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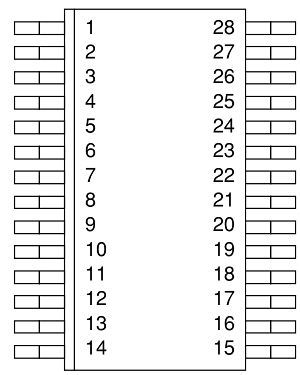
SL6649-1

200MHz DIRECT CONVERSION FSK DATA RECEIVER

The SL6649-1 is a low power direct conversion radio receiver for the reception of frequency shift keyed transmissions. It features the capability of 'power down' for battery conservation.

The device also includes a low battery flag indicator.



MP28

PIN	DESCRIPTION	PIN	DESCRIPTION
1	GND	28	CHANNEL B TEST.
2	BATTERY ECON	27	LO INPUT CHANNEL B
3	GYRATOR CURRT ADJ	26	LO INPUT CHANNEL A
4	REF VOLTAGE	25	V_{CC}1 (MIXER)
5	BANDGAP REF VOLT	24	MIXER I/P A
6	V_{CC}2	23	MIXER I/P B
7	BIT RATE FILTER	22	CHANNEL A TEST
8	DATA OUTPUT	21	LO CURRENT SOURCE
9	GND	20	RFA II (EMIT) RF DEC
10	NC	19	RFA II (BASE) RF INPUT
11	NC	18	RF DEC
12	NC	17	RF O/P
13	BATT FLAG INPUT	16	COLPITTS OSC O/P DISABLE
14	BATT FLAG OUTPUT	15	NC

N.B. It is advisable to connect NC pins to ground.

Figure 1: Pin Connections - Top View

FEATURES

- Very Low Power Operation - typ. 3.7mW
- Single Cell Operation with External Inverter
- Complete Radio Receiver in One Package
- Operation up to 200MHz
- 100nV Typical Sensitivity
- Operates up to 1200 BPS
- On Chip Tunable Active Filters
- Minimum External Component Count
- Low Power Down Current Typical 5µA

APPLICATIONS

- Low Power Radio Data Receiver
- Wristwatch Credit Card Pager
- Radio Paging
- Ultrasonic Direction Indication
- Security Systems
- Remote Control Systems

ABSOLUTE MAXIMUM RATINGS

Supply Voltage	6V
Storage Temperature	-55°C to +150°C
Operating Temperature	-20°C to +70°C

ORDERING INFORMATION

SL6649-I/KG/MPES - Small outline (MP28) supplied in tubes

SL6649-1/KG/MPEF - Small outline (MP28) supplied in tape & reel

ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed over the following conditions (unless otherwise stated).
T_{amb} = 25°C, $V_{CC}1$ = 2.5V, $V_{CC}2$ = 3.5V

Characteristic	Pin	Value Min	Value Typ	Value Max	Units	Conditions
Supply Voltage $V_{CC}1$	25	V_R	1.3	2.8	V	$V_{CC}1 \leq (V_{CC}2)$-0.7
Supply Voltage $V_{CC}2$	6,16	1.8	2.3	3.5	V	
Supply Current $I_{CC}1$	17, 25, 26, 27		1.6	2.0	mA	(I_{RF}) Included
Supply Current $I_{CC}2$	6,16		0.65	0.80	mA	
Power Down $I_{CC}1$	17, 21, 25, 26, 27		5	12	µA	Batt Econ Low
Power Down $I_{CC}2$	6,16		3	12	µA	Batt Econ Low
Bandgap Reference	5	1.15	1.22	1.35	V	
Voltage Reference	4	0.93	1.0	1.13	V	
RF Amplifier						
Supply Current (I_{RF})	17	430	535	640	µA	
Power Down	17				µA	Included in Power Down $I_{CC}1$
Mixers						
Gain to "IF Test"		32		38	dB	L.O. inputs driven in parallel with 50mV RMS @ 50MHz. IF = 2kHz
Oscillator						
Current Source	21	215	270	330	µA	
Power Down	21				µA	Included in Power Down $I_{CC}1$
Decoder						
Sensitivity				40	µVrms	Signal injected at "IF TEST" B.E.R. ≤1 in 30 5kHz deviation @ 500 bits/sec BRF capacitor = 1nF
Output Mark Space Ratio	8	7:9		9:7		
Output Logic High	8	85			%$V_{CC}2$	
Output Logic Low				15	%$V_{CC}2$	
Battery Economy						
Input Logic High	2	($V_{CC}2$)-0.3			V	Powered Up
Input Logic Low	2			0.3	V	Powered Down
Input Current			0.05	1	µA	
Battery Flag						
Output High Level	14	85			%$V_{CC}2$	Battery Low R_L > 1MΩ
Output Low Level	14			15	%$V_{CC}2$	Battery High R_L > 1 MΩ
Flag trig Level	13	V_R-25mV		V_R+25mV	V	Voltage Reference (V_R) pin 4
Colpitts Oscillator						
Frequency		15			kHz	R=90K, pin 3 to GND
				15	kHz	R=360K, pin 3 to GND

TYPICAL ELECTRICAL CHARACTERISTICS

These characteristics are guaranteed by design.
T_{amb} = 25°C, $V_{CC}1$ = 2.5V, $V_{CC}2$ = 3.5V

Characteristic	Pin	Value			Units	Conditions
		Min	Typ	Max		
RF Amplifier						
Noise Figure			5.5		dB	RS = 50Ω
Power Gain			14		dB	
Input Impedance	19					See Fig. 8
Mixer						
RF Input Impedance	23, 24					See Figs. 9 (a) and (b)
LO Input Impedance	26, 27					See Fig. 10
LO DC Bias Voltage	26, 27				V	Equal to pin 25
Detector						
Output Current	7		±4		μA	
Colpitts Oscillator						
Frequency	16		15		kHz	R = 270K, Pin 3 to GND
Output Voltage	16		20		mVp-p	R_L >> 1MΩ N.B. Refer to Channel Filter Fig. 4

RECEIVER CHARACTERISTICS (GPS DEMONSTRATION BOARD)

Measurement conditions (unless otherwise stated): Applications circuit diagram Fig.6; $V_{CC}1$ = 1.3V; $V_{CC}2$ = 2.3V; T_{amb} = 25°C; Colpitts oscillator resistor = 270kΩ; mixer input A and B phase balance = 180°; local oscillator input A and B phase balance = 90°. Measurement methods as described by CEPT Res 2 specification. F_{IN} = 153MHz (512 baud).

