storage temperature	-55°C to +150°C
Operating temperature	-20°C to +70°C

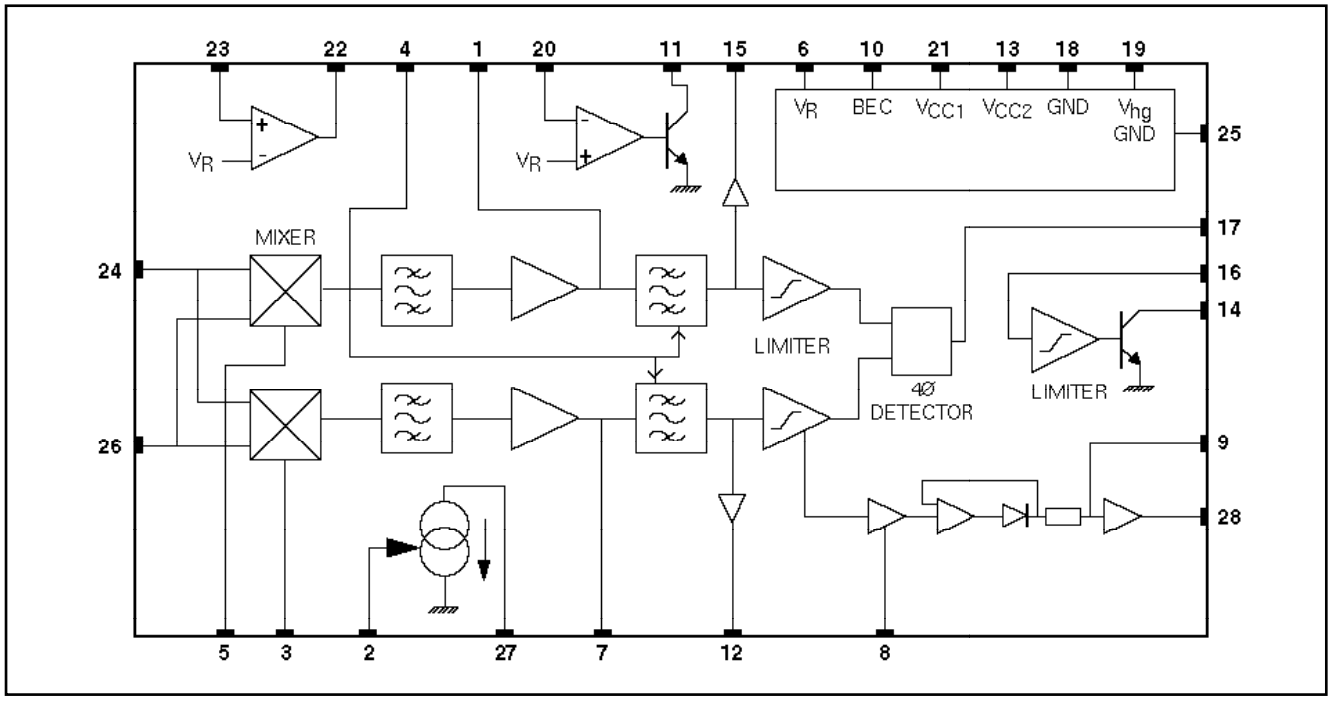


Fig.2 Block diagram of SL6609

ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated:
Tamb = 25°C, VCC1 = 1.3V, VCC2 = 2.7V

Characteristics	Pin	Value			Units	Comments
		Min	Typ	Max		
VCC1 - Supply voltage	21	0.95	1.3	2.8	V	VCC1 ≤ VCC2 - 0.7 volts
VCC2 - Supply voltage	13	1.8	2.7	3.5	V	
ICC1 - Supply current	21,27,28		1.5	1.8	mA	Includes 500µA IRF. Does not include regulator supply. Audio AGC inactive
ICC2 - Supply current	11,13,14		550	700	µA	Batt flag & Data O/P high Pin 27 voltage: 0.3 - 1.3V
Power down ICC1	21,27,28			1	µA	
Power down ICC2	11,13,14			8	µA	
1 volt regulator	23	0.95	1.0	1.05	V	I Load = 3mA. Ext PNP. ß = 100, V_{CE} = 0.1 volt
Band gap voltage reference	19	1.15	1.21	1.27	V	
Band gap current source	19			20	µA	
Voltage reference	6	0.93	1.0	1.07	V	
Voltage reference sink/source	6			10	µA	VCC1 > 1.1V
1 volt regulator load current		0.25	3	5	mA	
Turn on Time			5		mS	Stable data o/p when 3dB above sensitivity. C_{BG} and C_{VR} = 2.2µF
Turn off Time			1		mS	Fall to 10% of steady state current C_{BG} and C_{VR} = 2.2µF
Detector output current	17		+/-4		µA	
RF current source						
Current Source (RFAMP)	27	450	520	600	µA	Pin 27 voltage: 0.3 - 1.3V
Decoder						
Sensitivity		40			µVrms	Signal injected at TPX and TPY B.E.R. ≤ 1 in 30 5KHz deviation @ 500 bits/sec BRF capacitor = 2nF
Output mark space ratio	14	7:9		9:7		
Data O/P Sink Current	14	100		500	µA	Output logic low
Data O/P Leakage Current	14			1.0	µA	Output logic high

ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions unless otherwise stated:
Tamb = 25°C, VCC1 = 1.3V, VCC2 = 2.7V

Characteristics	Pin	Value			Units	Comments
		Min	Typ	Max		
Battery Economy						
Input logic high	10	(V_{CC2} - 0.3)			V	Powered Up
Input logic low	10			0.3	V	Powered Down
Input current	10		0.05	1	µA	Powered Up
Input current	10		6	8	µA	Powered down transient initial
Battery Flag Input						
Input current	20			1		µA
Battery Flag Output						
Battfl Sink Current	11	100		500	µA	(VBATT-VR) > 20mV
Battfl leakage current	11			1	µA	(VBATT-VR) < -20mV
Mixers						
Gain to "IF Test"		34		41	dB	LO inputs driven in parallel with 50mVRMS @ 50MHZ.IF = 2KHz
RF input impedance	24, 26					See Figs.8a, 8b
LO input impedance	3, 5					See Fig.9
LO DC bias voltage	3, 5				V	Equal to Pin 21 (VCC1)
Audio AGC						
Max Audio AGC Sink Current	28	45	65	85	µA	

