

# PBL 3898/M

## Metering Subscriber Line Interface Circuit

### Description

PBL 3898/M is an analog Metering Subscriber Line Interface Circuit (SLIC), which is fabricated in a 75 V bipolar, monolithic process.

The programmable, constant current feed circuit incorporates a switch mode regulator to minimize on-chip power dissipation. A stand-by state further reduces idle power dissipation, while allowing the supervisory functions to be active.

Tip-ring polarity is reversible without altering SLIC supervisory and voice frequency (vf) functions. Tip and ring outputs can be set to high impedance states. These and other operating states are activated via a parallel, four bit control word.

An external resistor controls the off-hook detector threshold current. A ground key detector with internal reference reports tip/ring dc current unbalance. The ring trip detector can operate with both balanced and unbalanced ringing systems. The three detectors are read via a shared output.

Ring and test relay drivers with internal clamp diodes are provided.

The complex or real two-wire impedance is set by a scaled, lumped element network.

Two- to four-wire and four- to two-wire signal conversion is provided by the SLIC in conjunction with either a conventional or a programmable CODEC/filter.

Longitudinal line voltages are suppressed by a control loop within the SLIC.

The PBL 3898/M package is 32-pin plastic j-leaded chip carrier.

### Key Features

- On-chip switch mode regulator to minimize power dissipation
- Programmable, constant current feed
- Line feed characteristics independent of battery variations
- Tip-ring polarity reversal function
- Tip and ring open circuit state; tip open with ring active state
- Detectors:
  - programmable loop current/ring ground detector
  - ground key detector
  - ring trip detector
- Ring and test relay drivers
- Line terminating impedance, complex or real, set by a simple external network
- Hybrid function with conventional or programmable CODEC/filters
- 70 dB longitudinal to metallic balance
- Idle noise < 10 dBmC; < -80 dBup
- Supports 2.2 Vrms metering, 12 and 16 kHz
- Programmable open loop voltage

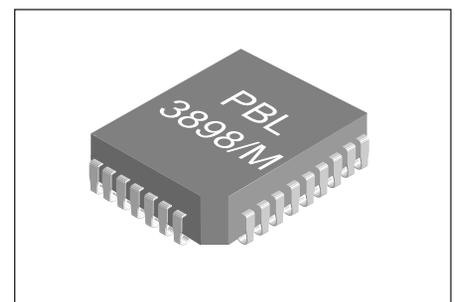
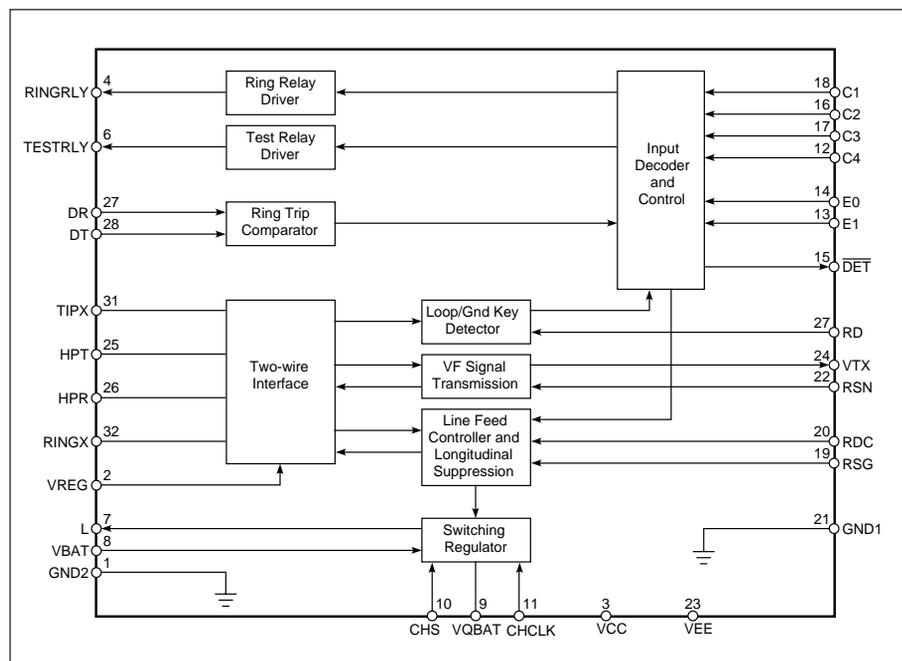


Figure 1. Block diagram.

**Absolute Maximum Ratings**

| Parameter  | Symbol           | Min       | Max      | Unit |
|--|------------------|-----------|----------|------|
| <b>Temperature and Humidity</b>  |                  |           |          |      |
| Storage temperature range  | $T_{Stg}$        | -55       | +150     | °C   |
| Operating ambient temperature range  | $T_{Amb}$        | -40       | +85      | °C   |
| Operating junction temperature range (Note 1)                                      | $T_j$            | -40       | +135     | °C   |
| <b>Power Supply</b>  |                  |           |          |      |
| $V_{CC}$ with respect to ground  | $V_{CC}$         | -0.4      | +6.5     | V    |
| $V_{EE}$ with respect to ground  | $V_{EE}$         | -6.5      | +0.4     | V    |
| $V_{Bat}$ with respect to ground   | $V_{Bat}$        | -70       | +0.4     | V    |
| <b>Power Dissipation</b>   |                  |           |          |      |
| Continuous power dissipation at $T_{Amb} = 70$ °C (Note 2)                         |                  |           |          |      |
| 32-pin, j-leaded chip carrier (RN)   |                  |           | 1.7      | W    |
| <b>Ground</b>  |                  |           |          |      |
| Voltage between GND1 and GND2 (Note 3)   |                  | -0.1      | +0.1     | V    |
| <b>Switch Mode Regulator</b>   |                  |           |          |      |
| Peak current through regulator switch (pin L)                                      | $I_{IPk}$        |           | 150      | mA   |
| Regulator switch output (pin L) peak off-state voltage                             | $V_{IPk}$        |           | +2       | V    |
| <b>Relay Drivers</b>   |                  |           |          |      |
| Test relay supply voltage  | $V_{TRly}$       | $V_{Bat}$ | $V_{CC}$ | V    |
| Ring relay supply voltage  | $V_{RRly}$       | $V_{Bat}$ | $V_{CC}$ | V    |
| Test relay current   | $I_{TRly}$       |           | 80       | mA   |
| Ring relay current   | $I_{RRly}$       |           | 80       | mA   |
| <b>Ring Trip Comparator</b>  |                  |           |          |      |
| Input voltage  | $V_{DT}, V_{DR}$ | $V_{Bat}$ | 0        | V    |
| Input current, $t_p = 10$ ms   | $I_{DT}, I_{DR}$ | -2        | +2       | mA   |
| <b>Digital Inputs, Outputs C1 - C4, E0, E1, <math>\overline{DET}</math>, CHCLK</b> |                  |           |          |      |
| Input voltage  | $V_{ID}$         | -0.4      | $V_{CC}$ | V    |
| Output voltage ( $\overline{DET}$ not active)                                      | $V_{OD}$         | -0.3      | $V_{CC}$ | V    |
| Output current   | $I_{OD}$         |           | 3        | mA   |
| <b>TIPX and RINGX Terminals</b>  |                  |           |          |      |
| TIPX or RINGX continuous voltage (Notes 4, 5)                                      | $V_{T'}, V_R$    | -70       | 1        | V    |
| TIPX or RINGX, pulsed voltage, $t_w < 10$ ms and $t_{rep} > 10$ s (Notes 4, 5)     | $V_{T'}, V_R$    | -70       | 5        | V    |
| TIPX or RINGX, pulsed voltage, $t_w < 1$ $\mu$ s and $t_{rep} > 10$ s (Notes 4, 5) | $V_{T'}, V_R$    | -90       | 10       | V    |
| TIPX or RINGX, pulsed voltage, $t_w < 250$ ns and $t_{rep} > 10$ s (Notes 4, 5, 6) | $V_{T'}, V_R$    | -120      | 15       | V    |
| TIPX or RINGX current  | $I_{Ldc}$        | -105      | 105      | mA   |

**Recommended Operating Conditions**

| Parameter   | Symbol     | Min   | Max   | Unit |
|---|------------|-------|-------|------|
| Ambient temperature                               | $T_{Amb}$  | 0     | 70    | °C   |
| Case temperature                                  | $T_{Case}$ | 0     | 90    | °C   |
| $V_{CC}$ with respect to ground                   | $V_{CC}$   | 4.75  | 5.25  | V    |
| $V_{EE}$ with respect to ground                   | $V_{EE}$   | -5.25 | -4.75 | V    |
| $V_{Bat}$ with respect to ground (Notes 7, 8, 10) | $V_{Bat}$  | -58   | -40   | V    |
| GND2 with respect to GND1 (Note 9)                | $V_{G12}$  | 0     | 0     | V    |

**Notes**

1. The circuit includes thermal protection. Refer to section Over-temperature protection. Operation above 135 °C may degrade device reliability.
2. 1.7W applies for a junction temperature of ≤120°C, without heatsink.
3. The GND1 and GND2 pins should be connected together via a direct printed circuit board trace.
4.  $V_T$  and  $V_R$  are referenced to ground.  $t_w$  is pulse width of a rectangular test pulse and  $t_{rep}$  is pulse repetition rate.
5. These voltage ratings require a diode to be installed in series with the VBAT pin as shown in figure 12 (D<sub>7</sub>).
6.  $R_{F1}, R_{F2} \geq 20$  ohms is also required. Pulse supplied to TIP and RING outside  $R_{F1}, R_{F2}$ .
7. For long loop applications with  $-64 V < V_{Bat} < -56 V$ , the saturation guard reference voltage,  $V_{SGRef}$ , should be adjusted by calculating a value for resistor  $R_{SG}$  as described in the text.
8.  $V_{Bat}$  should be applied with a  $\partial V_{Bat} / \partial t < 4 V/\mu\text{sec}$ . A time constant of 2.6  $\mu\text{s}$  is suggested (e.g. 5.6 ohms and 0.47  $\mu\text{F}$ ). The VBAT terminal must at all times be at a lower potential than any other terminal to maintain proper junction isolation. Refer to section Power-up sequence.
9. GND1 and GND2 must be connected before supply voltages.
10.  $|V_{Bat}|$  as low as 40V may be used. However with a  $V_{Bat}$  of -40 to -46 V, the performance on long lines will degrade outside the specified limits. Parameters affected are; line current, longitudinal balance, Idle channel noise and  $V_{Bat}$  PSRR. Long lines is in this case outside the constant current range with the  $V_{Bat}$  dependent saturation guard activated.

