GEC PLESSEY
SEMICONDUCTORS

3115 - 4.1

# SL6649-1

## 200MHz DIRECT CONVERSION FSK DATA RECEIVER

*(Supersedes edition in August 1994 Personal Communications IC Handbook)*

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.

### 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

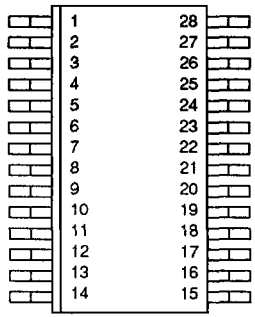
### ABSOLUTE MAXIMUM RATINGS

| | |
|---|---|
| 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




**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*

## 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 | | | Units | Conditions |
|---|---|---|---|---|---|---|
| | | Min | Typ | Max | | |
| 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. |

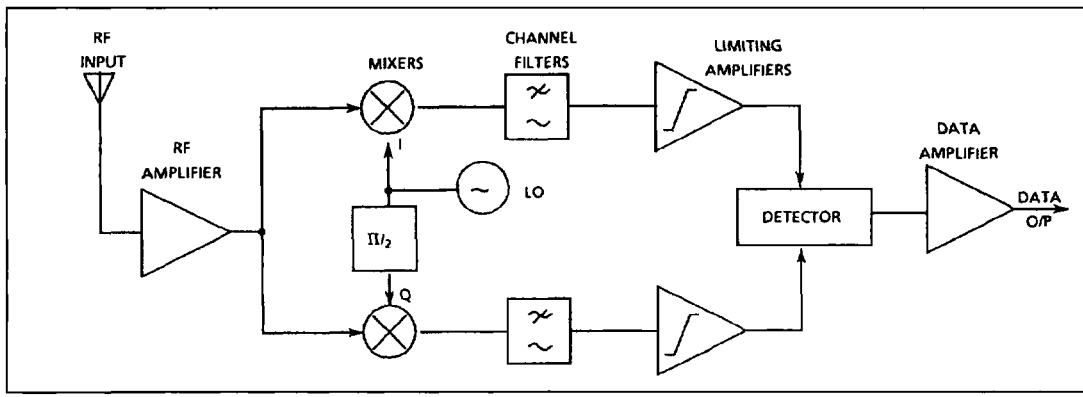



*Figure 2: Block Diagram of SL6649-1 Direct Conversion Receiver*

## 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.

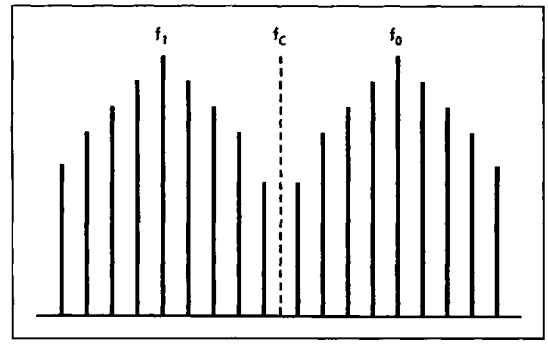



*Figure 3: Spectrum Diagram*

## 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.

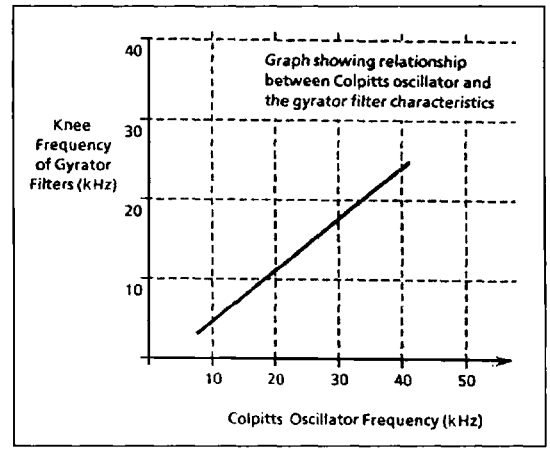



*Figure 4*

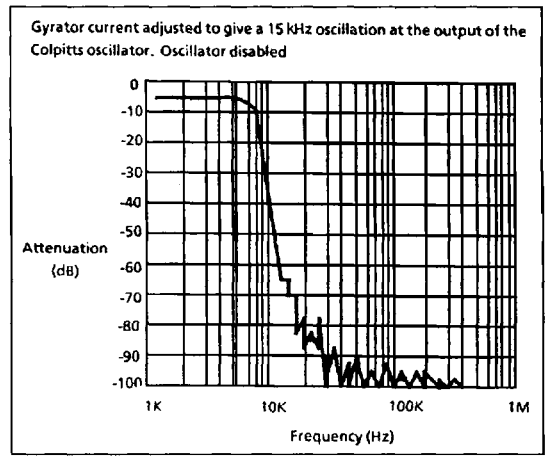



*Figure 5: Channel Filter Response*

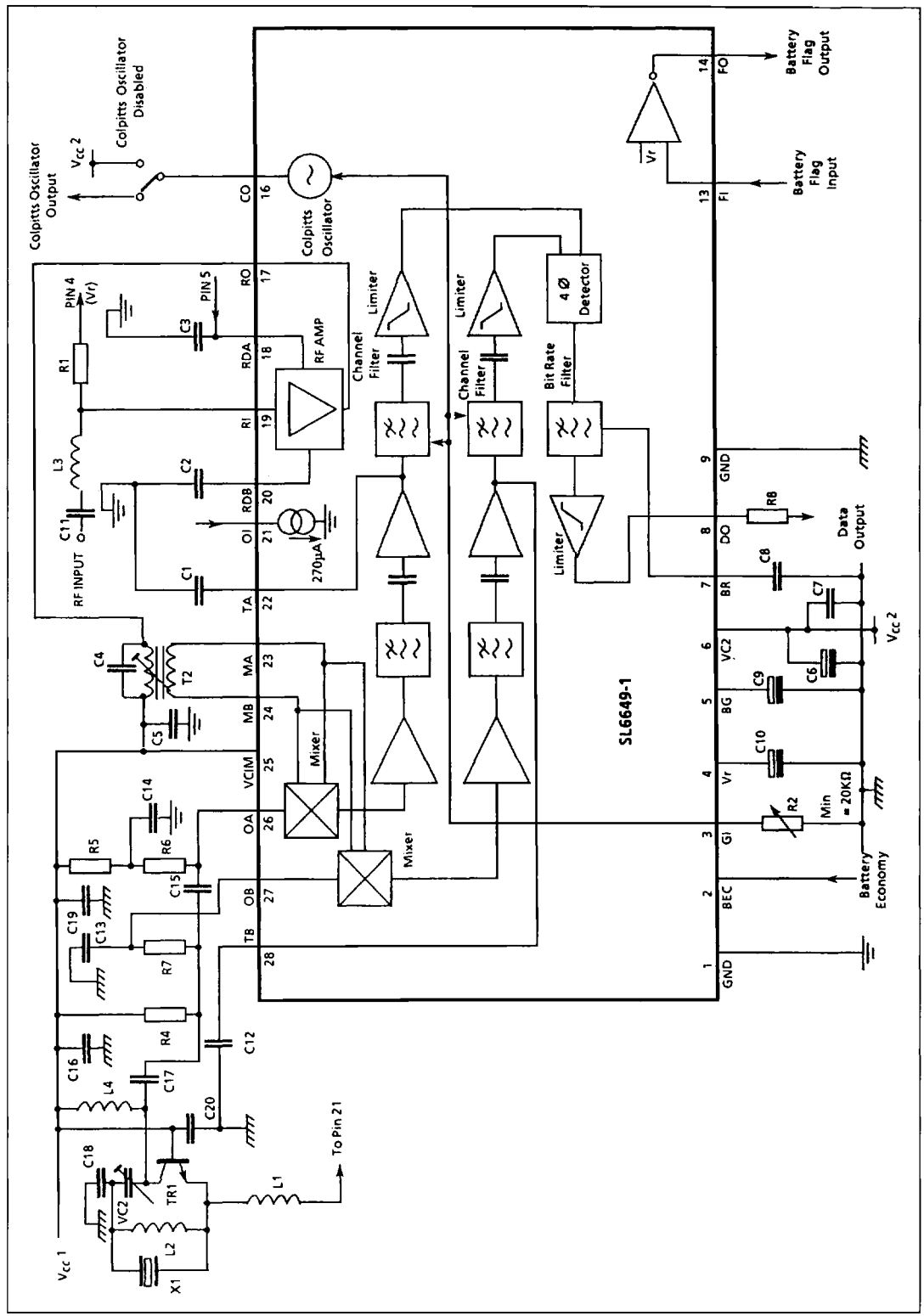



*Figure 6: Block Diagram and Applications Circuit (for component values see next page)*