Characteristic	Value			Units	Conditions
	Min	Typ	Max		
Terminal Sensitivity Tone only 4/5 call reception		-127	-124	dBm	Δf = 4.5kHz, R_S = 50Ω
Deviation Acceptance		±2.5		kHz	3dB De-Sensitisation. F_{IN} = F_{LO}
Centre Frequency Acceptance	±2.0	±2.5		kHz	Δf = 4.5kHz
Adjacent Channel Rejection	65	70		dB	Δf = 4.5kHz Channel Spacing 25kHz
Adjacent + 1 Channel Rejection	65	70		dB	External capacitors on test
Third Order Intermod adj-1 + adj-2	52	53		dB	pins A and B.

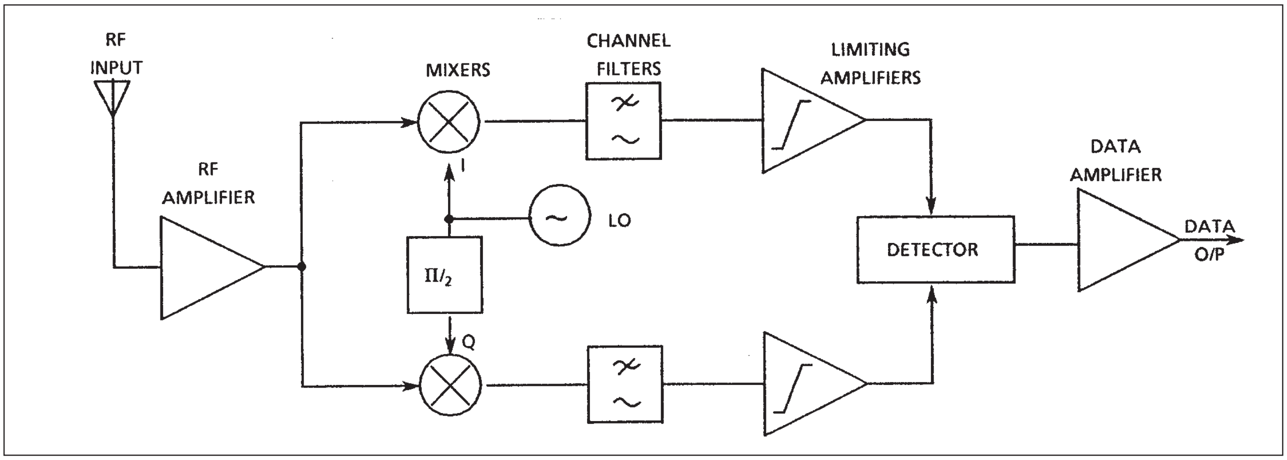


Figure 2: Block Diagram of SL6649-1 Direct Conversion Receiver

PRINCIPLE OF OPERATION

The incoming signal is split into two parts and frequency converted to baseband. The two paths are produced in phase quadrature (see Fig 2) and detected in a phase detector which provides a digital output. The quadrature network must be in the local oscillator path.

At a data rate of 512 baud and a deviation frequency of 4.5kHz, the input to the system has a demodulation index of 18. This gives a spectrum as in Fig 3. f_1 and f_0 represent the 'steady state' frequencies (i.e. modulated with continuous '1' and '0' respectively). The spectrum in Fig 3 is for reversals (a 0-1-0-1-0-1 etc. pattern) at the system bit rate; f_C is the nominal carrier frequency).

When the LO is at the nominal carrier frequency, then a continuous '0' or '1' will produce an audio frequency, at the output of the mixers corresponding to the difference between f_0 and f_C or f_1 and f_C. If the LO is precisely at fc, then the resultant output signal will be at the same frequency regardless of the data state; nevertheless, the relative phases of the two paths will reverse between '0' and '1' states. By applying the amplified outputs of the mixers to a phase discriminator, the digital data is reproduced.

TUNING THE CHANNEL FILTERS

The adjacent channel rejection performance of the SL6649-1 receiver is determined by the channel filters. To obtain optimum adjacent channel rejection, the channel filters' cut off frequency should be set to 8kHz. The process tolerances are such that the cut off frequency cannot be accurately defined, hence the channel filters must be tuned. However the receiver characteristics on the previous page can be achieved with a fixed 270kΩ resistor between pin 3 and GND.

Tuning is performed by adjusting the current in the gyrator circuits. This changes the values of the gyrator's equivalent inductance. The cut off frequency is tuned to 8kHz. To accurately define the cut off of the channel filters, a gyrator based Colpitts oscillator circuit has been included on the SL6649-1. The Colpitts oscillator and channel filters use the same type of architecture, hence there is a direct correlation between oscillator frequency and cut off frequency. By knowing the Colpitts oscillator frequency the channel filter cut off frequency can be estimated from Figure 4.

Once the channel filters have been tuned it may be necessary to disable the Colpitts oscillator. The Colpitts oscillator is disabled by connecting the Colpitts oscillator output/disable pin (pin # 16) to $V_{CC}2$. This is needed since the Colpitts oscillator may impair the performance of the receiver.