**Electrical Characteristics**

$0\text{ }^\circ\text{C} \leq T_{Amb} \leq 70\text{ }^\circ\text{C}$ ,  $V_{CC} = +5\text{ V} \pm 5\%$ ,  $V_{EE} = -5\text{ V} \pm 5\%$ ,  $-58\text{ V} \leq V_{Bat} \leq -46\text{ V}$ ,  $\text{GND1} = \text{GND2}$ ,  $Z_{TR}$  (2-wire ac terminating impedance) = 600 ohms,  $Z_L$  (line impedance) = 600 ohms,  $R_{F1} = R_{F2} = 0\text{ ohm}$ ,  $R_T = 30.6\text{ kohms}$ ,  $R_{RX} = 30\text{ kohms}$ ,  $R_{DC1} = R_{DC2} = 3.125\text{ kohms}$ ,  $R_{SG} = \infty$ ,  $R_D = 51.1\text{ kohms}$ ,  $R_{CH} = 910\text{ ohms}$ ,  $R_{Bat} = 10\text{ ohms}$ ,  $C_{HP} = 0.33\text{ }\mu\text{F}$ ,  $C_{DC} = 0.47\text{ }\mu\text{F}$ ,  $C_D = 0.01\text{ }\mu\text{F}$ ,  $C_{TC} = C_{RC} = 2200\text{ pF}$ ,  $C_{CH1} = 0.047\text{ }\mu\text{F}$ ,  $C_{CH2} = 1500\text{ pF}$ ,  $C_{Flt} = 0.47\text{ }\mu\text{F}$ ,  $C_{Bat} = 0.47\text{ }\mu\text{F}$ ,  $C_Q = 0.33\text{ }\mu\text{F}$ ,  $L = 1\text{ mH}$ , unless otherwise specified. The specifications are with respect to exact external component values.

| Parameter                                      | Ref fig | Conditions  | Min                 | Typ               | Max | Unit   |
|--|---------|---|---------------------|-------------------|-----|--|
| <b>2-wire port</b>                             |         |   |                     |                   |     |  |
| Overload level, $V_{TRO}$                      | 2       | 1% THD, $E_L = 0$ , $f = 1\text{ kHz}$ ,<br>(Notes 1, 2)  | 5.5<br>14.0<br>14.0 | 6<br>14.8<br>14.8 |     | $V_{Pk}$<br>dBm<br>dBu   |
| Input impedance, $Z_{TRX}$                     |         | Note 3  |                     |                   |     |  |
| Longitudinal impedance, $Z_{LoT}, Z_{LoR}$     | 3       | $f \leq 100\text{ Hz}$  |                     | 20                | 40  | ohm/wire   |
| Longitudinal current limit, $I_{LoT}, I_{LoR}$ |         | $f \leq 100\text{ Hz}$<br>Active state<br>Stand-by state  | 20<br>8.5           | 30<br>25          |     | $\text{mA}_{rms}/\text{wire}$<br>$\text{mA}_{rms}/\text{wire}$ |
| Longitudinal to metallic balance, $B_{LM}$     |         | IEEE Standard 455-1985<br>Normal polarity, Note 4<br>$0.2\text{kHz} < f < 1.0\text{kHz}$<br>$1.0\text{kHz} < f < 3.4\text{kHz}$<br>Reversed polarity, Note 4<br>$0.2\text{kHz} < f < 3.4\text{kHz}$ | 60<br>55<br>55      | 70<br>70<br>70    |     | dB<br>dB<br>dB   |

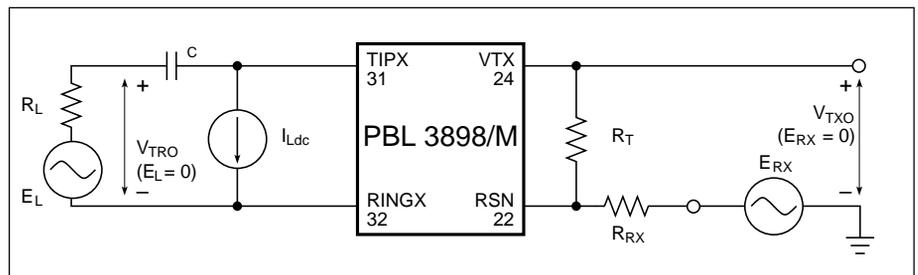


Figure 2. Overload level.  
 $1/\omega C \ll R_L, R_L = 600\text{ ohm}$ ,  
 $R_T = 30,6\text{ kohms}, R_{RX} = 30\text{ kohms}$ .

| Parameter                                    | Ref fig | Conditions  | Min | Typ | Max | Unit |    |    |
|--|---------|---|-----|-----|-----|------|----|----|
| Metallic to longitudinal balance, $B_{ML}$   |         | FCC part 68 paragraph 68.310  | 38  | 60  |     | dB   |    |    |
|  |         | $0.2\text{kHz} < f < 4.0\text{kHz}$<br>$f = 1.0\text{kHz}$                                    |     |     |     | dB   |    |    |
| Longitudinal to metallic balance, $B_{LME}$  | 4       | $B_{LME} = 20 \cdot \log \left  \frac{E_{LO}}{V_{TR}} \right $                                |     |     |     |      |    |    |
|  |         | Normal polarity, Note 4   | 60  | 70  | dB  |      |    |    |
|  |         | $0.2\text{kHz} < f < 1.0\text{kHz}$   | 55  | 70  | dB  |      |    |    |
|  |         | $1.0\text{kHz} < f < 3.4\text{kHz}$   | 55  | 70  | dB  |      |    |    |
| Longitudinal to four wire balance, $B_{LFE}$ | 4       | $B_{LME} = 20 \cdot \log \left  \frac{E_{LO}}{V_{TR}} \right $                                |     |     |     |      |    |    |
|  |         | Normal polarity, Note 4   | 60  | 70  | dB  |      |    |    |
|  |         | $0.2\text{kHz} < f < 1.0\text{kHz}$   | 55  | 70  | dB  |      |    |    |
|  |         | $1.0\text{kHz} < f < 3.4\text{kHz}$   | 55  | 70  | dB  |      |    |    |
| Metallic to longitudinal balance, $B_{MLE}$  | 5       | $B_{MLE} = 20 \cdot \log \left  \frac{E_{TR}}{V_{Lo}} \right , E_{RX} = 0$                    | 38  | 60  |     | dB   |    |    |
|  |         | $0.2\text{kHz} < f < 4.0\text{kHz}$<br>$f = 1.0 \text{ kHz}$                                  |     |     |     | dB   |    |    |
| Four wire to longitudinal balance, $B_{FLE}$ | 5       | $B_{FLE} = 20 \cdot \log \left  \frac{E_{RX}}{V_{Lo}} \right , E_{TR} \text{ source removed}$ | 38  | 60  |     | dB   |    |    |
|  |         | $0.2\text{kHz} < f < 4.0\text{kHz}$<br>$f = 1.0 \text{ kHz}$                                  |     |     |     | dB   |    |    |
| 2-wire return loss, $r$                      |         | $r = 20 \cdot \log \left  \frac{Z_L + Z_{TR}}{Z_L - Z_{TR}} \right , \text{ Note 5}$          | 30  | 40  |     | dB   |    |    |
|  |         | $0.2\text{kHz} \leq f < 0.5\text{kHz}$  |     |     |     | 25   | 40 | dB |
|  |         | $0.5\text{kHz} \leq f < 1.0\text{kHz}$  |     |     |     | 15   | 40 | dB |
|  |         | $1.0\text{kHz} \leq f \leq 3.4\text{kHz}$   |     |     |     |      |    | dB |

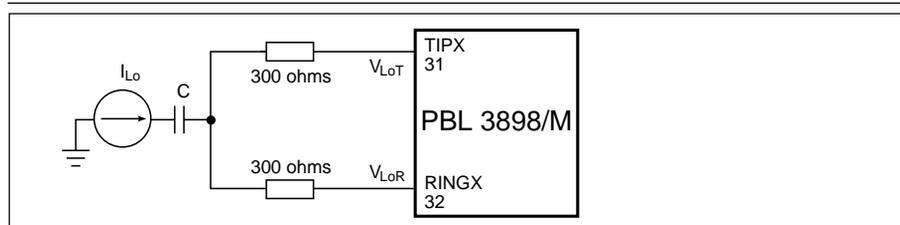


Figure 3. Longitudinal input impedance.  
 $Z_{LoT} = Z_{LoR} = \frac{V_{LoT} + V_{LoR}}{I_{Lo}}$

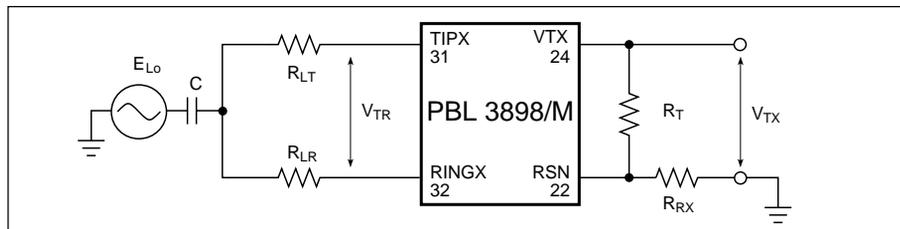


Figure 4. Longitudinal-to-metallic ( $B_{LME}$ ) and Longitudinal-to-four-wire ( $B_{LFE}$ ) balance.  
 $1/\omega C \ll 150 \text{ ohms}$ ,  
 $R_{LT} = R_{LR} = 300 \text{ ohms}$ ,  $R_T = 30,6 \text{ kohms}$ ,  
 $R_{RX} = 30 \text{ kohms}$ .

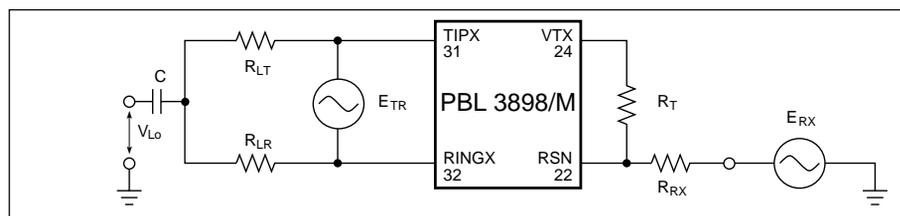


Figure 5. Metallic-to-longitudinal ( $B_{MLE}$ ) and four-wire-to-longitudinal ( $B_{FLE}$ ) balance.  
 $1/\omega C \ll 150 \text{ ohms}$ ,  
 $R_{LT} = R_{LR} = 300 \text{ ohms}$ ,  $R_T = 30,6 \text{ kohms}$ ,  
 $R_{RX} = 30 \text{ kohms}$ .

| Parameter   | Ref fig | Conditions  | Min        | Typ         | Max   | Unit            |
|---|---------|---|------------|-------------|-------|-----------------|
| Polarity reversal time, $t_{pol}$   |         | Normal to reversed polarity or reversed to normal polarity  |            | 10          | 30    | ms              |
| TIPX idle voltage, $V_{Ti}$   |         | Normal polarity, stand-by<br>$V_{Bat} = -48V$<br>$V_{Bat} = -63V$ , Note 6  | -10.0      | -7.5        | -5.0  | V               |
|   |         | Active<br>$V_{Bat} = -48V$<br>$V_{Bat} = -63V$ , Note 6   | -10.0      | -7.0        | -5.0  | V               |
| TIPX to RINGX idle voltage, $V_{Tro}$   |         | Active and standby<br>$V_{Bat} = -48V$ , $R_I = \text{open loop}$   |            |             | 40.0  | V               |
|   |         | Normal polarity   |            |             |       | V               |
|   |         | Reversed polarity   | -40.0      |             |       | V               |
| <b>4-wire Transmit Port (VTX)</b>   |         |   |            |             |       |                 |
| Overload level, $V_{TXO}$   | 2       | Load impedance > 20 kohms, $f = 1 \text{ kHz}$ , 1% THD, $E_{RX} = 0$<br>Note 7   | 3.1<br>9.0 | 3.5<br>10.1 |       | $V_{Pk}$<br>dBu |
| Output offset voltage, $\Delta V_{TX}$  |         |   | -50        | $\pm 5$     | +50   | mV              |
| Output impedance, $Z_{TX}$  |         | $0.2\text{kHz} \leq f \leq 3.4\text{kHz}$   |            | 3           | 20    | ohm             |
| <b>4-wire Receive Port (RSN)</b>  |         |   |            |             |       |                 |
| RSN dc voltage, $V_{RSN}$   |         | $I_{RSN} = 0$   | -10        | 0           | +10   | mV              |
| RSN impedance, $Z_{RSN}$  |         | $0.2\text{kHz} \leq f \leq 3.4\text{kHz}$   |            | 3           | 20    | ohm             |
| RSN current ( $I_{RSN}$ ) to metallic loop current ( $I_L$ ) gain, $\alpha_{RSN}$ |         | $0.2\text{kHz} \leq f \leq 3.4\text{kHz}$ ,<br>$\alpha_{RSN} = \frac{I_L}{I_{RSN}}$   |            | 40          |       | dB              |
| <b>Frequency Response</b>   |         |   |            |             |       |                 |
| Two-wire to four-wire, $g_{2-4}$  | 6       | $0.3\text{kHz} \leq f \leq 3.4\text{kHz}$<br>Relative to 1.0 kHz, 0 dBu<br>$E_{RX} = 0 \text{ V}$ , (Notes 2, 8)                                      | -0.1       | 0           | +0.1  | dB              |
| Four-wire to two-wire, $g_{4-2}$  | 6       | $0.3\text{kHz} \leq f \leq 3.4\text{kHz}$<br>Relative to 1.0 kHz, 0 dBu<br>$E_L = 0 \text{ V}$ , (Notes 2, 9)   | -0.1       | 0           | +0.1  | dB              |
| Four-wire to four-wire, $g_{4-4}$   | 6       | $0.3\text{kHz} \leq f \leq 3.4\text{kHz}$<br>Relative to 1.0 kHz, 0 dBu<br>$E_L = 0 \text{ V}$ , (Notes 2, 9)   | -0.1       | 0           | +0.1  | dB              |
| <b>Insertion Loss</b>   |         |   |            |             |       |                 |
| Two-wire to four-wire, $G_{2-4}$  | 6       | 0 dBu, 1 kHz, $E_{RX} = 0$<br>(Notes 8, 10)   | -6.05      | -5.85       | -5.65 | dB              |
| Four-wire to two-wire, $G_{4-2}$  | 6       | 0 dBu, 1 kHz, $E_L = 0$<br>(Notes 9, 10)<br>$R_L = 260 \text{ ohms}$ , $V_{TR} = 2.2 V_{Rms}$<br>$f = 16 \text{ kHz}$ , $R_{MG} = 17,4\text{k}\Omega$ | -0.20      | 0           | +0.20 | dB              |
| Four-wire to four-wire, $G_{4-4}$   | 6       | 0 dBu, 1 kHz, $E_L = 0$<br>(Notes 9, 10)  | -6.05      | -5.85       | -5.65 | dB              |