## COMPONENTS LIST FOR FIGURE 6

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

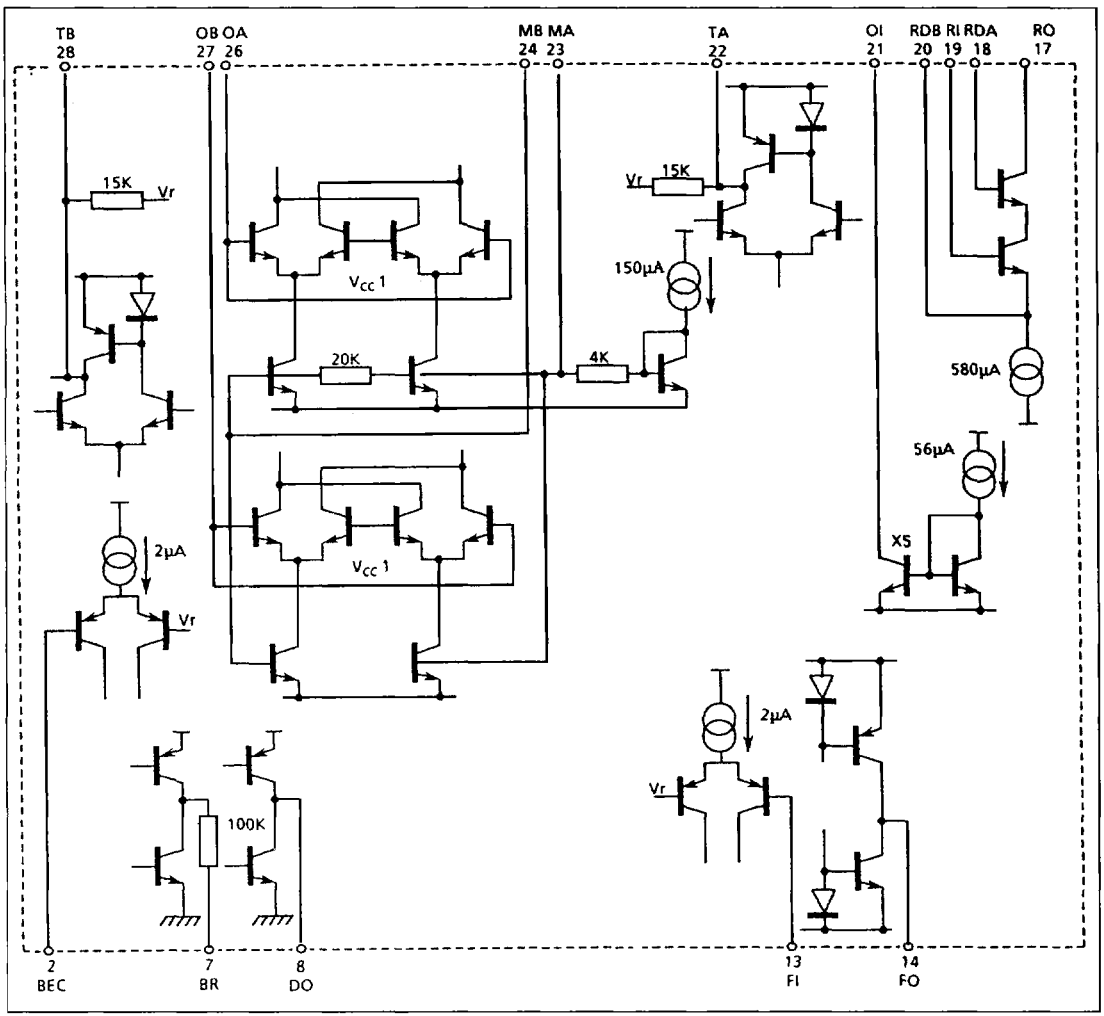
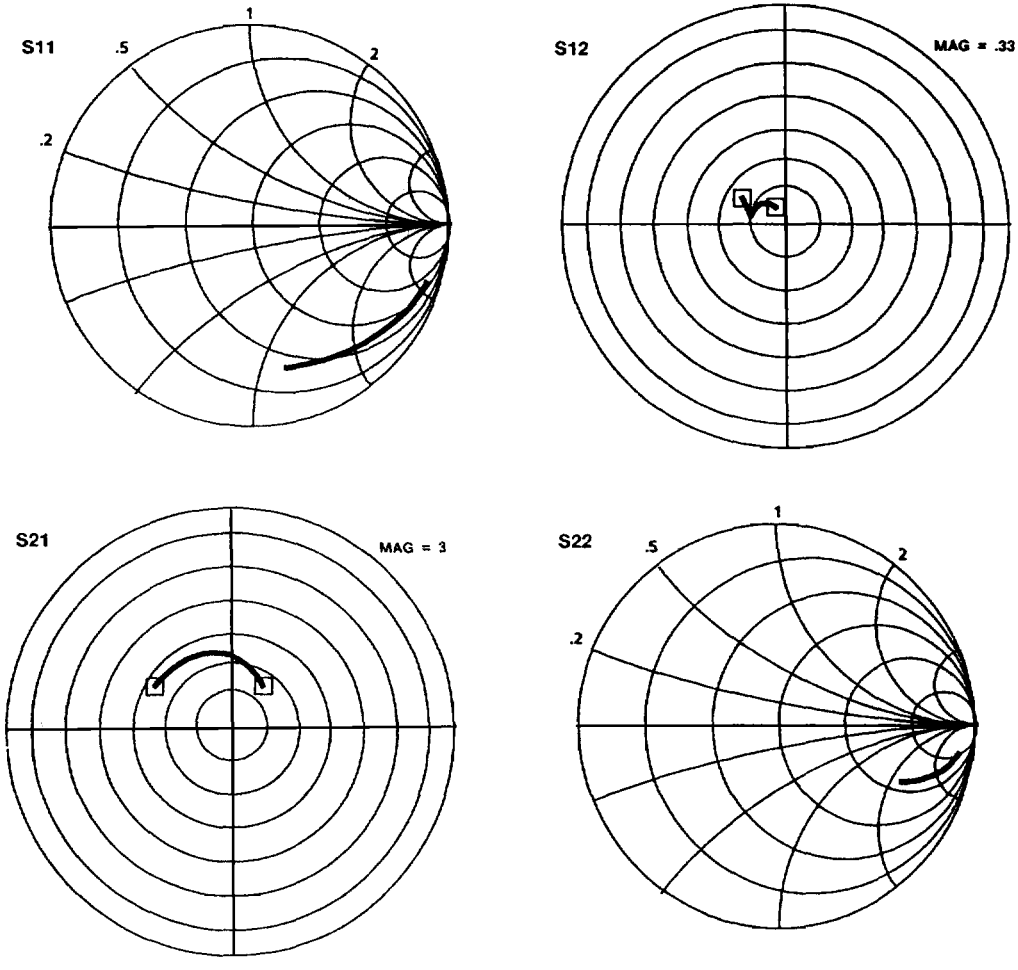