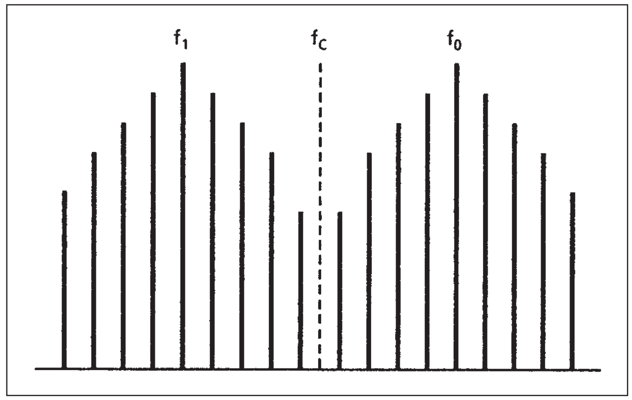


Figure 3: Spectrum Diagram

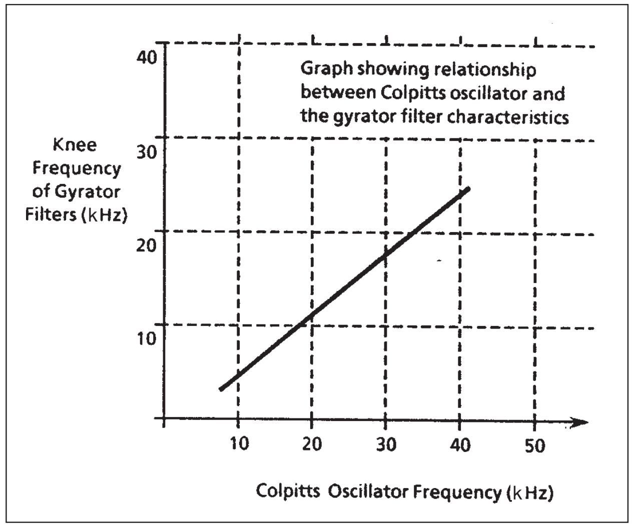


Figure 4

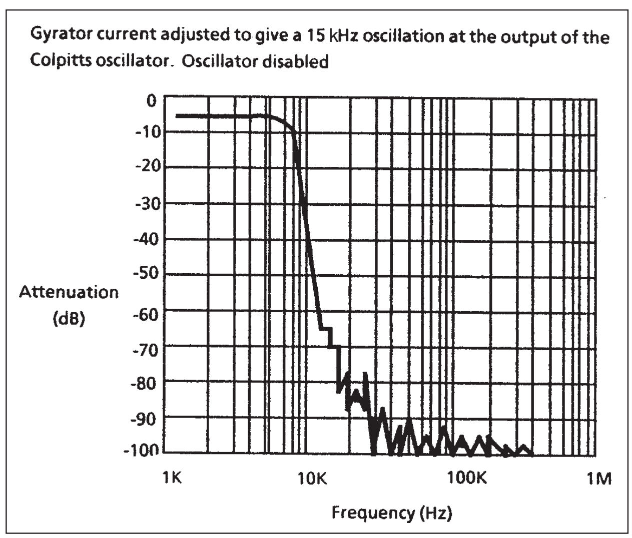


Figure 5: Channel Filter Response

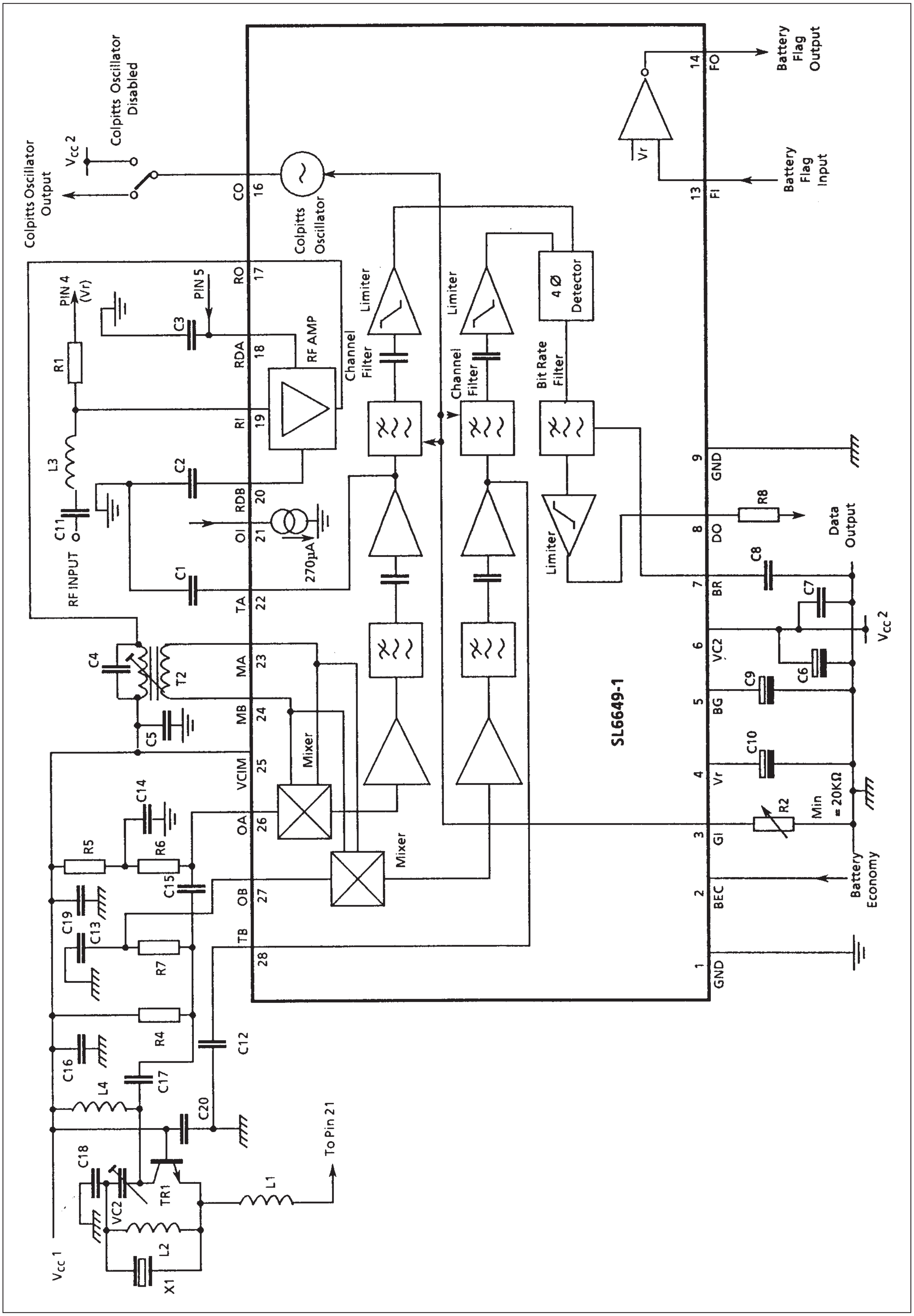


Figure 6: Block Diagram and Applications Circuit (for component values see next page)