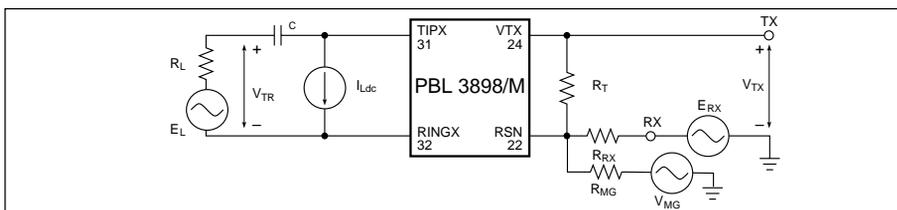


Figure 6. Frequency response, insertion loss, gain tracking, idle channel noise, THD, inter-modulation.  
 $1/\omega C \ll R_L$ ,  $R_L = 600 \text{ ohms}$ ,  
 $R_T = 30,6 \text{ kohms}$ ,  $R_{RX} = 30 \text{ kohms}$ .

| Parameter  | Ref fig | Conditions   | Min      | Typ        | Max        | Unit          |
|--|---------|--|----------|------------|------------|---------------|
| <b>Gain Tracking</b>   |         |  |          |            |            |               |
| Two-wire to four-wire (Note 8) and<br>Four-wire to two-wire (Note 9)               | 6       | Referenced to -10 dBu, 1 kHz<br>+3 dBu to -30 dBu<br>-30 dBu to -55 dBu  | -0.1     | ±0.1       | +0.1       | dB<br>dB      |
| <b>Noise</b>   |         |  |          |            |            |               |
| Idle channel noise at four-wire(VTX)port   | 6       | $E_{RX} = E_L = 0$ , Notes 2, 11<br>C-msg weighting<br>Psophometrical weighting  |          | 2<br>-88   | 10<br>-80  | dBrnC<br>dBup |
| Idle channel noise at two-wire<br>(TIPX-RINGX)port                                 |         |  |          | 7<br>-83   | 15<br>-75  | dBrnC<br>dBup |
| Idle channel noise with metering, two-wire<br>four-wire                            |         | Note 21  |          | -75<br>-80 | -46<br>-52 | dBup<br>dBup  |
| <b>Single Frequency out-of-band Noise (Note 12)</b>                                |         |  |          |            |            |               |
| Metallic, $V_{TR}$   | 7       | $12\text{ kHz} \leq f \leq 1\text{ MHz}$   |          | -58        | -55        | dBu           |
| Longitudinal, $V_{Lo}$   | 7       | $12\text{ kHz} \leq f \leq 90\text{ kHz}$  |          | -68        | -63        | dBu           |
| Longitudinal, $V_{Lo}$   | 7       | $90\text{ kHz} \leq f \leq 1\text{ MHz}$   |          | -53        | -50        | dBu           |
| <b>Total Harmonic Distortion</b>   |         |  |          |            |            |               |
| Two-wire to four-wire,<br>Four-wire to two-wire                                    | 6       | $0.3\text{kHz} \leq f \leq 3.4\text{kHz}$<br>0 dBu, 1 kHz test signal, Note 2  |          | -75        | -50        | dB            |
| Two-wire to four-wire,<br>four-wire to two-wire with metering,                     |         | Note 20  |          | -65        | -35        | dB            |
| <b>Intermodulation</b>   |         |  |          |            |            |               |
| Type $2f_1 - f_2$  | 6       | $0.3\text{ kHz} < f_1, f_2 < 3.4\text{ kHz}$ ,<br>Level $f_1 = \text{level } f_2 = -25\text{ to } 0\text{ dBv}$<br>$f_1 \neq nf_2, f_2 \neq nf_1$ , Note 2                       |          |            |            |               |
| Two-wire to four-wire  |         | $E_{RX} = 0$   |          | -70        | -50        | dB            |
| Four-wire to two-wire  |         | $E_L = 0$  |          | -75        | -50        | dB            |
| Type $f_1 \pm 50\text{ Hz}$  | 6       | $0.3\text{kHz} < f_1 < 3.4\text{kHz}$<br>Level 50 Hz = level $f_1 - 14\text{ dB}$ ,<br>Level $f_1 = -15\text{ dBv to } 0\text{ dBv}$<br>$f_1 \neq n \cdot 50\text{ Hz}$ , Note 2 |          |            |            |               |
| Two-wire to four-wire  |         | $E_{RX} = 0$   |          | -80        | -50        | dB            |
| <b>Battery Feed Characteristics</b>  |         |  |          |            |            |               |
| Loop current in constant current<br>region, $ I_{Ldc} $                            | 17      | $R_{DC1} = R_{DC2} = 3125\text{ ohm}$<br>Active state $p = 1$ ,<br>Active polarity reversal state $p = -1$<br>$I_{Ldc} = p \cdot \frac{250}{R_{DC1} + R_{DC2}}$                  | 37       | 40         | 43         | mA            |
|  |         | Stand-by state $p = 1$<br>Stand-by polarity reversal state $p = -1$<br>$I_{Ldc} = p \cdot \frac{125}{R_{DC1} + R_{DC2}}$   | 18       | 20         | 22         | mA            |
| Loop current in constant current<br>region at maximum loop resistance, $ I_{Ldc} $ | 17      | $R_{DC1} = R_{DC2} = 3125\text{ ohm}$<br>Active state<br>$V_{Bat} = -48\text{ V}, R_{Lmax} = 650\text{ ohm}$<br>$V_{Bat} = -63\text{ V}, R_{Lmax} = 1100\text{ ohm}$             | 37<br>37 |            |            | mA<br>mA      |

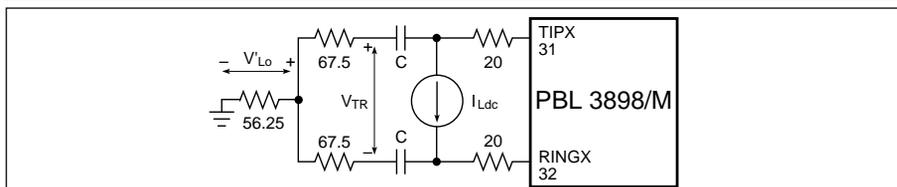


Figure 7. Single-frequency out of band noise.  
Resistance values in ohms,  
 $V_{Lo} = 1.6 \cdot V'_{Lo}$   
 $1/\omega C \ll 100\text{ ohms}$

| Parameter  | Ref fig | Conditions  | Min           | Typ           | Max           | Unit    |
|--|---------|---|---------------|---------------|---------------|---------|
| Current limit with both wires shorted to ground, $ I_{LLIM} $                |         |   |               |               | 140           | mA      |
| Loop current outside constant current region, $ I_{Ldc} $                    | 17      | $R_{DC1} = R_{DC2} = 3125$ ohm<br>Active state<br>$V_{Bat} = -48$ V, $R_{Lmax} = 2$ kohm<br>$V_{Bat} = -63$ V, $R_{Lmax} = 2$ kohm<br>Note 13 | 12.5          |               |               | mA      |
|  |         |   | 20.5          |               |               | mA      |
| <b>Open Circuit State</b>  |         |   |               |               |               |         |
| Loop current, $I_{Ldc}$  |         | $R_L = 0$ ohm, open circuit state   | -1            | $\pm 0.5$     | 1             | mA      |
| <b>Tip Open Circuit State</b>  |         |   |               |               |               |         |
| TIPX current, $I_{LTLKTo}$   | 8       | Tip open circuit state<br>$V_{Bat} < V_{TTO} < 0$   | -1            | $\pm 0.1$     | 1             | mA      |
| RINGX current, $I_{LRT0}$  | 8       | Tip open circuit state<br>$R_{LRGnd} = 0$ ohm<br>$R_{LRGnd} = 2.5$ kohms, $V_{Bat} = -63$ V<br>$R_{LRGnd} = 2.5$ kohms, $V_{Bat} = -48$ V     | 23            | 35            | 50            | mA      |
|  |         |   | 22            | 24            |               | mA      |
|  |         |   | 16            | 18            |               | mA      |
| RINGX voltage, $V_{RTo}$   | 8       | $I_{LRT0} < I_{LThoff} \times 1.05$   | $V_{Bat} + 1$ | $V_{Bat} + 4$ | $V_{Bat} + 6$ | V       |
| <b>Loop Current Detector</b>   |         |   |               |               |               |         |
| Loop current detector conversion factor<br>On-hook to off-hook, $K_{LThOff}$ |         | $I_{LThOff} = K_{LThOff} / R_D$<br>Active, standby, polarity reversal state<br>Tip open circuit state (Note 14)                               | 370           | 435           | 500           | V       |
|  |         |   | 695           | 870           | 1045          | V       |
| Loop current detector conversion factor<br>Off-hook to on-hook, $K_{LThOn}$  |         | $I_{LThOn} = K_{LThOn} / R_D$<br>Active, standby, polarity reversal state<br>Tip open circuit state (Note 14)                                 | 327           | 385           | 443           | V       |
|  |         |   | 615           | 770           | 925           | V       |
| Loop current detector conversion factor<br>hysteresis, $K_{LTh}$             |         | Active, standby and<br>Polarity reversal state (Note 15)  | 20            | 55            | 90            | V       |
| Dial pulse distortion  |         | 10 pps, Off-hook: 600 ohms<br>On-hook: $\infty$ ohms  |               | 1             | 5             | %       |
| <b>Ring Trip Comparator Inputs (DT, DR)</b>                                  |         |   |               |               |               |         |
| Offset voltage, $\Delta V_{DTR}$   | 9       | $V_{Bat} + 1$ V $<$ $V_{DT}$ , $V_{DR} <$ -2 V<br>$R = 0$ ohm<br>$R = 200$ kohm   | -20           | $\pm 10$      | 20            | mV      |
|  |         |   | -40           | $\pm 10$      | 40            | mV      |
| Input offset current, $\Delta I_B$   | 9       | $V_{Bat} + 1$ V $<$ $V_{DT}$ , $V_{DR} <$ -2 V, $R = 200$ kohm  |               | 0.05          | 1             | $\mu$ A |
| Input bias current, $I_B$  | 9       | $V_{Bat} + 1$ V $<$ $V_{DT}$ , $V_{DR} <$ -2 V, $R = 200$ kohm<br>$I_B = (I_{DT} + I_{DR}) / 2$   |               | 0.1           | 1             | $\mu$ A |
| Input resistance<br>unbalanced, $R_{DT}$ , $R_{DR}$                          |         | $V_{Bat} + 1$ V $<$ $V_{DT}$ , $V_{DR} <$ -2 V  | 1             |               |               | Mohm    |
| balanced, $R_{DTR}$  |         |   | 3             |               |               | Mohm    |
| Common mode range, $V_{DT}$ , $V_{DR}$                                       |         |   | $V_{Bat} + 1$ |               | -2            | V       |

Figure 8. Tip open circuit state.