*Figure 7: Pinning Diagram of the SL6649-1*




| 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 |

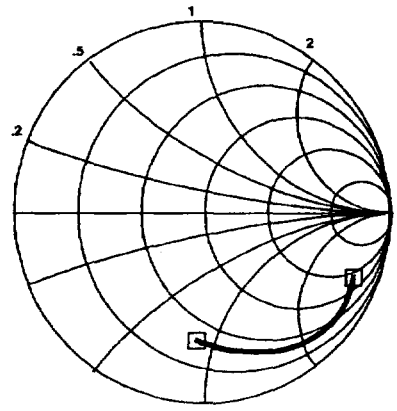



*Figure 9a: SL6649-1 Mixer RF input pin 23*

☐ 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 |

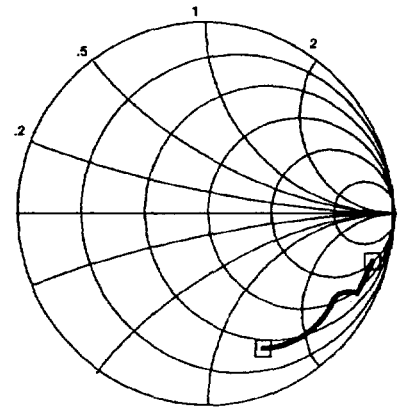



*Figure 9b: SL6649-1 Mixer RF input pin 24*

☐ 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 |

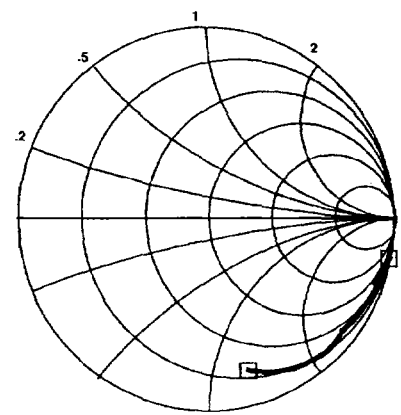



*Figure 10: SL6649-1 Mixer LO input pins 26 and 27*

## 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.

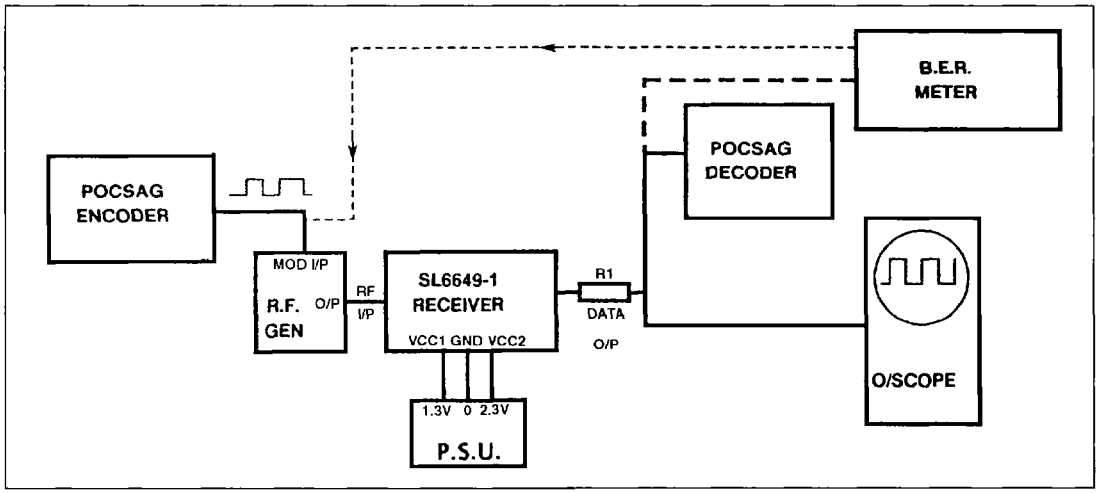



*Figure 11: Test System*

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.