RECEIVER CHARACTERISTICS (GPS Demonstration board)

Measurement conditions unless stated V_{CC1} = 1.3V, V_{CC2} = 2.7V, LNA = 18dB Gain, 2dB Noise figure,
Carrier frequency 153MHz, BER 1 in 30, Tamb = 25°C

Characteristics	Pin	Value			Units	Comments
		Min	Typ	Max		
Sensitivity		-130	-127.5	-125	dBm	512 bps Δf = 4.5kHz LO = -18dBm
		-128	-125.5	-123	dBm	1200 bps Δf = 4kHz LO = -18dBm
Intermodulation		54	55		dB	512 bps Δf = 4.5kHz LO = -18dBm
Adjacent channel		68	72.5		dB	512 bps Δf = 4.5kHz LO = -18dBm Channel spacing 25kHz
Centre frequency acceptance		+/- 2.0	+/- 2.5 +/-2		kHz kHz	512 bps Δf = 4.5kHz 1200 bps Δf = 4kHz LO = -18dBm
Deviation acceptance			+/- 2.5 +/-2		kHz kHz	512 bps Δf = 4.5kHz 1200 bps Δf = 4kHz LO = -18dBm

RECEIVER CHARACTERISTICS (GPS Demonstration board)

Measurement conditions unless stated V_{CC1} = 1.3V, V_{CC2} = 2.7V, LNA = 18dB Gain, 2dB Noise figure,
Carrier frequency 282MHz, BER 1 in 30, Tamb = 25°C

Characteristics	Pin	Value			Units	Comments
		Min	Typ	Max		
Sensitivity		-130	-128.5	-125	dBm	512 bps Δf = 4.5kHz LO = -15dBm
		-128	-126	-123	dBm	1200 bps Δf = 4.0kHz LO = -15dBm
Intermodulation		54	55.5		dB	512 bps Δf = 4.5kHz LO = -15dBm
Adjacent channel		68	72		dB	512 bps Δf = 4.5kHz LO = -15dBm Channel spacing 25kHz
Centre frequency acceptance		+/- 2.0	+/- 2.5 +/-2		kHz kHz	512 bps Δf = 4.5kHz 1200 bps Δf = 4kHz LO = -15dBm
Deviation acceptance			+/- 2.5 +/-2		kHz kHz	512 bps Δf = 4.5kHz 1200 bps Δf = 4kHz LO = -15dBm

RECEIVER CHARACTERISTICS

Measurement conditions unless stated V_{CC1} = 1.3V, V_{CC2} = 2.7V, LNA = 18dB Gain, 2dB Noise figure,
Carrier frequency 470MHz, BER 1 in 30, Tamb = 25°C

Characteristics	Pin	Value			Units	Comments
		Min	Typ	Max		
Sensitivity		-127	-125	-122	dBm	1200 bps Δf = 4kHz LO = -15dBm
Intermodulation		50	53		dB	1200 bps Δf = 4kHz LO = -15dBm
Adjacent channel		65	70		dB	1200 bps Δf = 4kHz LO = -15dBm Channel spacing 25kHz
Centre frequency acceptance			+/- 2		kHz	1200 bps Δf = 4kHz LO = -15dBm
Deviation acceptance			+/- 2		kHz	1200 bps Δf = 4kHz LO = -15dBm

OPERATION OF SL6609

The SL6609 is a Direct Converson Receiver designed for use up to 470MHz. It is available in a 28 pin SSOP package and it integrates all the facilities required for the conversion of an RF FSK signal to a base-band data signal.

Low Noise Amplifier

To achieve optimum performance it is necessary to incorporate a Low Noise RF Amplifier at the front end of the receiver. This is easily biased using the on chip voltage and current sources provided.

All voltages and current sources used for bias of the RF amplifier, receiver and mixers should be RF decoupled using suitable capacitors (see fig.4 for a suitable Low-Noise-Amplifier).

Local Oscillator

The Local Oscillator signal is applied to the device in phase quadrature. This can be achieved with the use of two RC networks operating at the -3dB/45° transfer characteristic, giving a full 90° phase differential between the LO ports of the device. Each LO port of the device also requires an equal level of drive from the Oscillator. (see Fig.5).

Gyrator Filters

The on chip filters include an adjustable gyrator filter. This may be adjusted with the use of an additional resistor between pin 4 and GND. This allows flexibility of filter characterstics and also allows for compensation for possible process variations.

Audio AGC

The Audio AGC fundamentally consists of a current sink which is controlled by the audio (baseband data) signal. It has three parameters that may be controlled by the user. These are the Attack (turn on) time, Decay (duration) time and Threshold level (see Fig.6 and 7). See Application note for details.

Regulator

The on chip regulator must be used in conjunction with a suitable PNP transistor to achieve regulation. As the transistor forms part of the regulator feedback loop the transistor should exhibit the following characteristics:-

H_{FE} > = 100 for V_{CE} > = 0.1V

Pin Number	Pin Name	Pin Description
1	TPX	X channel pre-gyrator filter test-point. This can be used for input and output
2	RFIADJ	RF current source adjustment pin
3	LOY	LO input channel Y
4	GYRI	Gyrator current adjust pin
5	LOX	LO input channel X
6	VR	VREF 1.0 V internal signal ground
7	TPY	Y channel pre-gyrator filter test point, input or output
8	GTHADJ	Audio AGC gain and threshold adjust. RSSI signal indicator
9	TCADJ	Audio AGC time constant adjust
10	BEC	Battery economy control
11	BATTFL	Battery flag output
12	TPLIMY	Y channel limiter (post gyrator filter) test point, output only
13	VCC2	Supply connection
14	DATAOP	Data output pin
15	TPLIMX	X channel limiter (post gyrator filter) test point, output only
16	BRF2	Bit rate filter 2, input to data output stage
17	BRF1	Bit rate filter 1, output from detector
18	DIG GND	Digital ground
19	VBG	Bandgap voltage output
20	VBATT	Battery flag input voltage
21	VCC1	Supply connection
22	REGCNT	1V regulator control external PNP drive
23	VREG	1V regulator output voltage
24	MIXB	Mixer input B
25	GND	Ground
26	MIXA	Mixer input A
27	IRFAMP	Current source for external LNA. Value of current output will decrease at high mixer input signal levels due to RF AGC
28	IAGCOUT	Audio AGC output current