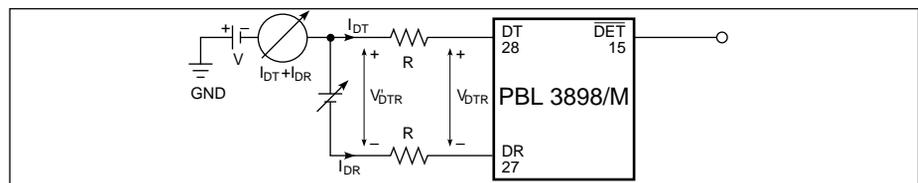
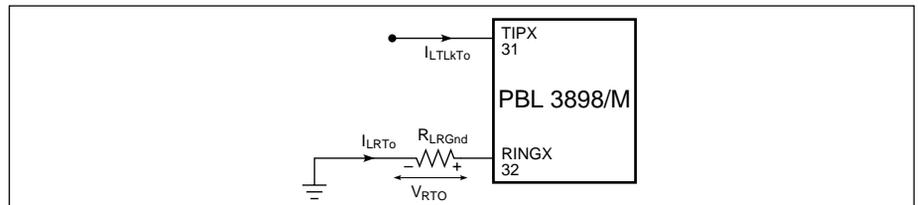
Figure 9. Ring trip comparator.

$$2V < V < |V_{Bat} + 1|,$$

$$\frac{I_{DT} + I_{DR}}{2} = I_{B'}$$

$$V_{DTR} = \Delta V_{DTR'}$$

$$\Delta I_B = \frac{V_{DTR'} - V_{DTR}}{R}$$



| Parameter  | Ref fig | Conditions   | Min          | Typ          | Max          | Unit          |
|--|---------|--|--------------|--------------|--------------|---------------|
| <b>Ground Key Detector</b>   |         |  |              |              |              |               |
| Ground key detection threshold, $R_{Gnd}$  | 10      | Active & stand-by states, $E_0 = E_1 = 1$<br>Note 19<br>Switch S1 open | 1.7          |              | 10.0         | kohm          |
|  |         | Switch S1 closed   | 0.9          |              | 10.0         | kohm          |
| Longitudinal current threshold, $I_{LoGkTh}$   | 10      | S1 closed  |              | 8            |              | mA            |
| <b>Relay Driver Outputs (RINGRLY, TESTRLY)</b>   |         |  |              |              |              |               |
| On state voltage, $V_{TRly}, V_{RRly}$   |         | $I_{TRly}, I_{RRly} = 25 \text{ mA}$                                   | $V_{CC}-2.0$ | $V_{CC}-1.6$ | $V_{CC}-1.0$ | V             |
| Off state leakage current, $I_{TRly}, I_{RRly}$  |         | $V_{TRly}, V_{RRly} = V_{Bat}$   |              | 5            | 100          | $\mu\text{A}$ |
| Clamp voltage  |         | $I_{TRly}, I_{RRly} = 25 \text{ mA}$                                   | $V_{Bat}-3$  |              | $V_{Bat}-1$  | V             |
| <b>Digital Inputs (C1-C4, E0, E1, CHCLK)</b>   |         |  |              |              |              |               |
| Input low voltage, $V_{IL}$  |         |  |              |              | 0.8          | V             |
| Input high voltage, $V_{IH}$   |         |  | 2.0          |              |              | V             |
| Input low current, $I_{IL}$  |         | $V_{IL} = 0.4 \text{ V}$   | -0.4         |              |              | mA            |
| Input high current, $I_{IH}$   |         | $V_{IH} = 2.4 \text{ V}$   |              |              | 40           | $\mu\text{A}$ |
| <b>Digital Output (DET)</b>  |         |  |              |              |              |               |
| Output low voltage, $V_{OL}$   |         | $I_{OL} = 1.0 \text{ mA}$  |              |              | 0.45         | V             |
| Output high voltage, $V_{OH}$  |         | $I_{OH} = -0.1 \text{ mA}$   | 2.4          |              |              | V             |
| Resistive pull-up  |         |  | 12           | 15           | 18           | kohm          |
| <b>Switch Mode Regulator Transistor Output (L)</b>   |         |  |              |              |              |               |
| Switch transistor saturation voltage, $V_{ISat}$   |         | $I_l = 100 \text{ mA}$ , Note 16                                       |              |              | 1.5          | V             |
| Leakage current, $I_{ILk}$   |         | $V_l = 0 \text{ V}$  |              |              | 200          | $\mu\text{A}$ |
| <b>Switch Mode Regulator Clock Input (CHCLK)</b>   |         |  |              |              |              |               |
| Clock frequency, $f_{ChClk}$   |         |  | 253          | 256          | 259          | kHz           |
| Rise and fall time   |         |  |              |              | 50           | ns            |
| Duty cycle ratio   |         |  | 46           |              | 54           | %             |
| <b>Power Supply Rejection Ratio (PSRR)</b>   |         |  |              |              |              |               |
| $V_{CC}$ to two-wire port and<br>$V_{CC}$ to four-wire port<br>rejection ratio, $PSRR_{CC}$    |         | 50 Hz < f < 3.4 kHz<br>3.4 kHz < f < 50 kHz, Note 17                   | 30           | 40           |              | dB            |
| $V_{EE}$ to two-wire port and<br>$V_{EE}$ to four-wire port<br>rejection ratio, $PSRR_{EE}$    |         | 50 Hz < f < 3.4 kHz<br>3.4 kHz < f < 50 kHz<br>Note 17                 | 10           | 30           |              | dB            |
| $V_{Bat}$ to two-wire port and<br>$V_{Bat}$ to four-wire port<br>rejection ratio, $PSRR_{Bat}$ |         | 50 Hz < f < 3.4 kHz<br>3.4 kHz < f < 50 kHz<br>Note 17                 | 30           | 60           |              | dB            |
| <b>Power Supply Currents (relay drivers off)</b>   |         |  |              |              |              |               |
| $V_{CC}$ supply current, $I_{CC}$  |         | On- or off-hook, active state  |              | 9            | 12           | mA            |
| $V_{EE}$ supply current, $ I_{EE} $  |         | On- or off-hook, active state  |              | 3.5          | 6            | mA            |
| $V_{Bat}$ supply current, $ I_{Bat} $  |         | On-hook, active state  |              | 3            | 6            | mA            |

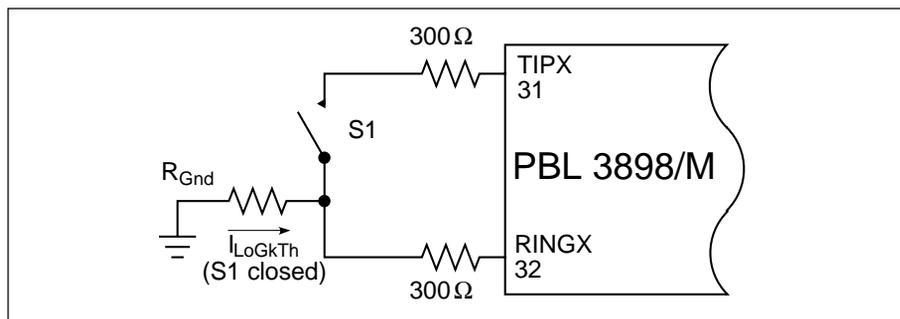


Figure 10. Ground key detector.

| Parameter                                       | Ref fig | Conditions   | Min | Typ | Max  | Unit |
|---|---------|--|-----|-----|------|------|
| <b>Power Dissipation</b>                        |         |  |     |     |      |      |
| On-hook total dissipation, $P_{OnOp}$           |         | $V_{Bat} = -48$ V, Open circuit state  |     | 50  | 80   | mW   |
| On-hook total dissipation, $P_{OnSb}$           |         | $V_{Bat} = -48$ V, Stand-by state  |     | 160 | 200  | mW   |
| On-hook total dissipation, $P_{OnAct}$          |         | $V_{Bat} = -48$ V, Active state  |     | 200 | 300  | mW   |
| Off-hook total dissipation, $P_{Off68}$         |         | $V_{Bat} = -48$ V, Active state<br>$R_L = 600$ ohms, $R_{DC1} = R_{DC2} = 3.125$ kohm<br>Note 18 |     | 900 | 1000 | mW   |
| <b>Temperature Guard</b>                        |         |  |     |     |      |      |
| Junction temperature at threshold, $T_{JG}$     |         |  |     | 140 |      | °C   |
| Temperature guard hysteresis, $\partial T_{JG}$ |         |  |     | 10  |      | °C   |

**Notes**

- The overload level is specified at the two-wire port with the signal source at the four-wire receive port, i.e.  $E_L = 0$  in figure 2.
- dBm is the ratio between power level P and a 1 mW reference power level, expressed in decibels, i.e.  

$$dBm = 10 \cdot \log_{10} \frac{P}{1 \text{ mW}}$$
 dBu is the ratio between voltage  $V_{rms}$  and a 0.775  $V_{rms}$  reference, expressed in decibels, i.e.  

$$dBu = 20 \cdot \log_{10} \frac{V_{rms}}{0.775 \text{ Vrms}}$$
 dBu = dBm at impedance level 600 ohms  
 dBv is the ratio between voltage V and a 1 V reference, expressed in decibels, i.e.  

$$dBv = 20 \cdot \log_{10} \frac{V}{1 \text{ V}}$$
 dBup is the ratio between voltage  $V_p$ , measured via a psophometrical filter and a 0.775  $V_{rms}$  reference, expressed in decibels, i.e.  

$$dBup = 20 \cdot \log_{10} \frac{V_p}{0.775 \text{ Vrms}}$$
 dBnC is the ratio between power level  $P_c$ , measured via a C-message filter and a 1 pW reference power level, expressed in decibels, i.e.  

$$dBnC = 10 \cdot \log_{10} \frac{P_c}{1 \text{ pW}}$$
- The two-wire impedance,  $Z_{TRX}$ , is programmable by selection of external component values according to:  

$$Z_{TRX} = Z_T / (G_{2-4S} \cdot \alpha)$$
 where:  
 $Z_{TRX}$  = impedance between the TIPX and RINGX terminals  
 $Z_T$  = programming network between the VTX and RSN terminals  
 $G_{2-4S}$  = TIPX-RINGX to  $V_{TA}$  gain, nom = 0.51 (-5.85 dB ± 0.20 dB)  
 $\alpha$  = receive current gain, nominally = 100 (40 dB ± 0.20 dB)  
 The line protection resistors  $R_F$  add to the impedance presented by the SLIC at terminals TIPX and RINGX for a total two-wire impedance of  $Z_{TR} = Z_{TRX} + 2R_F$ .
- Normal polarity is defined as the tip lead being at a more positive potential than the ring lead. Reversed polarity is defined as the ring lead being at a more positive potential than the tip lead.
- Higher return loss values can be achieved by adding a reactive component to  $R_T$ , the two-wire terminating impedance programming resistor, e.g. by dividing  $R_T$  into two equal halves and connecting a capacitor from the common point to ground. For  $R_T = 30.6$  kohms the capacitance value is approximately 680 pF.
- $V_{Bat} = -63$  V is applicable to the PBL 3898/M in a 32-pin leaded chip carrier with the RSG terminal connected to the  $V_{EE}$  supply.
- The overload level,  $V_{TXO}$ , is specified at the four-wire transmit port, VTX, with the signal source at the two-wire port. Note that the gain from the two-wire port to the four-wire transmit port is  $G_{2-4S} = 0.51$ .
- The level is specified at the two-wire port.
- The level is specified at the four-wire receive port (RSN).
- Fuse resistors  $R_{F1}$  and  $R_{F2}$  impact the insertion loss as explained in the text, section Transmission. The specified insertion loss is for  $R_{F1} = R_{F2} = 0$  ohm.
- The two-wire idle noise is specified with the port terminated in 600 ohms ( $R_L$ ) and with the four-wire receive port grounded ( $E_{RX} = 0, E_L = 0$ ; see figure 6).  
 The four-wire idle noise at VTX is specified with the two-wire port terminated in 600 ohms ( $R_L$ ). The four-wire receive port is grounded ( $E_{RX} = 0, E_L = 0$ ; see figure 6).  
 The idle channel noise degrades by approximately 5 dB when the saturation guard is active. Refer to section Battery feed for a description of the saturation guard.
- These specifications are valid for a longitudinal impedance of 90 ohms and a metallic impedance of 135 ohms.
- Refer to section Battery Feed, Case 2.
- Refer to Loop Monitoring Function, Loop current detector-active state, Loop current detector - tip open state.
- The loop current detector threshold hysteresis is a function of the  $R_D$  value. Refer to note 14 above.
- $V_{ISat}$  is the voltage across the saturated transistor, i.e. between terminals VBAT and L.