COMPONENTS LIST FOR FIGURE 6

Capacitors		Resistors	Inductors	Transformers	Miscellaneous
C1 1nF	C11 1nF	R1 2.2kΩ	L1 10µH	T1 1:1 Transformer Primary/Secondary Inductance=200nH	IC1 SL6649-1
C2 1nF	C12 1nF	R2 500kΩ Variable	L2 220nH		TR1 SOT-23 Transistor with $f_\tau \geq$ 1.3GHz (EG. ZETEX BFS 17)
C3 1nF	C13 10pF	R4 100Ω	L3 150nH		X1 153MHz 7th overtone crystal
C4 5.6pF	C14 1nF	R5 100Ω	L4 100nH		VC2 1.5-10pF
C5 1nF	C15 10pF	R6 100Ω			
C6 2.2µF	C16 1nF	R7 100Ω			
C7 1nF	C17 5.6pF	R8 100KΩ			
C8 1nF	C18 4.7pF				
C9 2.2µF	C19 1nF				
C10 2.2µF	C20 1nF				

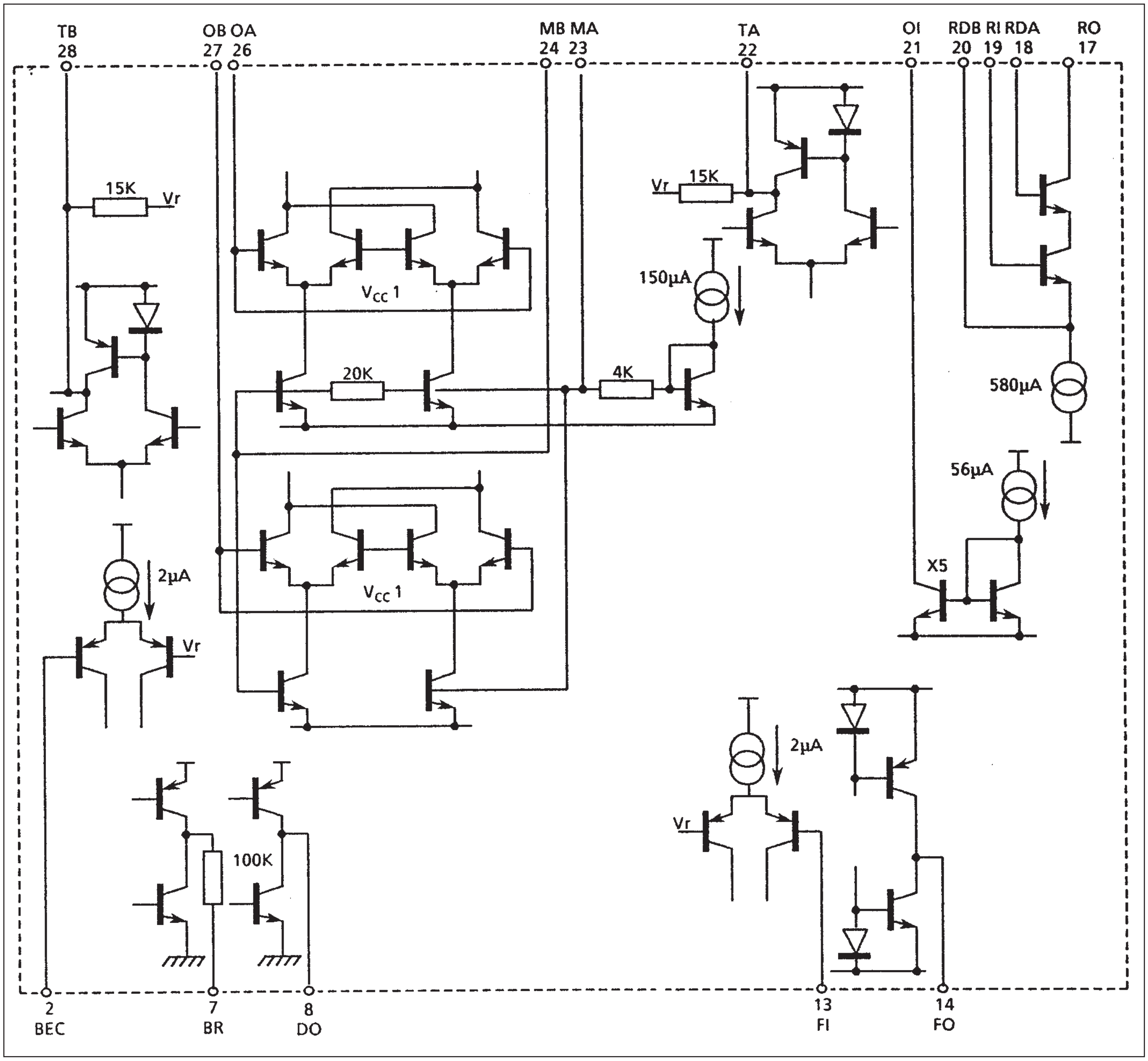
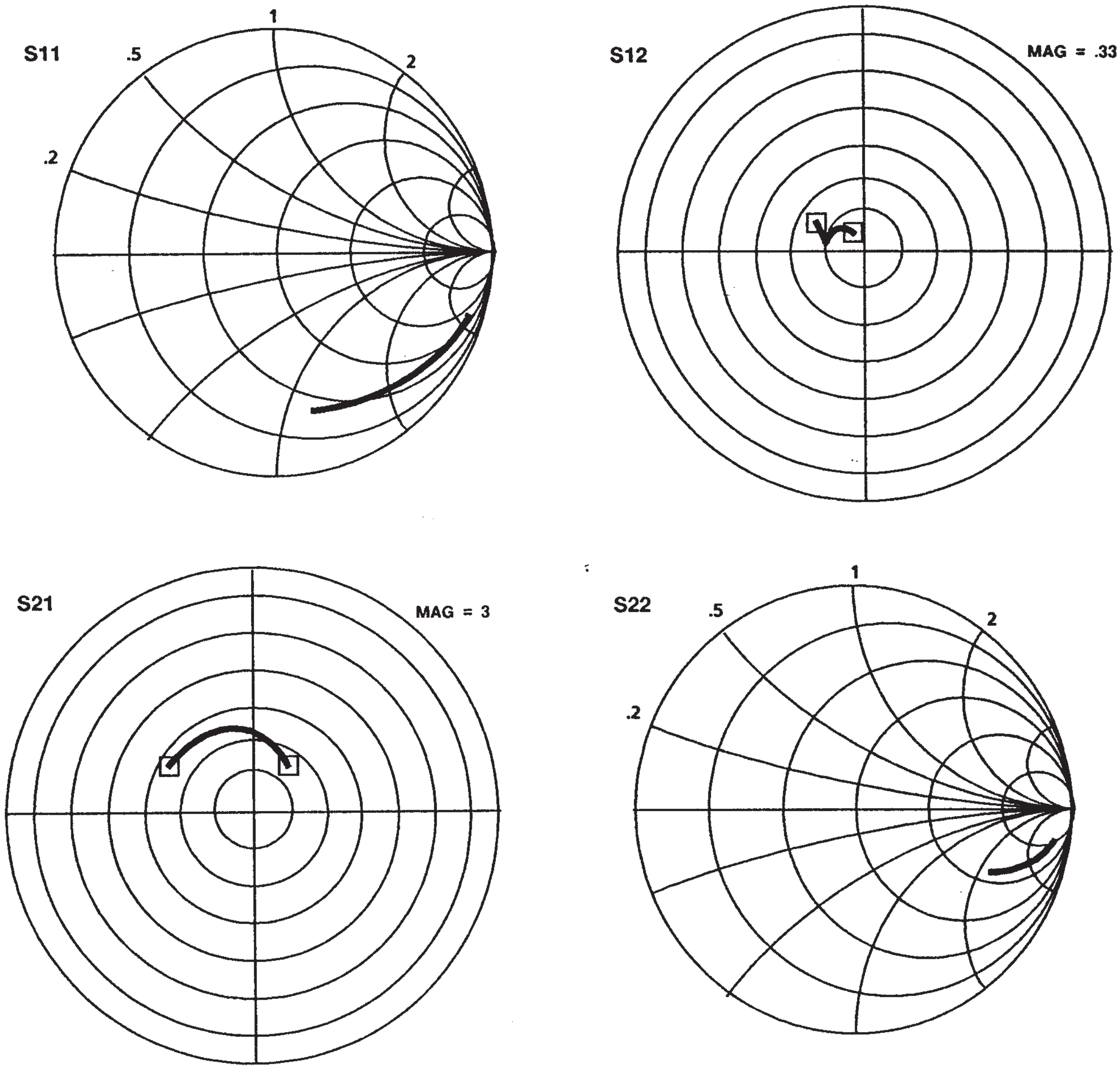