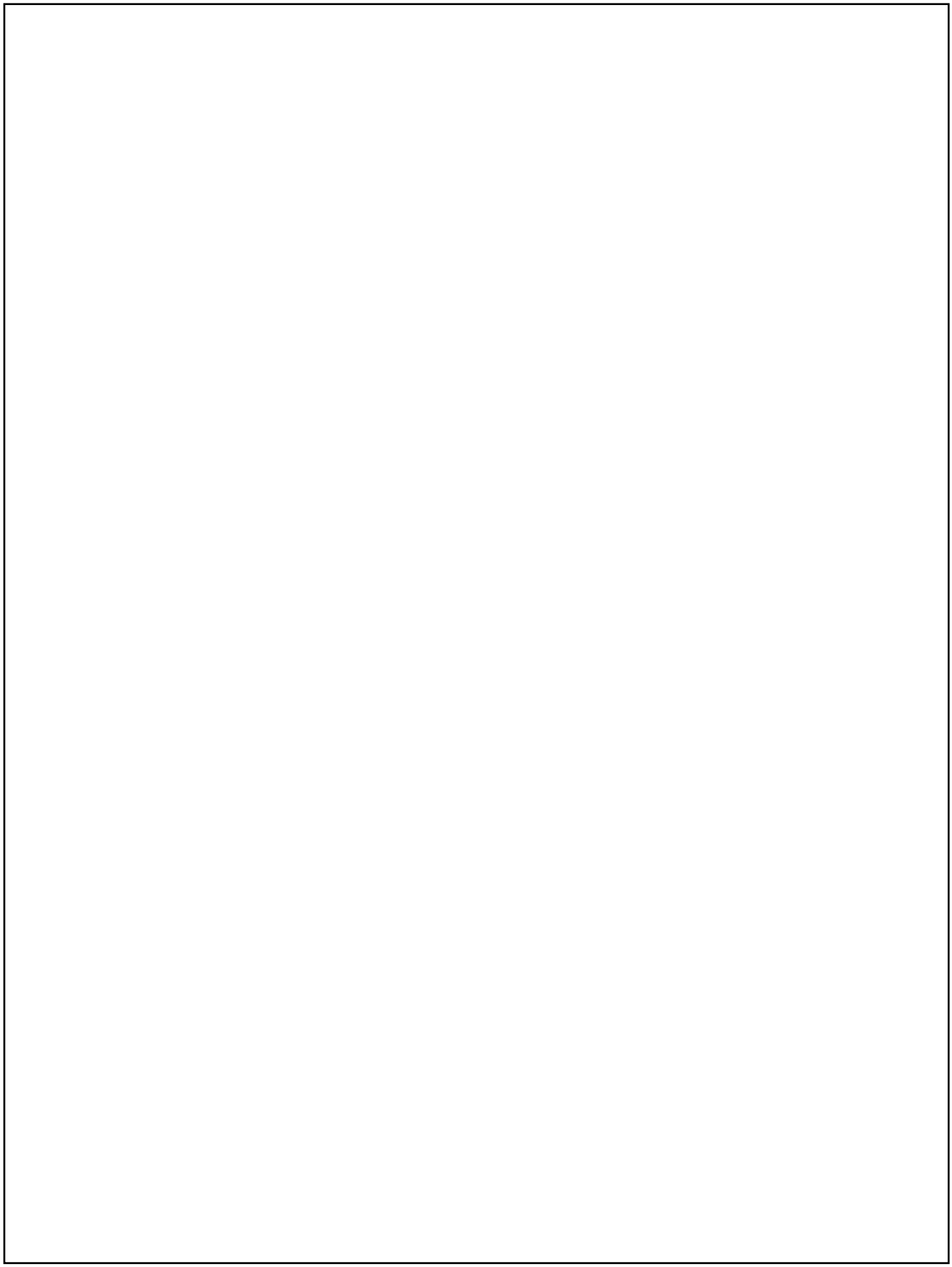


Fig.3 Application circuit board

COMPONENTS LIST FOR APPLICATION BOARD At 282MHz, 25kHz Channel Spacing.

Resistors

R1	open circuit
R2	open circuit
R3	220
R4	100k
R5	1k
R6	1k
R7	220
R8	open circuit
R9	220k
R10	1M
R11	100k (6)
R12	not used
R13	2k7
R14	4k7
R15	4k7
R16	33k
R17	not used (3)
R18	0R (3)
R19	10k
R20	680
R21	1k
R22	open circuit

Capacitors

C1	1n
C2	2p7
C3	4p7
C4	1n
C5	2p7
C6	2u2
C7	1n
C8	100n
C9	1n (2)
C10	2u2
C11	100n
C12	1n
C13	1n
C14	1n
C15	1n
C16	1n
C17	1n
C17a	1n
C18	1n
C19	not used
C20	1n
C21	1n
C22	not used
C23	1n
C24	1n
C25	1n
C26	5p6 (4)
C27	1n
C28	1n
C29	100p
C30	2u2
C31	2u2
C32	4p7
C33	4p7
C34	3p3
C35	not used
VC1	1-10p
VC2	1-10p
VC3	1-10p

Inductors

L1	100n (4)
L2	not used
L3	470n
L4	39n
L5	680n

Active Components

Q1	FMMT589
Q2	BFT25A
Q3	BFT25A
Q4	not used
Q5	BFT25A
D1	Panasonic MA862 (5)

Misc

T1	30nH 1:1
	Coilcraft M1686-A
Xtal	5th Overtone
	94.075MHz

Notes

1. The values of R13 is determined by the set-up procedure. See Application Note.

2. The value of C9 is determined by the output data rate. Use 2nF for 512bps, 1nF for 1200bps and 470pF for 2400bps.

3. R17 (See figure.6) forms a part of the audio AGC circuit and is determined by the voltage drop required to make the diode D1, conduct to give the RF attenuation required. R17 should be sufficiently large to ensure the voltage at pin 28 does not drop below 200mV. The maximum AGC current expected is 85µA. For the characteristics of the audio AGC current source see figure 7. If the audio AGC is not required then the current source (Pin 28) may be disabled by connecting Pin 9 (TCADJ) to VR (pin 6) and by connecting Pin 28 (IAGCOUT) to Vcc1., (R18). The voltage at Pin 8 may still be used as an RSSI. R9, C8, C14, C19, R17 and D1 may then be omitted. See figure.6 for AGC component values.