- 17. Power supply rejection ratio test signal is 100 mVrms (sinusoidal).
- 18. Line protection resistor  $R_{F1} = R_{F2} = 0$  ohm.
- 19.  $R_{Gnd}$  resistance value less than the specified range will trigger the ground key detector, i.e. set the  $\overline{DET}$  output to logic level low.
- 20. Total harmonic distortion with metering as specified with a metering signal of 2.2 Vrms at the two-wire output, and a

- transmit signal of +3 dBm or receive signal of -4dBm. The transmit or receive signals are single-frequency inputs, and the distortion is measured as the highest in band harmonic at the two-wire or the four-wire output relative to the input signal.
- 21. Noise with metering is measured by applying a 2.2Vrms metering signal (measured at the two-wire output) and measuring the psophometric noise at the two-wire and four-wire outputs over a 200 ms time interval.

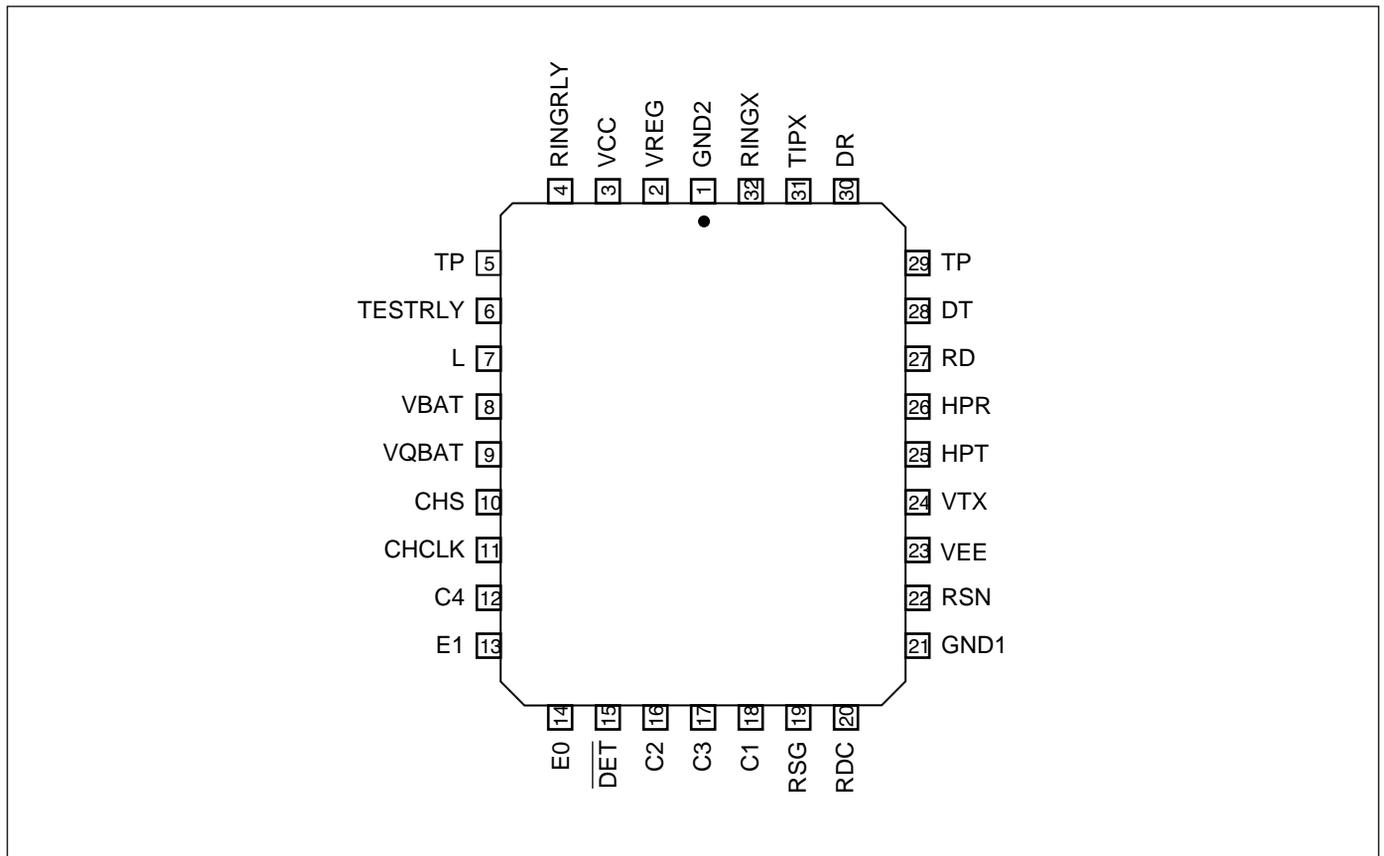


Figure 11. Pin configuration, 32-pin j-leaded chip carrier , Top view.

### Pin Description

PLCC: 32-pin, j-leaded chip carrier. Refer to figure 11.

| 32PLCC | Symbol  | Description   |
|--------|---------|---|
| 1      | GND2    | Ground. No internal connection to GND1. Note 1.   |
| 2      | VREG    | Regulated negative voltage for power amplifiers. The switch-mode regulator inductor, filter capacitor and RC stabilization network connect to this pin.   |
| 3      | VCC     | +5 V power supply.  |
| 4      | RINGRLY | Ring relay driver output. Sources up to 80 mA from VCC.   |
| 5      | TP      | TP is a thermal conduction pin tied to substrate ( $V_{QBat}$ ). Note 2.  |
| 6      | TESTRLY | Test relay driver output. Sources up to 80 mA from VCC.   |
| 7      | L       | Switch-mode regulator drive transistor output. The 1 mH inductor and the catch diode connect to this pin. These components must be connected with shortest possible lead lengths. The catch diode, including connecting leads, must exhibit a low inductance to clamp effectively, when the regulator switch opens. |

| 32PLCC | Symbol                  | Description   |
|--------|-------------------------|---|
| 8      | VBAT                    | Battery supply voltage. Negative with respect to GND2.  |
| 9      | VQBAT                   | Quiet battery. An external filter capacitor connects between this pin and GND1 to provide filtered battery supply to signal processing circuits.  |
| 10     | CHS                     | Switch-mode regulator stabilization network input. From this pin a capacitor connects to GND1 and a series RC network to VREG.  |
| 11     | CHCLK                   | Switch-mode regulator TTL compatible clock input. Nominal frequency: 256 kHz.   |
| 12     | C4                      | C1 , C2 , C3 and C4 are TTL compatible decoder inputs controlling the SLIC operating states.  |
| 13     | E1                      | Detector select input. A logic high level enables the ground key detector. A logic low level enables the loop/ring-trip detector. TTL compatible input.   |
| 14     | E0                      | Detector output enable. A logic high level enables the $\overline{\text{DET}}$ output. A logic low level disables the $\overline{\text{DET}}$ output. TTL compatible input.   |
| 15     | $\overline{\text{DET}}$ | Detector output. Inputs C1...C3 and E1 select the detector to be connected to this output. When $\overline{\text{DET}}$ is enabled via E0 a logic low level indicates that the selected detector is tripped. The $\overline{\text{DET}}$ output is open collector with internal pull-up resistor (15 kohms) to VCC. When disabled, $\overline{\text{DET}}$ thus appears to be a resistor connected to $V_{CC}$ .    |
| 16     | C2                      | Refer to pin C4 description.  |
| 17     | C3                      | Refer to pin C4 description.  |
| 18     | C1                      | Refer to pin C4 description.  |
| 19     | RSG                     | Saturation guard programming input. A resistor, $R_{SG}$ , between pins RSG and VEE adjusts the saturation guard for operation with $V_{Bat}$ from -64 V to -46 V.  |
| 20     | RDC                     | The constant dc loop current is programmed by two resistors connected in series from this pin to the receive summing node (RSN). The resistor junction point is decoupled to GND1 to filter noise and other disturbances before reaching the RSN input. $V_{RDC}$ polarity is negative for normal tip-ring polarity and positive for reversed tip-ring polarity. $ V_{RDC}  = 2.5V$ in the constant current region. |
| 21     | GND1                    | Ground. No internal connection to GND2. Note 1.   |
| 22     | RSN                     | Receive summing node. 100 times the current (dc and ac) flowing into this pin equals the metallic (transversal) current flowing between the TIPX and RINGX terminals. Programming networks for constant loop current, 2-wire impedance, and receive gain connect to the receive summing node.   |
| 23     | VEE                     | -5 V power supply.  |
| 24     | VTX                     | Transmit vf output. The ac voltage difference between TIPX and RINGX, the ac metallic voltage, is reproduced as an unbalanced GND1 referenced signal at VTX with a gain of 0.51. The two-wire impedance programming network connects between VTX and RSN.   |
| 25     | HPT                     | Tip side (HPT) of ac/dc separation capacitor.   |
| 26     | HPR                     | Ring side (HPR) of ac/dc separation capacitor.  |
| 27     | RD                      | Loop current detector programming resistor, $R_D$ , connects from RD to VEE. A filter capacitor $C_D$ may be connected from RD to GND1.   |
| 28     | DT                      | Inverting ring trip comparator input.   |
| 29     | TP                      | TP is a thermal conduction pin tied to substrate ( $V_{OBat}$ ). Note 2.  |
| 30     | DR                      | Non-inverting ring trip comparator input.   |
| 31     | TIPX                    | The TIPX pin connects to the tip lead of the 2-wire line interface via overvoltage protection components, ring and test relays.   |
| 32     | RINGX                   | The RINGX pin connects to the ring lead of the 2-wire line interface via overvoltage protection components, ring and test relays.   |

## Notes

1. The GND1 and GND2 pins should be connected together via a direct printed circuit board trace.
2. These pins (5 and 29) should be connected to  $V_{OBat}$ , serving as a heatsink.

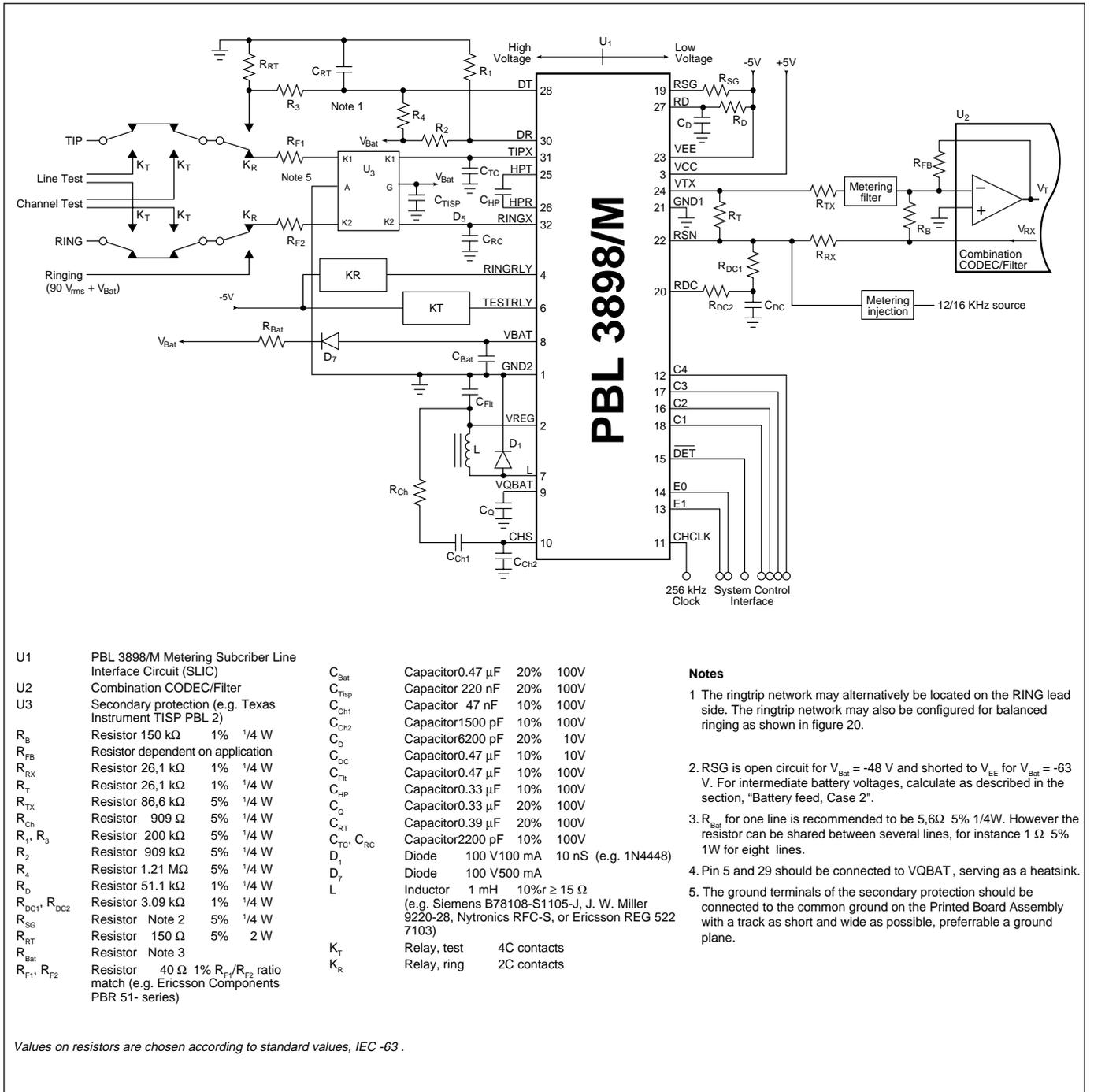


Figure 12. PBL 3898/M application example.