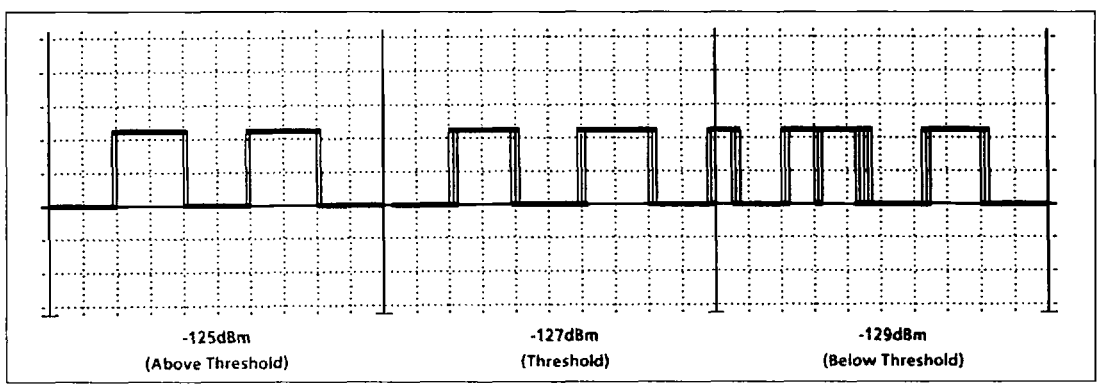
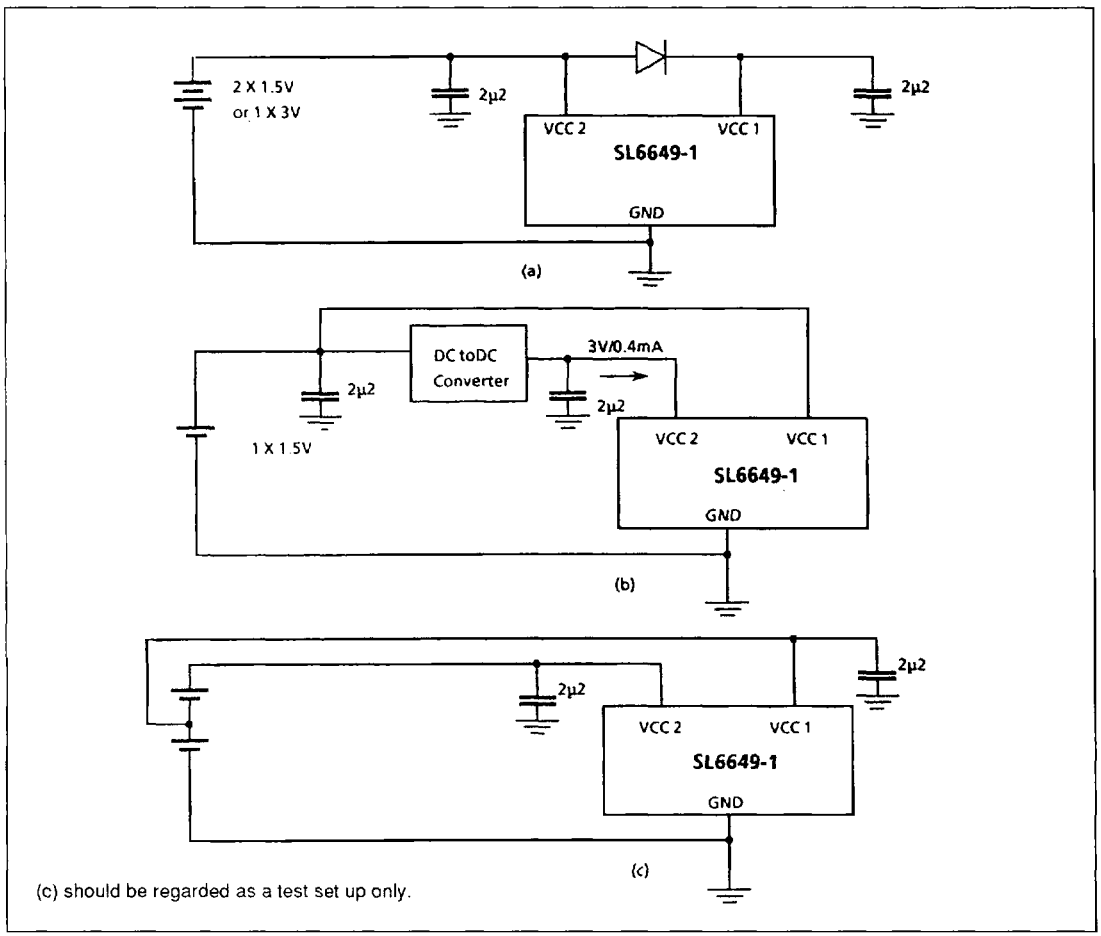