4. L1and C26 form the low noise matching network for the RF amplifier. The values given are for the RF amplifier specified in the Applications Circuit with no Audio AGC connected. i.e. R17 and D1 omitted.

5. Suggested diode for use with the Audio AGC circuit (see figure.6) (D1 is not included on the general demonstration circuit).

6. The value of R11 is dependent on the data output load. R11 should allow sufficient current to drive the data output load.

COMPONENTS LIST FOR APPLICATION BOARD At 470MHz, 25kHz Channel Spacing.
(LO circuit is 50Ω network as in Fig.5 - crystal oscillator not specified)

Resistors

R1	open circuit
R2	open circuit
R3	100
R4	100k
R5	100
R6	100
R7	100
R8	open circuit
R9	220k
R10	1M
R11	100k (2)
R12	300 (3)
R13	open circuit (1)
R14	4k7
R15	4k7
R16	33k
R17	open circuit (4)
R18	0R (4)
R22	open circuit

Capacitors

C1	1n
C2	3.3pF
C3	1n
C4	1n
C5	3.9pF
C6	2u2
C7	1n
C8	100n
C9	1n (2)
C10	2u2
C11	100n
C12	1n
C13	1n
C14	1n
C15	1n
C16	1n
C17	1n
C18	1n
C19	not used
C20	1n
C21	1n
C22	not used
C23	not used
C24	1n
C25	1n
C26	2.2pF (5)
C27	not used
C28	not used
C29	100p
C30	2u2
C31	2u2
C34	not used
VC1	1-3pF

Inductors

L1	39nH (5)
L2	short circuit
T1	18nH 2 Turn 1:1 (Coilcraft) Q4123-A

Active Components

Q1	Zetex FMMT589
Q2	Philips BFT25A
Q3	Not Used
Q4	Philips BFT25A(3)
Q5	Philips BFT25A
D1	Panasonic MA862(6)

Notes

1. The values of R13 is determined by the set-up procedure. See Application Note.

2. The value of "C9" is determined by the output data rate. Use 2nF for 512bps, 1nF for 1200bps and 470pF for 2400bps.

3. R12 & Q4 form a dummy load for the regulator. Permitted load currents for the regulator are 250µA to 5mA. The 1V regulator (output pin 23) can be switched off by connecting pin 23 directly to VCC2. Q1, Q4, R12 and C12 must then be omitted

4. R17 forms a part of the audio AGC circuit (see figure 6) and is determined by the voltage drop required to make the PIN diode D1, conduct to give the RF attenuation required. R17 should be sufficiently large to ensure the voltage at pin 28 does not drop below 200mV. The maximum AGC current expected is 85µA. For the characteristics of the audio AGC current source see figure 7. If the audio AGC is not required then the current source (Pin 28) may be disabled by connecting Pin 9 (TCADJ) to VR (pin 6) and by connecting Pin 28 (IAGCOUT) to Vcc1., (R18). The voltage at Pin 8 may still be used as an RSSI. R9, C8, C14, C19, R17 and D1 may then be omitted.

5. L1and C26 form the low noise matching network for the RF amplifier. The values given are for the RF amplifier specified in the Applications Circuit with no Audio AGC connected. i.e. R17 and D1 omitted.

6. Suggested diode for use with the Audio AGC circuit (D1 is not included on the general demonstration circuit).

7. The value of R11 is dependent on the data output load. R11 should allow sufficient current to drive the data output load.