**Functional Description and Applications Information Transmission**

**Overview**

A simplified ac model of the transmission circuits is shown in figure 13. Neglecting the impact of the filters in figure 13 for frequencies from 300 Hz to 3.4 kHz (i.e. filter gain = 1), circuit analysis yields:

$$V_{TR} = V_{TX} / G_{2-4S} + I_L \cdot 2R_F \quad (1)$$

$$\frac{V_{TX}}{Z_T} + \frac{V_{RX}}{Z_{RX}} = \frac{I_L}{100} \quad (2)$$

$$V_{TR} = E_L - I_L \cdot Z_L \quad (3)$$

where:

$V_{TX}$  is the ground referenced, unity gain version of the ac metallic (transversal) voltage between the TIPX and RINGX terminals, i.e.  $V_{TX} = G_{2-4S} \cdot V_{TRX}$

$V_{TR}$  is the ac metallic voltage between tip and ring.

$E_L$  is the line open circuit ac metallic voltage.

$I_L$  is the ac metallic current.

$R_F$  is the overvoltage protection current limiting resistor.

$Z_L$  is the line impedance.

$Z_T$  is the programming network for the TIPX to RINGX impedance.

$Z_{RX}$  controls the four-wire to two-wire gain.

$V_{RX}$  is the analog ground referenced receive signal.

From equations (1), (2) and (3) expressions for two-wire impedance, two-wire to four-wire gain, four-wire to two-wire gain and four-wire to four wire gain may be derived.

**Two-Wire Impedance**

To calculate  $Z_{TR}$ , the impedance presented to the 2-wire line by the SLIC, including the resistors  $R_F$ , let  $V_{RX} = 0$ .

From (1) and (2):

$$Z_{TR} = \frac{Z_T}{100 \cdot G_{2-4S}} + 2R_F$$

Since  $Z_{TR}$  and  $R_F$  are known  $Z_T$  may be calculated from

$$Z_T = 100 \cdot G_{2-4S} \cdot (Z_{TR} - 2R_F)$$

Example: calculate  $Z_T$  to make the terminating impedance  $Z_{TR} = 900$  ohms in series with  $2.16 \mu F$ .  $R_F = 40$  ohms.

Using the expression above

$$Z_T = 100 \cdot G_{2-4S} \cdot \left( 900 + \frac{1}{j\omega \cdot 2.16 \cdot 10^{-6}} - 2 \cdot 40 \right)$$

$$= 41,8 \cdot 10^3 + \frac{1}{j\omega \cdot 42.4 \cdot 10^{-9}}$$

i.e.  $Z_T = 42,2$  kohms in series with  $47nF$ , according to standard component values. It is always necessary to have a high ohmic resistor in parallel with the capacitor. This gives a DC-feedback loop for low frequency which ensure stability and reduces noise.

**Two-Wire to Four-Wire Gain**

The two-wire to four-wire gain,  $G_{2-4}$ , can be obtained from (1) and (2) with  $V_{RX} = 0$ :

$$G_{2-4} = \frac{V_{TX}}{V_{TR}} = \frac{Z_T/100}{Z_T / (100 \cdot G_{2-4S}) + 2R_F}$$

**Four-Wire to Two-Wire Gain**

The four-wire to two-wire gain,  $G_{4-2}$ , is derived from (1), (2) and (3) with  $E_L = 0$ :

$$G_{4-2} = \frac{V_{TR}}{V_{RX}} = - \frac{Z_T}{Z_{RX}} \cdot \frac{Z_L / G_{2-4S}}{Z_T / (100 \cdot G_{2-4S}) + 2R_F + Z_L}$$

**Four-Wire to Four-Wire Gain**

The four-wire to four-wire gain,  $G_{4-4}$ , is derived from (1), (2) and (3) with  $E_L = 0$ :

$$G_{4-4} = \frac{V_{TX}}{V_{RX}} = - \frac{Z_T}{Z_{RX}} \cdot \frac{Z_L + 2R_F}{Z_T / (100 \cdot G_{2-4S}) + 2R_F + Z_L}$$

**Hybrid Function**

The PBL 3898/M SLIC forms a particularly flexible and compact line interface when used together with Siemens Codec Filter circuit (SiCoFi) or other similar programmable CODEC/filter. The SiCoFi allows for system controller adjustment of hybrid balance to accommodate different line impedances without change of hardware. The SiCoFi also permits the system controller to adjust transmit and receive gains as well as terminating impedance. Refer to SiCoFi or similar programmable CODEC/filter data sheets

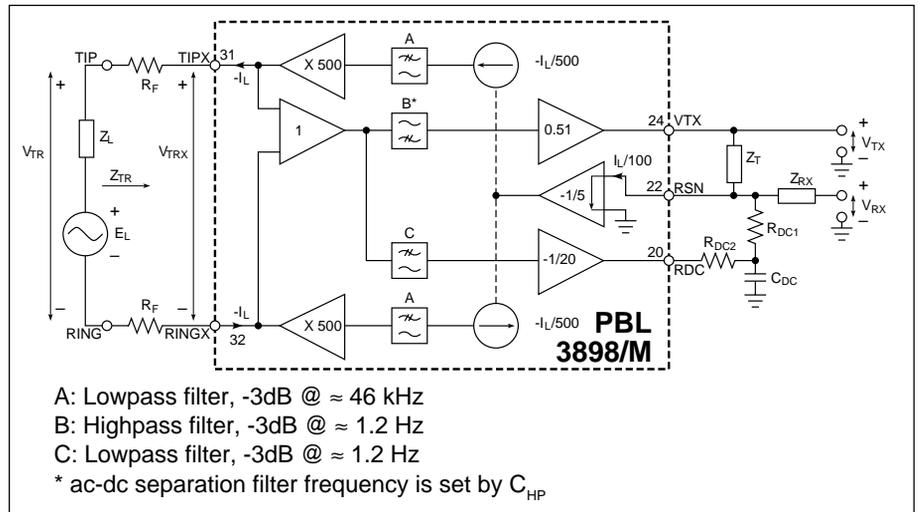


Figure 13. Simplified ac transmission circuit.

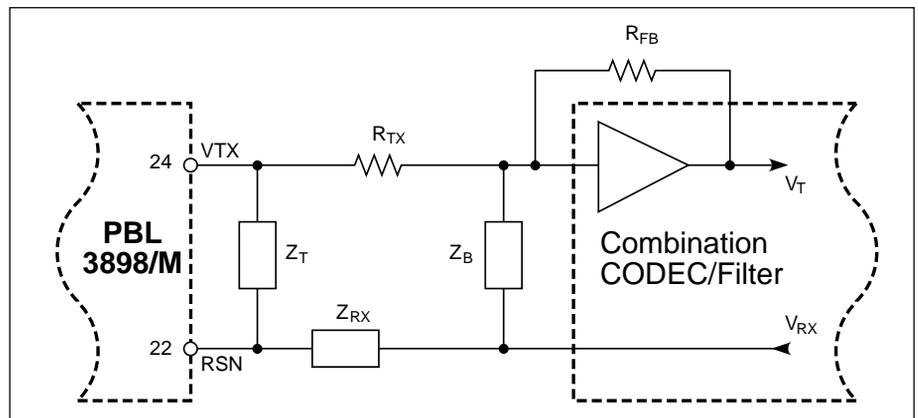


Figure 14. Hybrid function.

for design information.

The hybrid function in an implementation utilizing the uncommitted amplifier in a conventional CODEC/filter combination is shown in figure 14. Via impedance  $Z_B$  a current proportional to  $V_{RX}$  is injected into the summing node of the combination CODEC/filter amplifier. As can be seen from the expression for the four-wire to four-wire gain a voltage proportional to  $V_{RX}$  is returned at  $V_{TX}$ . This voltage is converted by  $R_{TX}$  to a current flowing into the same summing node. These currents can be made to cancel each other by letting:

$$\frac{V_{TX}}{R_{TX}} + \frac{V_{RX}}{Z_B} = 0 \quad (E_L = 0)$$

Substituting the four-wire to four-wire gain expression,  $G_{4-4}$ , for  $V_{RX}/V_{TX}$  yields

the formula for the balance network:

$$Z_B = -R_{TX} \cdot \frac{V_{RX}}{V_{TX}} = R_{TX} \cdot \frac{Z_{RX}}{Z_T} \cdot \frac{Z_T / (100 \cdot G_{2-4S}) + 2R_F + Z_L}{Z_L + 2R_F}$$

**Example:**  $Z_{TR} = Z_L = 900$  ohms ( $R_L$ ) in series with  $2.16 \mu F$  ( $C_L$ )  $R_F = 40$  ohms,  $R_{TX} = 38,3$  kohms,  $G_{4-2} = -1$ . Calculate  $Z_B$ .

Using the  $Z_B$  formula above:

$$Z_B = \{Z_L = Z_{TR}\} = R_{TX} \cdot \frac{Z_{RX}}{Z_T} \cdot \frac{2Z_L}{Z_L + 2R_F} = \{G_{4-2} = -1\} = R_{TX} \cdot \frac{Z_L}{Z_L + 2R_F} = R_{TX} \cdot \frac{1 + j\omega \cdot R_L \cdot C_L}{1 + j\omega \cdot (R_L + 2R_F) \cdot C_L}$$

A network consisting of  $R_{B1}$  in series

with the parallel combination of  $R_B$  and  $C_B$  has the same form as the required balance network,  $Z_B$ . Basic algebra yields:

$$R_{B1} = \frac{R_{TX}}{G_{2-4S}} \cdot \frac{R_L}{R_L + 2R_F} = 69 \text{ kohms}$$

$$R_B = \frac{R_{TX}}{G_{2-4S}} \cdot \frac{2R_F}{R_L + 2R_F} = 6,13 \text{ kohms}$$

$$C_B = \frac{(R_L + 2R_F)^2 \cdot C_L \cdot G_{2-4S}}{R_{TX} \cdot 2R_F} = 0.35 \mu F$$

### Longitudinal Impedance

A feedback loop counteracts longitudinal voltages at the two-wire port by injecting longitudinal currents in opposing phase. Therefore longitudinal disturbances will appear as longitudinal currents and the TIPX and RINGX terminals will experience very small longitudinal voltage excursions well within the SLIC common mode range. This is accomplished by comparing the instantaneous two-wire longitudinal voltage to an internal reference voltage,  $V_{LoRef}$ . As shown below, the SLIC appears as 20 ohms to ground per wire to longitudinal disturbances. It should be noted, that longitudinal currents may exceed the dc loop current without disturbing the vf transmission. From figure 15 the longitudinal impedance can be calculated:

$$\frac{V_{Lo}}{I_{Lo}} = \frac{R_{Lo}}{100} = 20 \text{ ohms}$$

where:

$V_{Lo}$  is the longitudinal voltage

$I_{Lo}$  is the longitudinal current

$R_{Lo} = 2$  kohms sets the longitudinal impedance

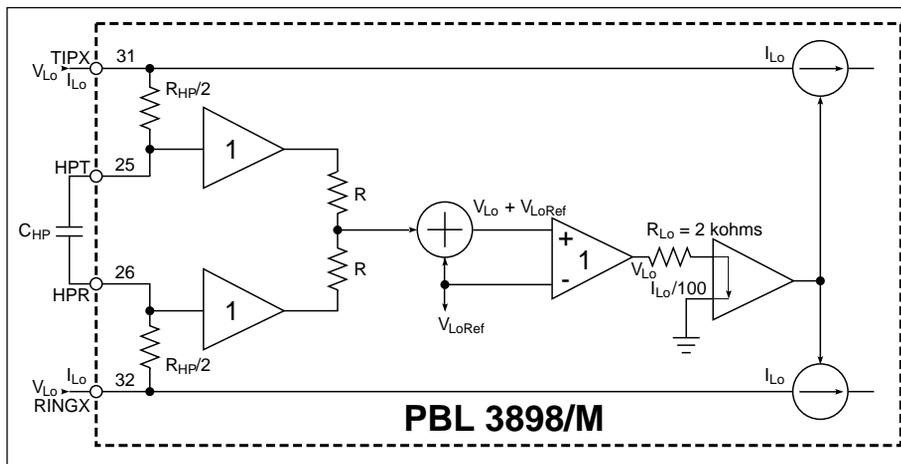


Figure 15. Longitudinal feedback loop.  $V_{LoRef} = (V_{Tip} + V_{Ring})/2$  (without any longitudinal voltage component).