Figure 7: Pinning Diagram of the SL6649-1



FREQ	S11		S12		S22		S21	
MHz	MAG.	ANG.	MAG.	ANG.	MAG.	ANG.	MAG.	ANG.
100.000	0.963	-15.971	0.016	120.281	1.036	-3.440	1.460	157.948
150.000	0.949	-21.603	0.017	121.732	0.991	-5.524	1.390	142.732
200.000	0.934	-27.247	0.017	123.174	0.946	-7.608	1.321	127.508
250.000	0.906	-33.835	0.021	124.612	0.938	-10.156	1.261	115.531
300.000	0.876	-40.519	0.025	126.042	0.934	-12.744	1.201	103.830
350.000	0.846	-45.789	0.029	139.335	0.925	-14.380	1.132	95.446
400.000	0.816	-50.979	0.032	153.381	0.915	-15.955	1.061	87.270
450.000	0.781	-58.616	0.039	163.051	0.872	-18.015	0.986	78.111
500.000	0.746	-66.363	0.045	172.537	0.827	-20.094	0.910	68.910
550.000	0.700	-72.624	0.062	165.197	0.771	-19.691	0.854	65.157
600.000	0.655	-78.856	0.079	157.518	0.716	-19.231	0.798	61.518

Figure 8: RF Amplifier

S11

FREQ.	MAG.	ANG.
100.000	0.943	-14.921
150.000	0.929	-21.059
200.000	0.914	-27.208
250.000	0.904	-35.234
300.000	0.895	-43.439
350.000	0.866	-52.138
400.000	0.836	-60.882
450.000	0.796	-68.177
500.000	0.756	-75.417
550.000	0.726	-82.654
600.000	0.696	-89.883

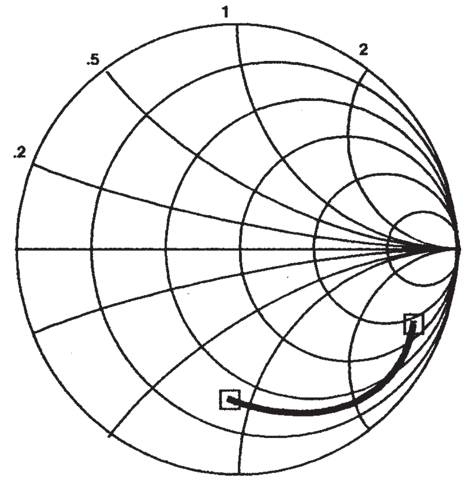


Figure 9a: SL6649-1 Mixer RF input pin 23

S11

FREQ.	MAG.	ANG.
100.000	0.963	-10.019
150.000	0.953	-15.143
200.000	0.944	-20.277
250.000	0.930	-20.764
300.000	0.915	-20.853
350.000	0.891	-30.479
400.000	0.866	-40.734
450.000	0.846	-46.135
500.000	0.826	-51.344
550.000	0.806	-57.057
600.000	0.786	-62.785

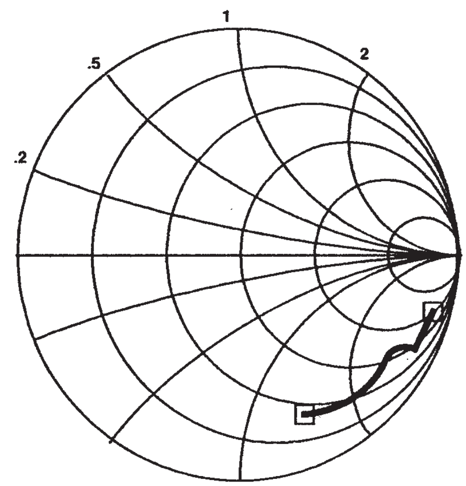


Figure 9b: SL6649-1 Mixer RF input pin 24

S11

FREQ.	MAG.	ANG.
100.000	0.993	-11.020
150.000	0.983	-16.144
200.000	0.974	-21.277
250.000	0.960	-27.820
300.000	0.945	-34.499
350.000	0.954	-39.765
400.000	0.946	-44.952
450.000	0.927	-52.586
500.000	0.907	-60.331
550.000	0.877	-67.086
600.000	0.847	-73.819