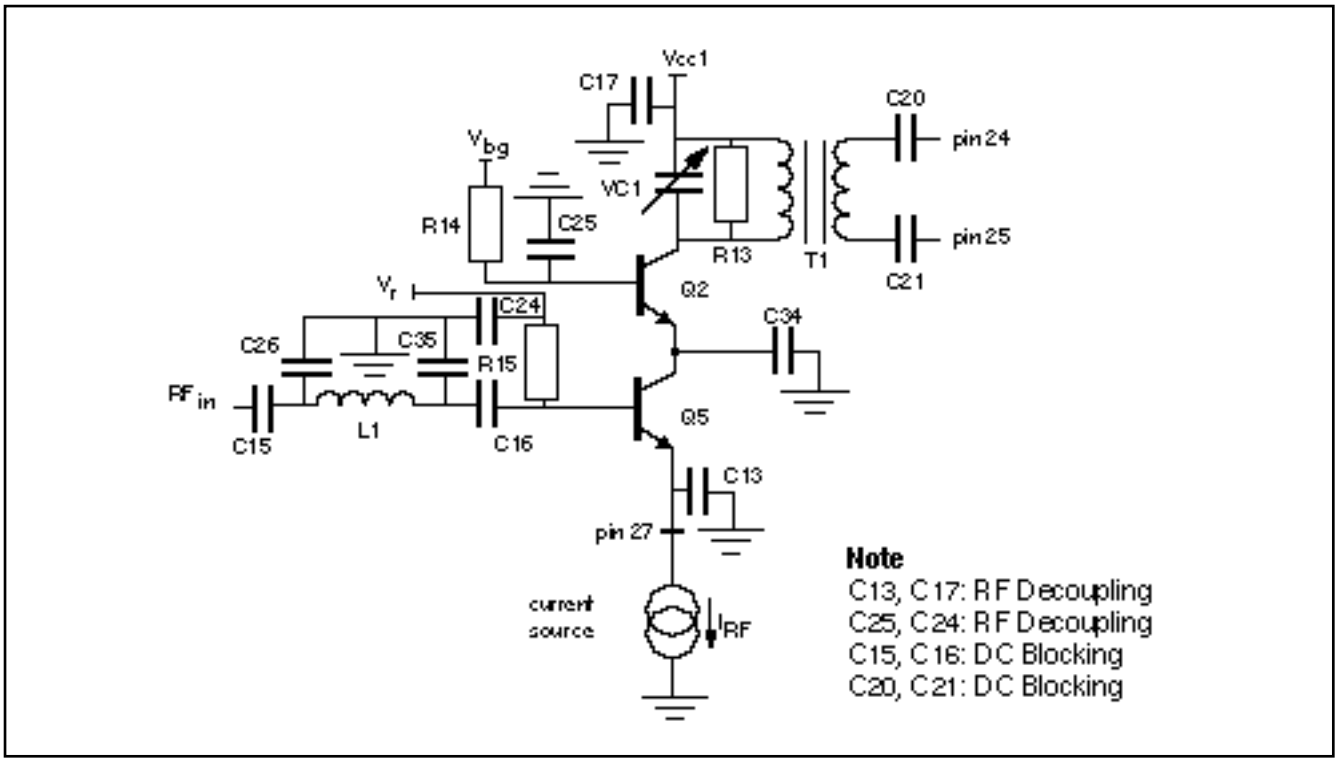


Fig.4 RF Amplifier

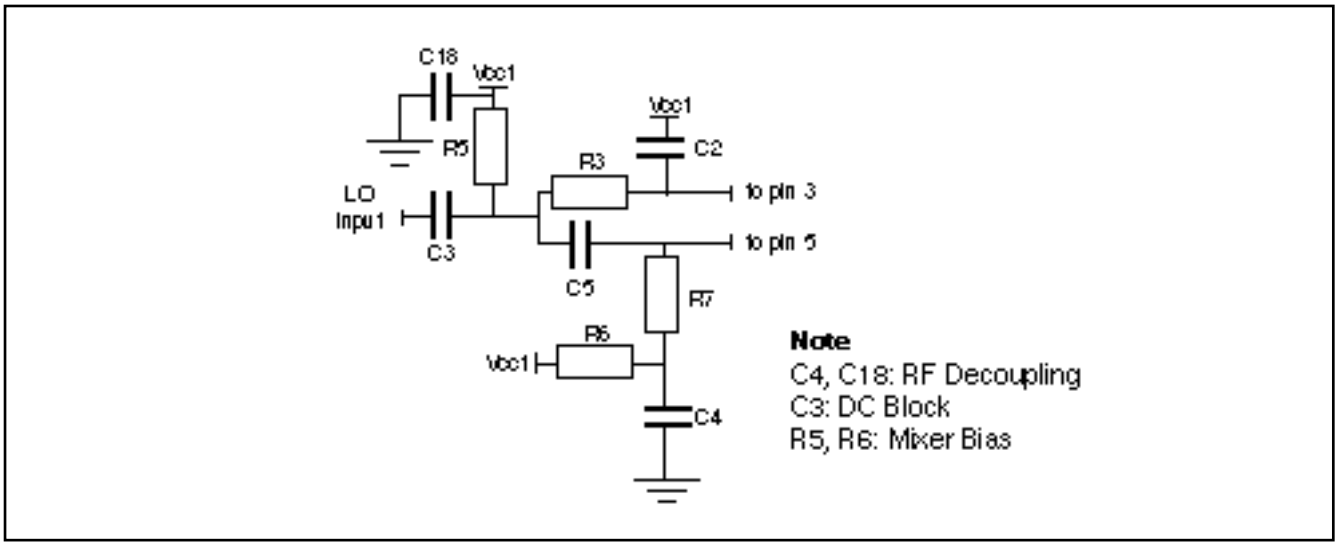


Fig.5 LO Network

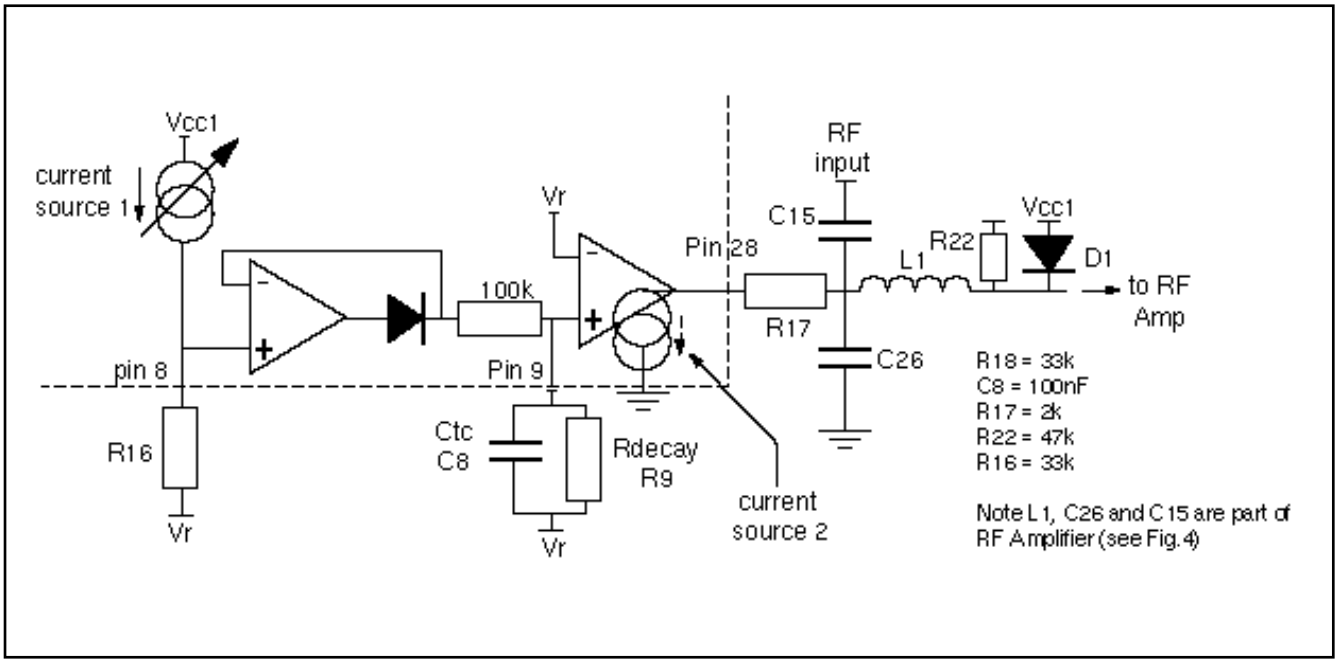


Fig.6 AGC Schematic

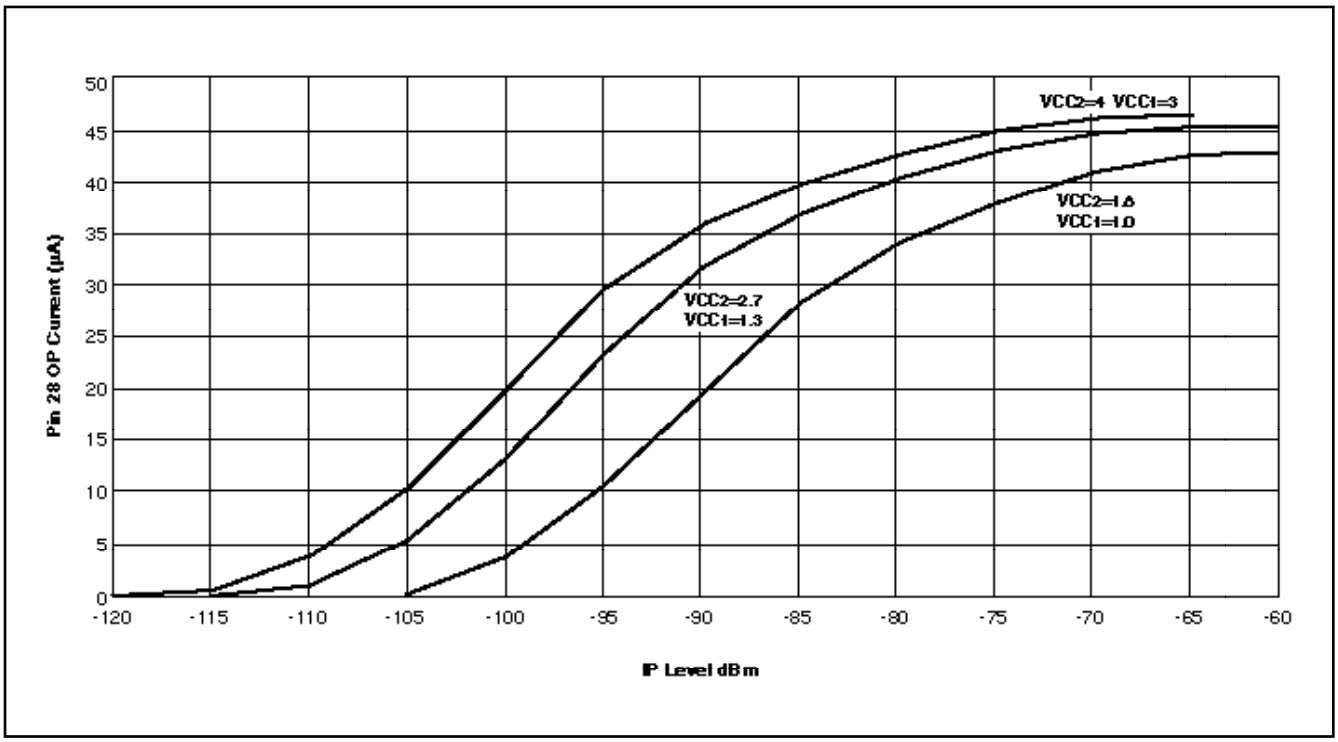


Fig.7 Audio AGC current vs. IP power at 25°C

S11

FREQ	MAG	ANG
50.000	0.969	-7.20
100.000	0.958	-14.45
150.000	0.942	-20.59
200.000	0.917	-26.40
250.000	0.893	-33.26
300.000	0.858	-39.84
350.000	0.832	-44.78
400.000	0.806	-49.01
450.000	0.781	-54.00
500.000	0.755	-59.53
550.000	0.743	-64-35
600.000	0.725	-68.43
650.000	0.703	-73.01
700.000	0.680	-78.74
750.000	0.666	-83.76
800.000	0.653	-87.48
850.000	0.636	-91.32
900.000	0.615	-97.17
950.000	0.604	-102.84
1000.00	0.600	-105.23

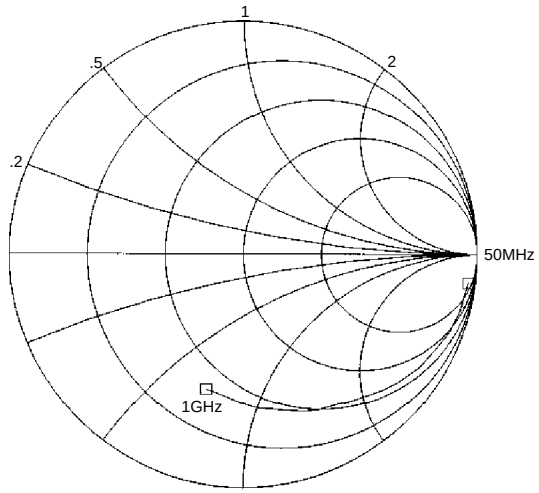


Fig.8a SL6609 Mixer A input S-Parameters

S11

FREQ	MAG	ANG
50.000	0.970	-7.06
100.000	0.960	-13.83
150.000	0.945	-19.90