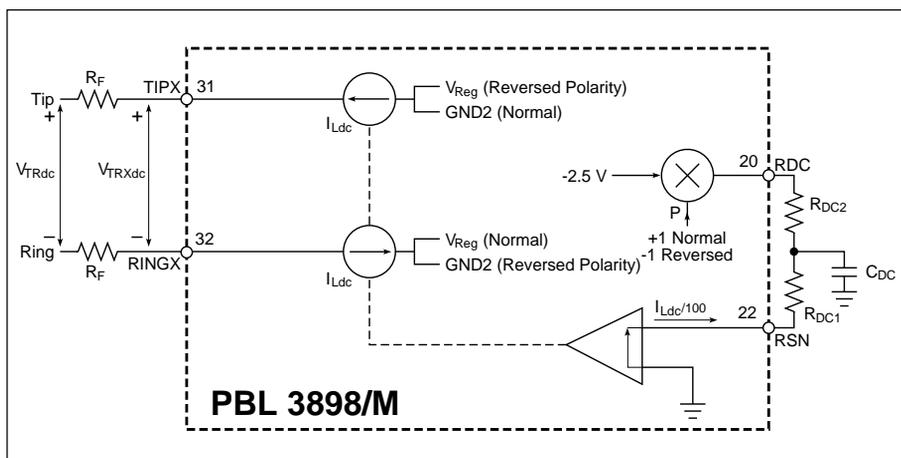


Figure 16. Battery feed.

### Capacitors $C_{TC}$ and $C_{RC}$

The capacitors designated  $C_{TC}$  and  $C_{RC}$  in figure 12, connected between TIPX and ground as well as between RINGX and ground, are recommended as an addition to the overvoltage protection network. Very fast transients, appearing on tip and ring, may pass by the overvoltage protection network, before this device has had time to activate and could damage the SLIC.  $C_{TC}$  and  $C_{RC}$  short such very fast transients to ground. The recommended value for  $C_{TC}$  and  $C_{RC}$  is 2200 pF. Higher capacitance values may be used, but care must be taken to prevent degradation of either longitudinal balance or return loss.  $C_{TC}$  and  $C_{RC}$  contribute a metallic impedance of  $1/(\pi \cdot f \cdot C_{TC}) \approx 1/(\pi \cdot f \cdot C_{RC})$ , a TIPX to ground impedance of  $1/(2 \cdot \pi \cdot f \cdot C_{TC})$  and

a RINGX to ground impedance of  $1/(2 \cdot \pi \cdot f \cdot C_{RC})$ .

**Ac - dc Separation Capacitor**

The high pass filter capacitor connected between terminals HPT and HPR provides separation between circuits sensing TIPX-RINGX dc conditions and circuits processing vf signals. The recommended  $C_{HP}$  capacitance value of 330 nF will position the 3 dB break point at 1.2 Hz.

**Battery Feed**

**Overview**

The PBL 3898/M SLIC synthesizes a constant current feed system without the disadvantage of high feed circuit power dissipation on short loops. To reduce power dissipation a switch mode regulator efficiently down-converts the battery supply voltage. The down-converted voltage is applied to the line drive amplifiers and is automatically adjusted to be precisely enough to feed the loop current as well as to allow distortion free vf signal transmission.

The magnitude of the constant loop current is set by two external resistors,  $R_{DC1}$ ,  $R_{DC2}$ .

The battery feed polarity can be set to either normal or reversed polarity via the SLIC digital control inputs.

To permit the line drive amplifiers to operate without signal distortion even on high resistance or open circuit loops, a saturation guard circuit limits the loop voltage, when the tip to ring dc voltage approaches the available battery supply voltage.

With the SLIC set to the stand-by state, power is further conserved by limiting the short circuit loop current to 50% of the active state short circuit current.

The following paragraphs describe the battery feed circuit in detail. At the end of this section a paragraph, Battery feed circuit programming procedure, summarizes the few simple calculations necessary to program the battery feed.

**Case 1: SLIC in the Active or Active Polarity Reversal State;  $|V_{TRdc}| < V_{SGRef}$ ,  $|V_{Bat}| > V_{SGRef} + 16V$**

In the active state C3, C2, C1 = 0, 1, 0 and in the active polarity reversal state C3, C2, C1 = 1, 1, 0.

The battery feed control loop is shown in block diagram form in figure 16. For tip to ring dc voltages less than the saturation guard reference voltage,  $V_{SGRef}$  (refer to case 2) the following expression is obtained from the block diagram for  $R_F = 0$ .

$$I_{Ldc} = p \cdot \frac{250}{R_{DC1} + R_{DC2}}$$

where:

$I_{Ldc}$  is the constant dc loop current

$R_{DC1}$ ,  $R_{DC2}$  are the external constant current programming resistors

$p = 1$  for normal polarity,  $-1$  for reversed polarity

In figure 17, curve segment AB and AC are described by case 1.

**Case 2: SLIC in the Active or Active Polarity Reversal State;**

$|V_{TRdc}| > V_{SGRef}$ ,  $|V_{Bat}| > V_{TRdc} + 16V$

In the active state C3, C2, C1 = 0, 1, 0 and in the active polarity reversal state C3, C2, C1 = 1, 1, 0.

When the tip to ring dc voltage approaches the  $V_{Bat}$  supply voltage, a circuit named saturation guard limits the two-wire voltage to a small additional increase beyond the saturation guard threshold,  $V_{SGRef}$ . This is to maintain distortion free vf transmission through the line drive amplifiers. The saturation guard feature makes on-hook transmission possible.

The tip to ring voltage at which the saturation guard becomes active,  $V_{SGRef}$  can be calculated from

$$V_{SGRef} = \frac{28.1}{1 - \frac{1.23}{R_{SG} + 3.35}}$$

where

$V_{SGRef}$  is in volts for  $R_{SG}$  in kohms

$R_{SG}$  is a resistor connected between terminal RSG and -5 V.

$R_{SG} = \infty$  ohm yields  $V_{SGRef} = 28.1V$

$R_{SG} = 0$  ohm yields  $V_{SGRef} = 44.4V$

The loop current,  $I_{Ldc}$ , as a function of the loop voltage,  $V_{TRdc}$ , for  $V_{TRdc} > V_{SGRef}$  is described by

$$I_{Ldc} = \frac{V_{SGRef} - V_{TRdc}}{35} + \frac{250}{R_{DC1} + R_{DC2}}$$

Figure 17. PBL 3898/M battery feed examples.

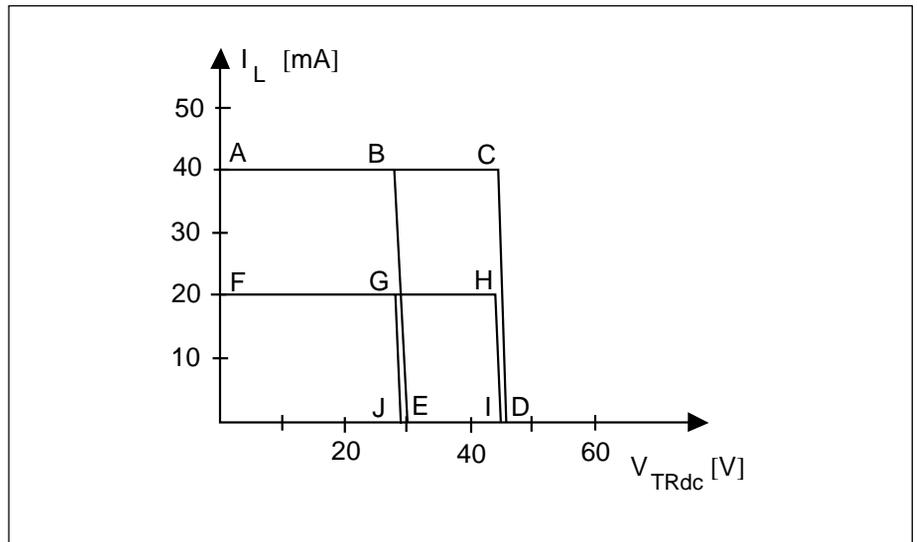
$R_{DC1} = R_{DC2} = 3.125$  kohms,  $I_{Ldc} = 40$  mA.

Curve ABE: active state. PBL 3898/M with  $R_{SG} = \infty$  ohms and  $V_{Bat} = -48V$ .

Curve ACD: active state. PBL 3898/M with  $R_{SG} = 0$  ohm and  $V_{Bat} = -63V$ .

Curve FGJ: stand-by state. PBL 3898/M with  $R_{SG} = \infty$  ohms and  $V_{Bat} = -48V$ .

Curve FHI: stand-by state. PBL 3898/M with  $R_{SG} = 0$  ohms and  $V_{Bat} = -63V$ .



The open circuit voltage is then, for a programmed loop current of 40mA, 29.5V for  $R_{SG} = \text{open circuit}$  and 45.8 V for  $R_{SG} = 0$ .

In figure 17, PBL 3898/M battery feed examples, curve segments CD and BE are described by Case 2.

**Case 3: SLIC in the stand-by or stand-by polarity reversal state;**

$$|V_{TRdc}| < V_{SGRef}, |V_{Bat}| > V_{SGRef} + 16 \text{ V}$$

The stand-by operating states reduce power dissipation.

The loop feed in the stand-by state (C3, C2, C1 = 0, 1, 1) and in the stand-by polarity reversal state (C3, C2, C1 = 1, 1, 1) is constant current according to:

$$I_{Ldc} = \rho \cdot \frac{125}{R_{DC1} + R_{DC2}}$$

In figure 17, PBL 3898/M battery feed examples, this corresponds to curve segments FG and FH.

**Case 4: SLIC in the Stand-by or Stand-by Polarity Reversal State;**

$$|V_{TRdc}| > V_{SGRef}, |V_{Bat}| > V_{SGRef} + 16 \text{ V}$$

In the stand-by state C3, C2, C1 = 0, 1, 1 and in the stand-by polarity reversal state C3, C2, C1 = 1, 1, 1.

When the tip-to-ring dc voltage exceeds the saturation guard reference voltage,  $V_{SGRef}$ , the loop feed is described by:

$$I_{Ldc} = \frac{V_{SGRef} - V_{TRdc}}{35} + \frac{125}{R_{DC1} + R_{DC2}}$$

In figure 17, this corresponds to curve segments HI and GJ.

**Case 5: SLIC in the TIPX Open Circuit State.**

In the TIPX open circuit state C3, C2, C1 = 1, 0, 0. Refer to figure 8. In this state the TIPX terminal is set to a high-impedance state ( $> 150 \text{ kohm}$ ). The RINGX terminal sinks a current ( $|I_{LRT0}| > 23 \text{ mA}$ ) until the  $V_{Bat}$  voltage is approached, whereafter the RINGX terminal changes to a constant voltage state and the RINGX current can be calculated from:

$$|I_{LRT0}| = \frac{|V_{Bat} + 4|}{R_{LRGnd}}$$

where;

$R_{LRGnd}$  is the resistor between ground and ring lead.