*Figure 12: Waveform at Data O/P*

| 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.

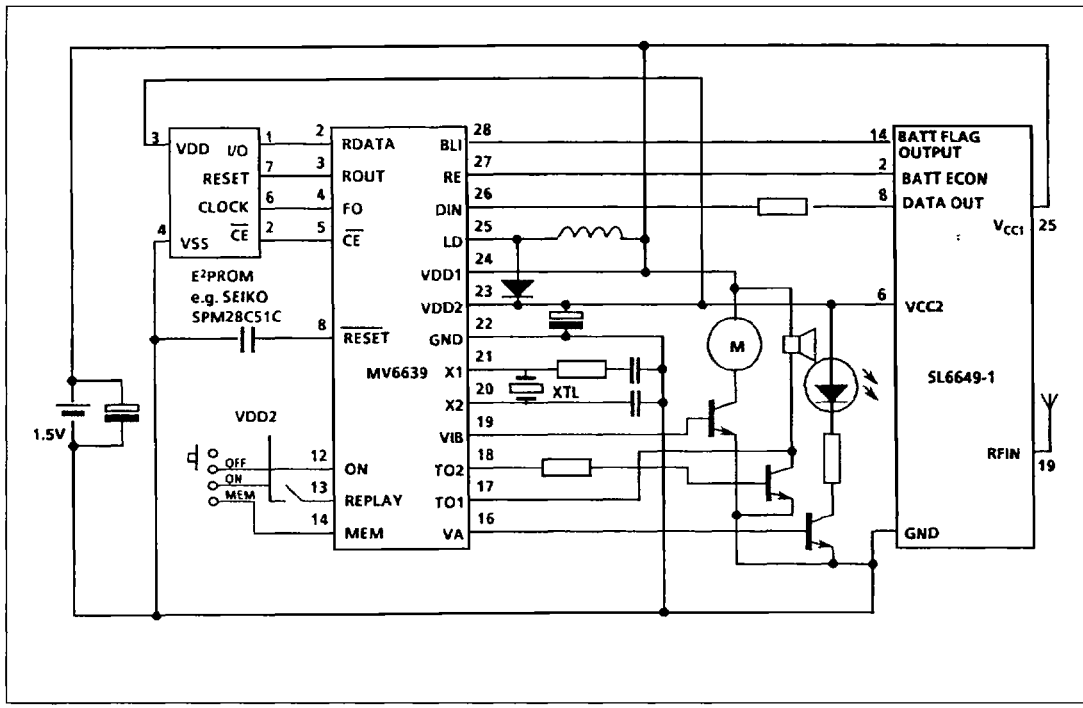



*Figure 13(b): Tone Pager Applications Example Showing Interface with SL6649-1 Receiver*

## 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.