200.000	0.919	-25.70
250.000	0.902	-32.18
300.000	0.872	-38.03
350.000	0.850	-43.07
400.000	0.825	-48.27
450.000	0.803	-53.58
500.000	0.776	-58.49
550.000	0.760	-63.08
600.000	0.739	-67.98
650.000	0.717	-72.63
700.000	0.698	-76.96
750.000	0.683	-81.09
800.000	0.666	-85.49
850.000	0.659	-89.51
900.000	0.647	-93.90
950.000	0.637	-98.42
1000.00	0.634	-102.40

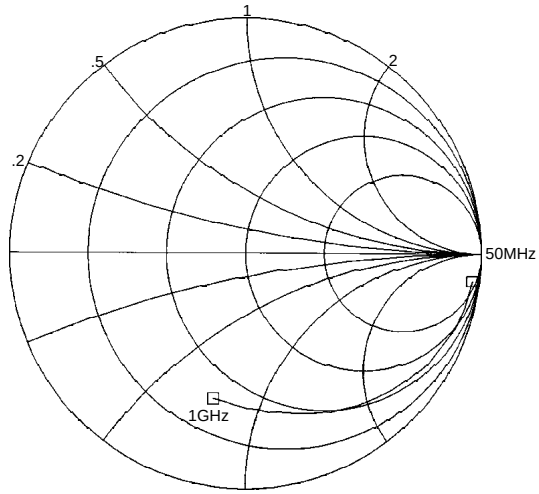


Fig.8b SL6609 Mixer B input S-Parameters

S11

FREQ	MAG	ANG
50.000	0.993	-4.17
100.000	0.995	-8.43
150.000	0.997	-12.88
200.000	0.997	-17.57
250.000	0.996	-22.63
300.000	0.986	-28.16
350.000	0.965	-33.87
400.000	0.936	-39.17
450.000	0.902	-43.88
500.000	0.872	-48.54
550.000	0.838	-52.81
600.000	0.804	-56.60
650.000	0.798	-59.47
700.000	0.810	-65.19
750.000	0.784	-71.49
800.000	0.779	-75.97
850.000	0.790	-82.54
900.000	0.788	-91.16
950.000	0.768	-100.20
1000.00	0.743	-108.52