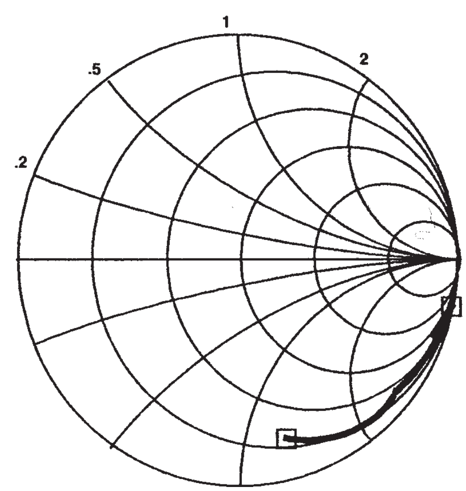


Figure 10: SL6649-1 Mixer LO input pins 26 and 27

METHOD FOR THE MEASUREMENT OF SENSITIVITY ON THE SL6649-1 RECEIVER

The method used by GEC Plessey Semiconductors in the measurement of terminal sensitivity is essentially the same as that described in the CEPT Res 2 Specification.

This method requires the following equipment:

1. A signal generator e.g. HP8640
2. A pocsag encoder
3. A pocsag decoder e.g. MV6639
4. An SL6649-1 Demo Board.
5. An interference free low impedance P.S.U. ($V_{CC}1$ and $V_{CC}2$ must be separate supplies and there must be at least 0.7V difference between them). Recommended supply configurations are shown in Fig. 13.

The test equipment and D.U.T. are set up as shown in Figure 11.

The R.F. frequency is set to the nominal L.O. frequency of the receiver and the peak deviation is set to 4.5kHz.

Care must be taken to avoid long power supply leads and any ground loops. Any interference from the decoder will be reduced by the insertion of a high value resistor R1 (100KΩ) between the receiver data output and the decoder input.

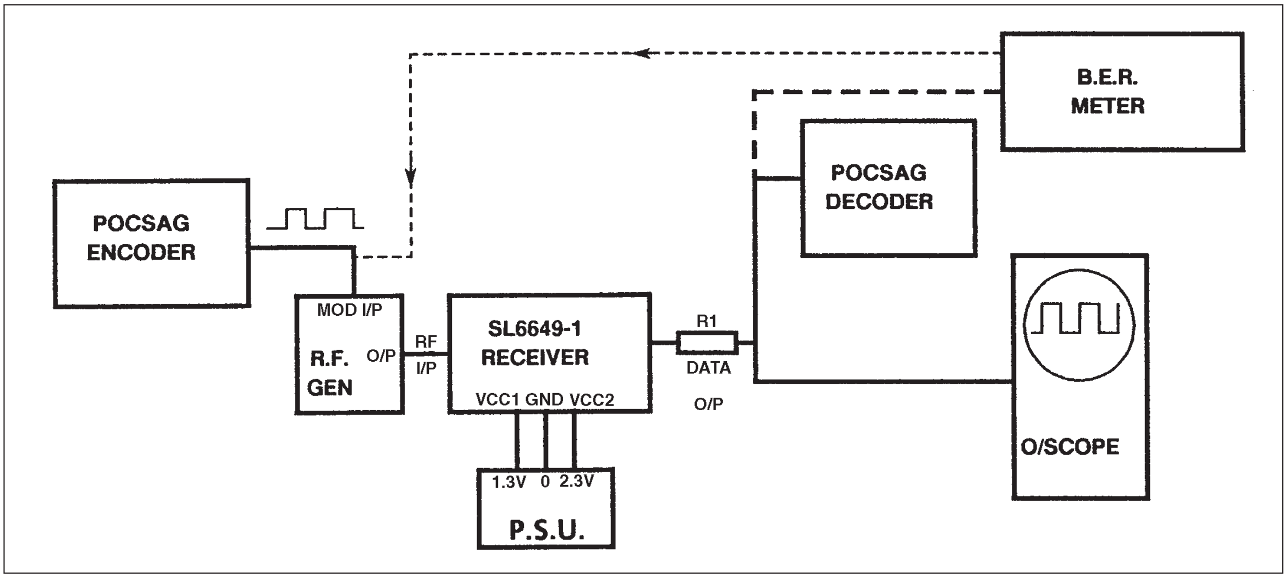


Figure 11: Test System

The generator output level is reduced successively until the decoder responds just 4 out of 5 times to the encoder signal. This output level is then recorded as the sensitivity threshold of the receiver.

We find that this threshold correlates to a bit error rate of 1 in 30. The data output waveforms for an input level which produces a B.E.R. of 1 in 30 and for input levels 2dB above and below this level, are shown below (square wave input). It can be seen that the edge jitter increases dramatically at signal levels below the sensitivity threshold of -127dBm. Typical waveforms that can be seen on an oscilloscope around the sensitivity threshold level are shown in Figure 12.

NB. In performing the sensitivity measurement great care should be taken in preventing coupling between test leads.

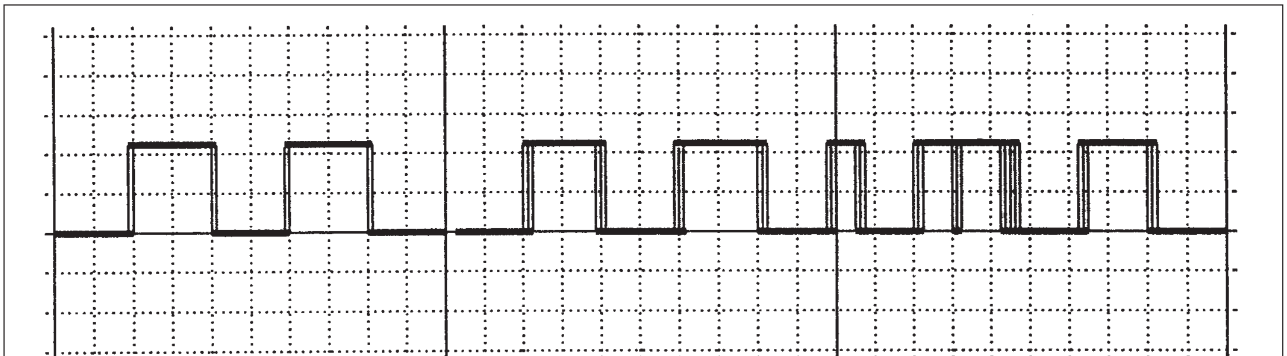
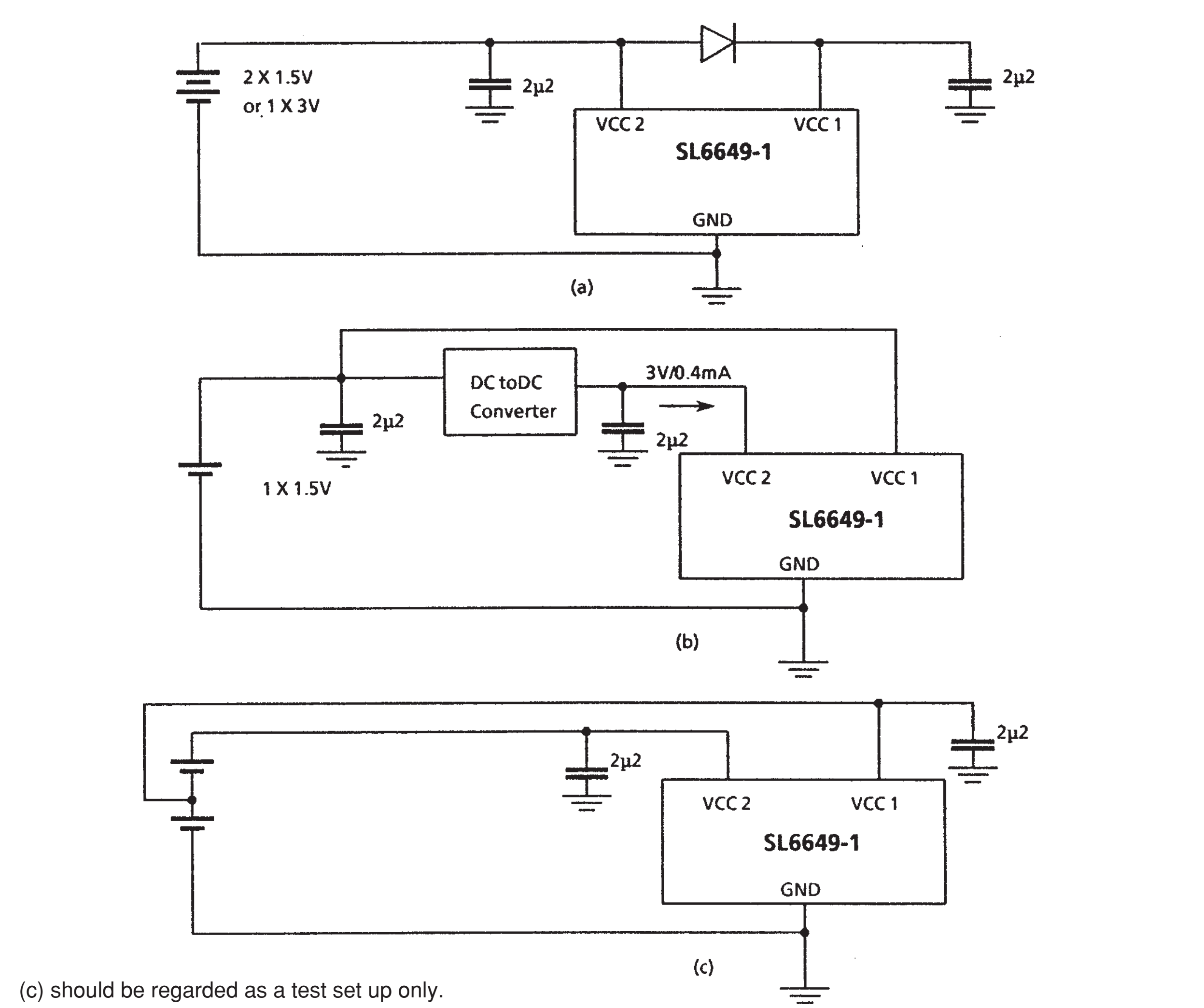


Figure 12: Waveform at Data O/P

PIN	MNEMONIC	FUNCTION
1	GND	Ground
2	BEC	Battery Economy
3	GI	Gyrator Current Adjust
4	Vr	Reference Voltage
5	BG	Bandgap Reference Voltage
6	Vc2	V_{CC} 2
7	BR	Bit rate Filter
8	DO	Data Output
9	GND	Ground
10		UNC
11		UNC
12		UNC
13	FI	Battery Flag Input
14	FO	Battery Flag Output

PIN	MNEMONIC	FUNCTION
15		UNC
16	CO	Colpitts Oscillator Output/Disable
17	RO	RFA I (collector) RF Output
18	RDA	RFA I (base) RF Decouple
19	RI	RFA II (base) RF Input
20	RDB	RFA II (emitter) RF Decouple
21	OI	LO Current Source
22	TA	Channel A Test
23	MA	Mixer I/P B
24	MB	Mixer I/P A
25	VCIM	V_{CC}1 (mixer)
26	OA	LO Input Channel A
27	OB	LO Input Channel B
28	TB	Channel B Test

POWER SUPPLIES



(c) should be regarded as a test set up only.

Figure 13(a): SL6649-1 Power Supply Options

PAGER APPLICATION EXAMPLE

A typical 1 volt pager system suitable as a wrist watch application is shown in Figure 13 (b). Only 3 integrated circuits are required to perform all the functions of a tone only pager. These are SL6649-1 direct conversion radio receiver and the MV6639 POCSAG decoder plus a 1 volt E^2PROM (eg. Seiko Epson SPM28C51).

The SL6649-1 receives and demodulates the data, and monitors the battery voltage. The interface between the decoder and receiver consists of only 3 connections excluding the supplies.

The MV6639 performs all the functions required for a POCSAG decoder for tone only and/or pager messaging at 512 or 1200 baud. A 32kHz watch crystal is used as the reference frequency for the decoder.

The decoder voltage doubler output $V_{CC}2$ is available to power not only the receiver, but an alternative higher voltage E^2PROM and microprocessor/LCD driver for a full tone and message pager.