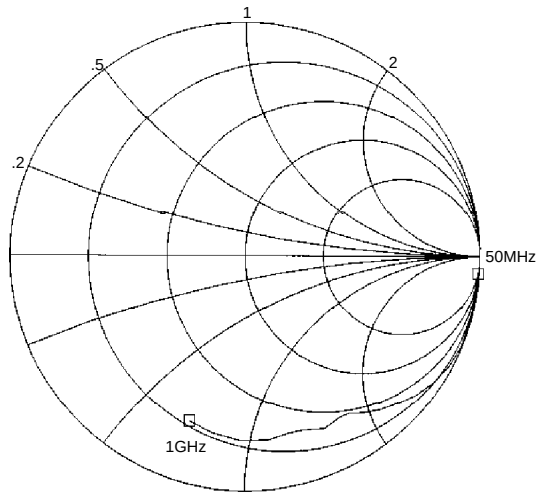


Fig.9 SL6609 LO X,Y inputs S-Parameters

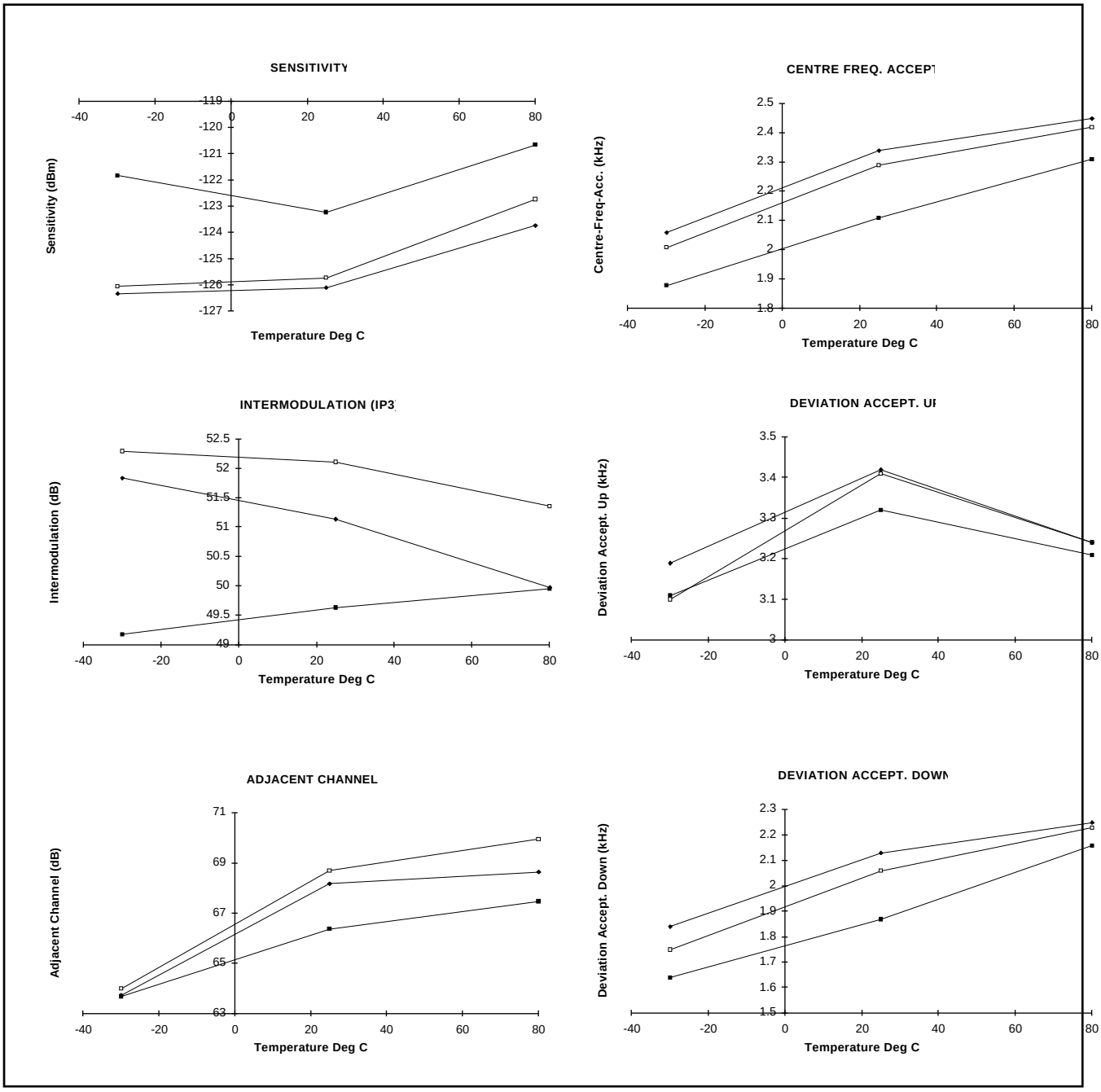
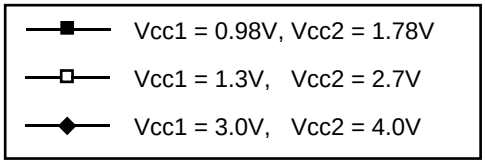


Fig.10 AC parameters vs. supply and temperature

Conditions:- 282MHz GPS demonstration board i.e. 18dB LNA, 2dB noise figure, carrier frequency 282MHz, 1200bps baud rate, 4kHz deviation frequency BER 1 in 30.