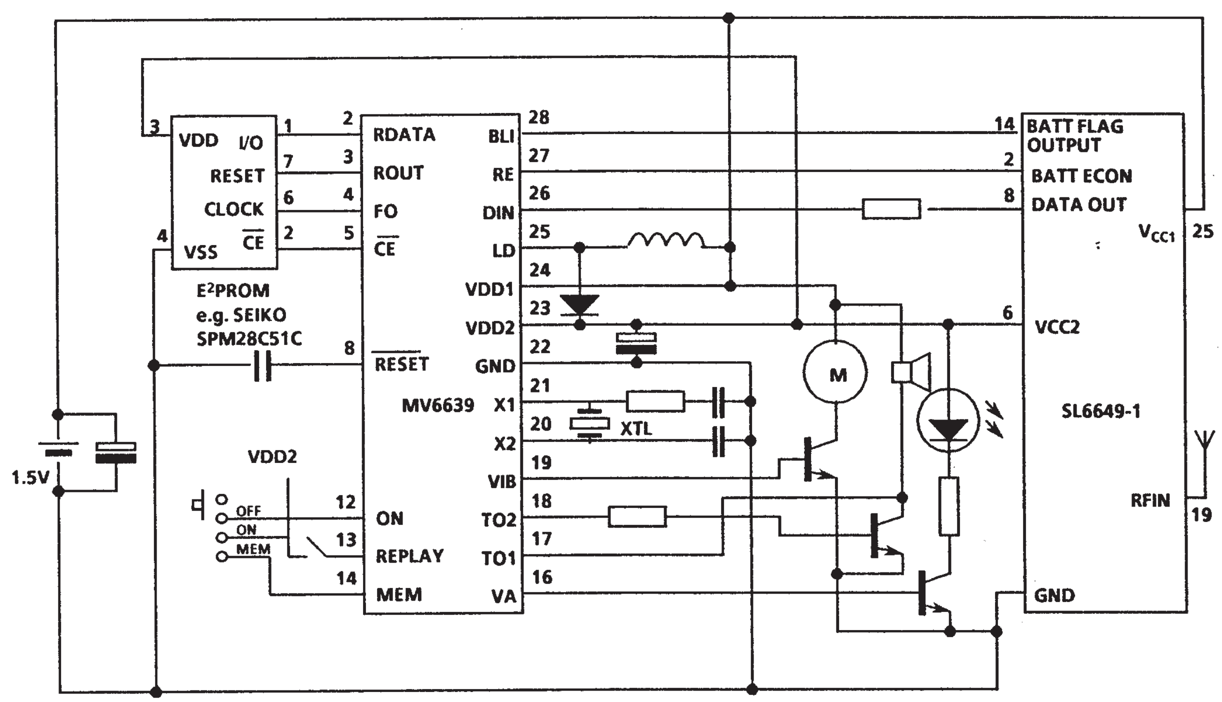


Figure 13(b): Tone Pager Applications Example Showing Interface with SL6649-1 Receiver

OPERATION AT OTHER FREQUENCIES AND DATA RATES

The values given in the components list for figure 6 are appropriate for frequencies nominally around 153MHz. In order to use the receiver at other frequencies it is necessary to change the capacitor C4 which is resonant with the transformer T1, and L2 and L4 in the oscillator circuit.

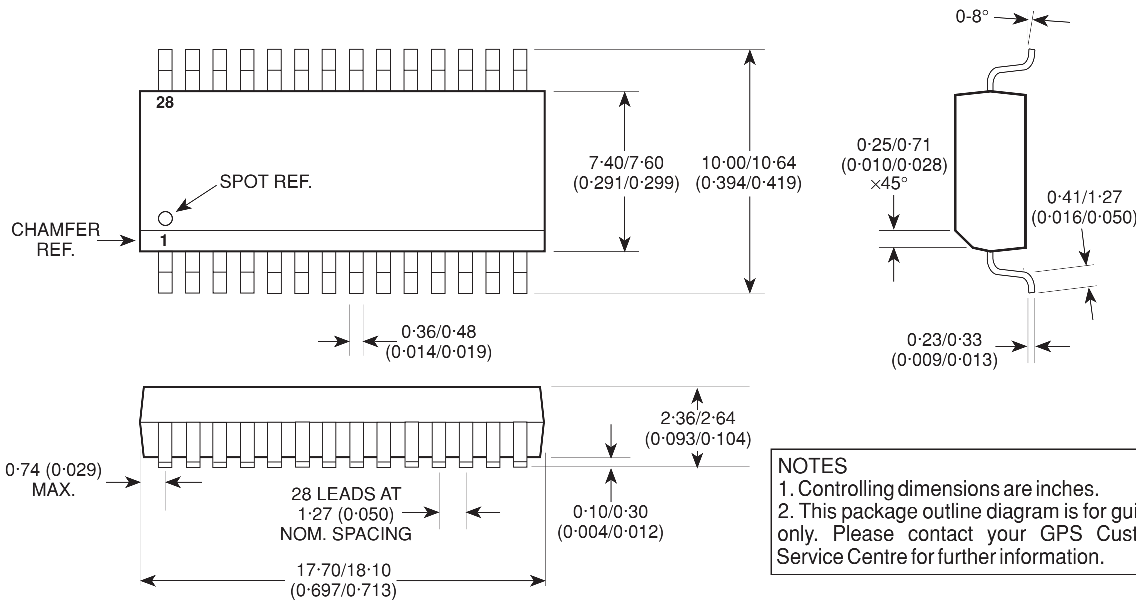
It is also necessary to change the values of capacitors C13 and C15 such that the reactance of these is equal to 100Ω at the required frequency.

It is of course necessary to use a crystal of the required frequency and stability. In order to use the receiver at higher data rates it is only necessary to reduce the value of C8, for example, at 1200bps, C8=470pf.

A demonstration board has been designed specifically to demonstrate terminal sensitivity. It is possible to connect an antenna to the board with suitable matching but no guarantee can be given regarding field strength sensitivity. However, with a suitably designed combination of PCB and antenna, a sensitivity of 5µV/M should be attainable.

PACKAGE DETAILS

Dimensions are shown thus: mm (in). For further package information, please contact your local Customer Service Centre.



NOTES
1. Controlling dimensions are inches.
2. This package outline diagram is for guidance only. Please contact your GPS Customer Service Centre for further information.

28-LEAD MINIATURE PLASTIC DIL - MP28

GEC PLESSEY SEMICONDUCTORS

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