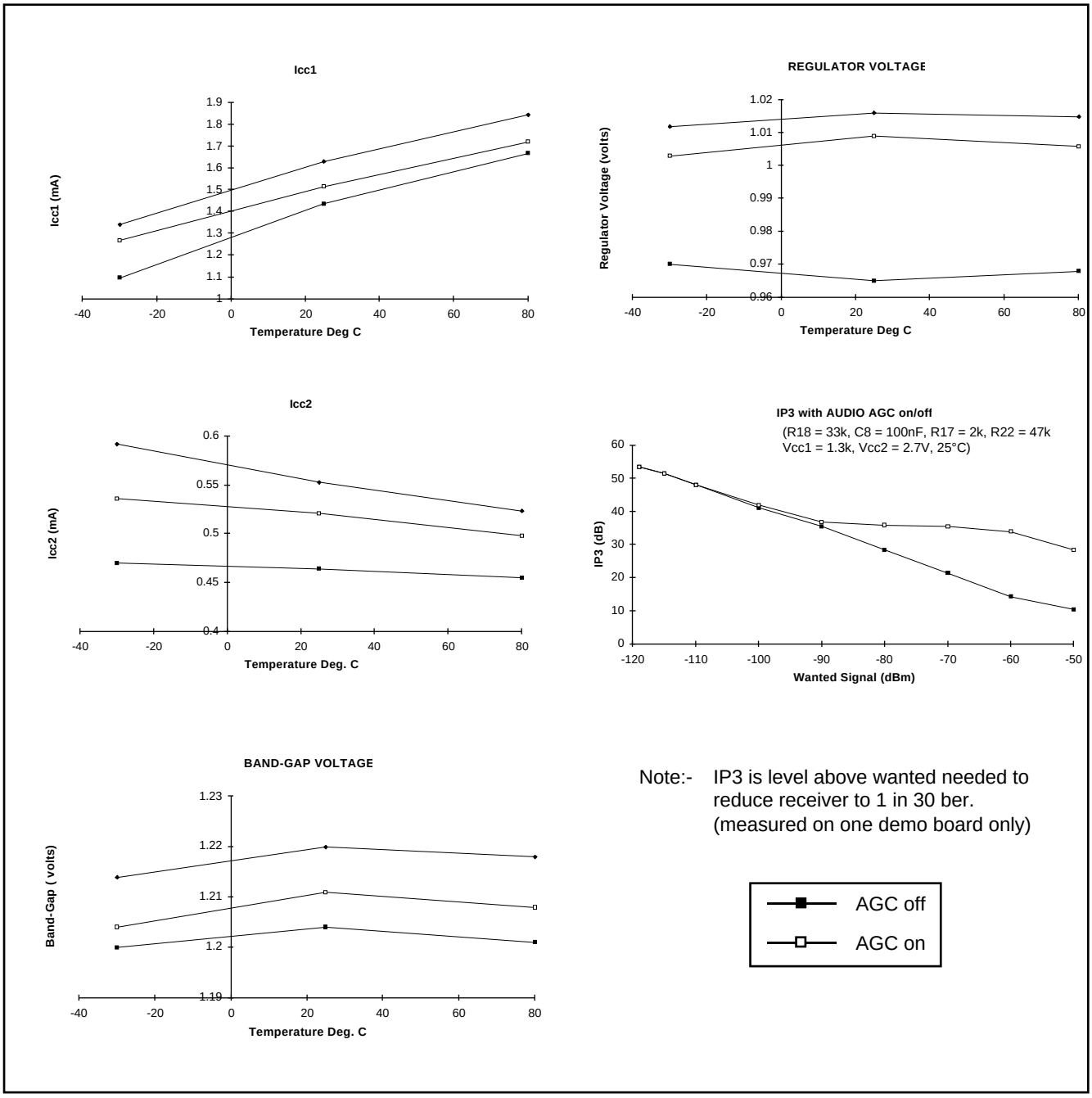


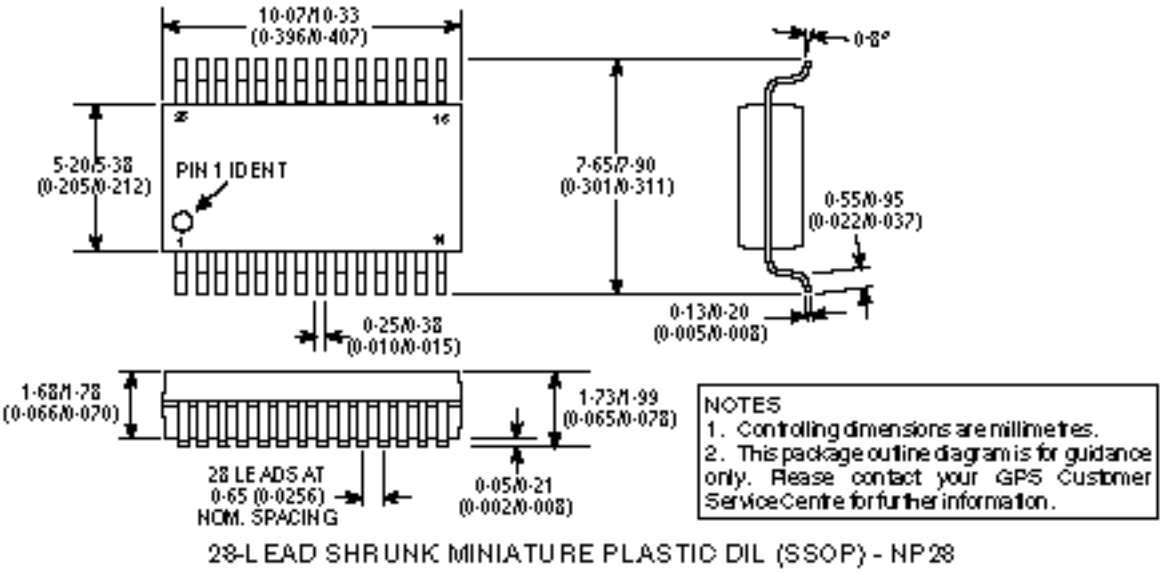
Fig.11 DC parameters vs. supply and temperature
(IP3 vs audio AGC both on and off)

Conditions:- ICC1 includes 500µA LNA current but does not include the regulator supply (audio AGC inactive). ICC2 measured with BATT FLAG and DATA O/P HIGH, Fc = 282MHz.

Vcc1 = 0.98V, Vcc2 = 1.78V
Vcc1 = 1.3V, Vcc2 = 2.7V
Vcc1 = 3.0V, Vcc2 = 4.0V

PACKAGE DETAILS

Dimensions are shown thus: mm (in)



28-LEAD SHRUNK MINIATURE PLASTIC DIL (SSOP) - NP28

ORDERING INFORMATION

SL6609 / KG / NPDS - SSOP devices in anti-static sticks
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