**C<sub>DC</sub> Capacitor**

Refer to the battery feed block diagram, figure 16. The battery feed programming resistors  $R_{DC1}$  and  $R_{DC2}$  together with capacitor  $C_{DC}$  form a low pass filter, which removes noise and vf signals from the battery feed control loop. The recommended 3 db break point frequency is 160 Hz  $< f_{3dB} < 240 \text{ Hz}$ . The  $C_{DC}$  capacitance value is then calculated from:

$$C_{DC} = \frac{1}{2\pi \cdot f_{3dB}} \cdot \left[ \frac{1}{R_{DC1}} + \frac{1}{R_{DC2}} \right]$$

Note that  $R_{DC1} = R_{DC2}$  yields minimum  $C_{DC}$  capacitance value.

**Switch Mode Regulator**

The switch mode regulator down-converts

the  $V_{Bat}$  supply voltage to a value, which is just enough for the line drive amplifiers to feed the required loop current and maintain transmission quality. Since the voltage conversion efficiency is high and the minimum required voltage drop across the line drive amplifiers is low, a significant power dissipation reduction is realized. A 50 mA constant current feed with 200 ohm line resistance and -48 V battery will have 1.9 W dissipated in the line feed circuit. The PBL 3898/M set up for the same 50 mA constant current feed and with the same 200 ohm line resistance and  $V_{Bat} = -48 \text{ V}$ , would generate only 0.72 W in the line feed circuits (90% power conversion efficiency), i.e. a 1.18 W or 62.1% reduction in line card power dissipation.

Refer to figure 18 for a block diagram of the switch mode regulator.  $V_{Bat}$  is the input voltage, which the regulator converts to  $V_{Reg}$  with high efficiency.  $V_{Reg}$  powers the line drive amplifiers. The switch mode regulator adjusts its  $V_{Reg}$  output to be equal to the reference voltage,  $V_{Ref}$ . The reference voltage is derived from the TIPX to RINGX dc metallic voltage according to

$$V_{Ref} = -( |V_{TRdc}| + V_{Bias} )$$

where  $V_{Bias}$  is approximately 16 V.

Since  $V_{Bias}$  is the voltage drop across the line drive amplifiers, the SLIC power loss is greatly reduced compared to supplying the amplifiers directly from the  $V_{Bat}$  supply.

The battery supply voltage,  $|V_{Bat}|$ , must be larger than  $|V_{Reg}|$ , i.e.  $|V_{Bat}| \geq |V_{TRdc}| + V_{Bias}$ . If this condition is not met, the tip to ring voltage will be limited by the SLIC according to  $|V_{TRdc}| = |V_{Bat}| - V_{Bias}$ . Although the SLIC continues to function, this mode of operation should be avoided due to increased noise and a much reduced  $V_{Bat}$  to transmission ports rejection ratio.

To minimize noise as well as battery feed circuit power dissipation on long loops the switch mode regulator is automatically turned off for tip to ring dc voltages exceeding a threshold value of approximately  $V_{SGRef}$ . With the regulator disabled, the  $V_{Bat}$  supply voltage is passed on to the VREG input without being down-converted.

The inductor, L, should be 1 mH with a series resistance larger than 15 ohms. A saturated inductor with less than 15 ohms of series resistance may damage the

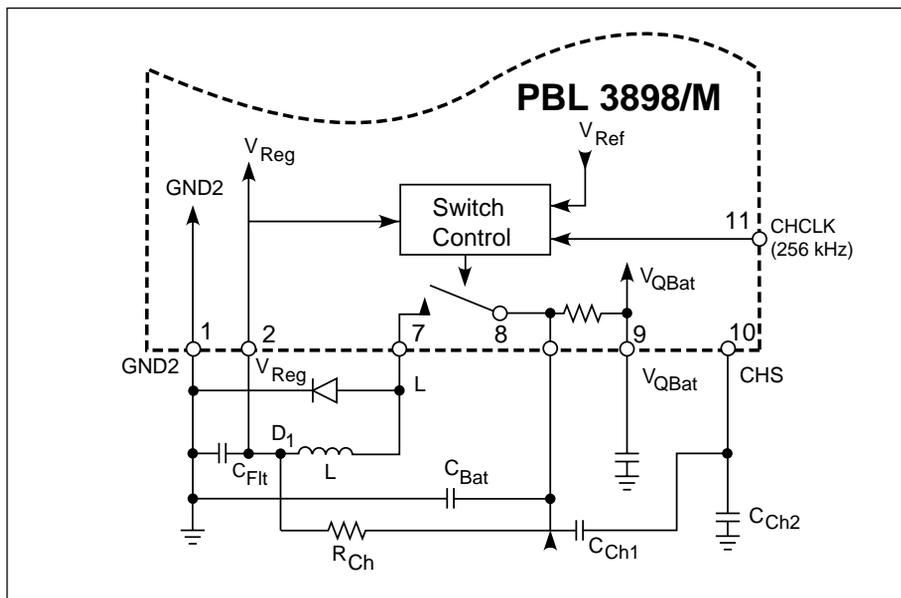


Figure 18. Switch mode regulator.

SLIC due to excessive regulator switch current.

$C_{Filt}$ , 0.47  $\mu$ F, is the regulator output filter capacitor.

The catch diode,  $D_1$ , (e.g. 1N4448) must withstand 70 V reverse voltage, conduct an average of 50 mA (150 mA peak) and turn off in less than 10 nsec.

$C_{CH1}$ ,  $C_{CH2}$  and  $R_{CH}$  make up a compensation network for an internal voltage comparator. Values are given in the applications example, figure 12.

The components associated with the switching regulator must be connected via the shortest possible PCB trace lengths. Other circuits should be kept isolated from this area. The L terminal voltage variations are large and very fast. To avoid interference the inductor and the catch diode should be located directly at this terminal. Inductors with closed magnetic path core (e.g. toroid, pot core) will reduce interference originating from the inductor.

### Battery Feed Circuit Programming Procedure

Extracting the key elements from the preceding description results in the following step-by-step procedure.

1. Establish the battery feed requirements.

Constant loop current,  $I_{Ldc} = ?$

Maximum loop resistance, including fuse resistors  $R_{F1}$  and  $R_{F2}$ ,  $R_{LMax} = ?$

Loop resistance, above which it is permissible for the loop feed to change from constant current feed to resistive feed,  $R_{LSGRef} = ?$

Loop current at the maximum loop resistance (applies if  $I_{Ldc} \cdot R_{LMax} > V_{SGRef}$ )  $I_{LMin} = ?$

SLIC supply voltage,  $V_{Bat} = ?$

2. Calculate the constant current programming components  $R_{DC1}$  and  $R_{DC2}$  from

$$R_{DC1} = R_{DC2} = \frac{250}{I_{Ldc}} \cdot \frac{1}{2}$$

3. Calculate  $C_{DC}$  from

$$C_{DC} = \frac{1}{2\pi \cdot f_{3dB}} \cdot \left[ \frac{1}{R_{DC1}} + \frac{1}{R_{DC2}} \right]$$

where  $f_{3dB} \approx 200$  Hz

4. Calculate the saturation guard programming resistor,  $R_{SG}$ .

RSG terminal open circuit:  $V_{SGRef} = 28.1$  V.

RSG terminal shorted to  $V_{EE}$ :  $V_{SGRef} = 44.4$  V.

For intermediate  $V_{SGRef}$  values calculate  $R_{SG}$  according to

$$R_{SG} = \frac{2.12}{1 + \frac{16.3}{V_{SGRef} - 44.4}}$$

where  $R_{SG}$  is in kohms for  $V_{SGRef}$  in volts.

The minimum required battery voltage is  $|V_{Batmin}| = V_{SGRef} + 16$  V. For loop voltages greater than  $V_{SGRef}$ ,  $|V_{Batmin}| = V_{TRdc} + 16$  V.

5. Calculate the loop resistance at which the saturation guard becomes active,  $R_{LSGRef}$ :

$$R_{LSGRef} = \frac{V_{SGRef}}{I_{Ldc}}$$

Confirm compatibility with requirements.

6. If  $I_{Ldc} \cdot R_{LMax} > V_{SGRef}$  calculate loop current at maximum loop resistance:

$$I_{Ldcmin} = \frac{V_{SGRef} + 35 \cdot (250 / (R_{DC1} + R_{DC2}))}{35 + R_{LMax}}$$

Confirm compatibility with requirements.

7. Recommended switch mode regulator component values:

$L = 1$  mH  $\pm 10$  %;

$C_{Filt} = 0.47$   $\mu$ F  $\pm 10$  %, 100 V;

$D_1 = 1N4448$  (or equivalent),

$R_{CH} = 909$  ohm  $\pm 2$  %, 0.25 W;

$C_{CH1} = 0.047$   $\mu$ F  $\pm 10$  %, 100 V;

$C_{CH2} = 1500$  pF  $\pm 10$  %, 100 V.

## Loop Monitoring Functions

### Overview

The PBL 3898/M SLIC contains three detectors: the loop current, the ground key and the ring trip detector. These three detectors report their status via the shared  $\overline{DET}$  output. The detector to be connected to the  $\overline{DET}$  output is selected according to the logic states at the control inputs C1, C2, C3 and enable input E1. Enable input E0 sets the DET output to either active or high impedance state.

### Loop Current Detector - Active State and Standby State

Active state (C3, C2, C1 = 0, 1, 0) and active polarity reversal state (C3, C2, C1 = 1, 1, 0) as well as standby state (C3, C2, C1 = 0, 1, 1) and standby polarity reversal state (C3, C2, C1 = 1, 1, 1)

The loop current value at which the loop current detector changes state is programmable by calculating a value for resistor  $R_D$ .  $R_D$  connects between terminals RD and VEE.

Figure 19 shows a block diagram for the loop current detector. The two-wire interface produces a current,  $I_{RD}$ , flowing out of pin RD:

$$I_{RD} = 0.5 \cdot \frac{|I_{LT} - I_{LR}|}{300} = \frac{|I_L|}{300}$$

where  $I_{LT}$  and  $I_{LR}$  are currents flowing into the TIPX and RINGX terminals and  $I_L$  is the loop current. The voltage generated across the programming resistor  $R_D$  by  $I_{RD}$  is applied to an internal comparator with hysteresis. The comparator reference voltage for transition on-hook to off-hook is 1.55 V. The reference voltage for a transition off-hook to on-hook is 1.37 V. A logic low level results at the  $\overline{DET}$  output, when the comparator reference voltage is exceeded.

For a specified on-hook to off-hook loop current threshold,  $I_{LThOff}$ ,  $R_D$  is calculated from

$$R_D = \frac{1.55 \cdot 300}{|I_{LThOff}|}$$

The calculated  $R_D$  value corresponds to an off-hook to on-hook loop current threshold,  $I_{LThOn}$ , of

$$|I_{LThOn}| = \frac{1.37 \cdot 300}{R_D}$$

### Loop Current Detector - Tip Open Circuit State

Tip open circuit state (C3, C2, C1 = 1, 0, 0)

In the tip open circuit state the loop current detector function is similar to the active state, but the RD terminal current,  $I_{RD}$ , is calculated from

$$I_{RD} = \frac{I_{LR}}{600}$$

where  $I_{LR}$  is the ring lead current.

The detector is triggered at a ring lead threshold current  $I_{LThOff0}$  with the  $R_D$

resistance value set to

$$R_D = \frac{1.55 \cdot 600}{I_{LRThOffTo}}$$

The ring lead current must be reduced to less than

$$I_{LRThOnTo} = \frac{1.37 \cdot 600}{R_D}$$

for the detector to return to its non-triggered state.

**Loop Current Detector - Filter Capacitor**

To increase the loop current detector noise immunity, a filter capacitor may be added from terminal RD to ground.

A suggested value for  $C_D$  is:

$$C_D = \frac{1}{2\pi \cdot R_D \cdot f_{3dB}}$$

where

$f_{3dB} = 500$  Hz is the high end frequency response 3dB break point for the low pass filter created.

$C_D$  is in farads for  $R_D$  in ohms.

Note that  $C_D$  may not be required if the detector output is software filtered.

**Ground Key Detector**

Refer to figure 19 for a block diagram of the ground key detector. The ground key detector examines the difference between

TIPX and RINGX currents. When the longitudinal current from ground exceeds an internally set threshold value of nominally 8 mA, the detector triggers and sets the  $\overline{DET}$  output to a logic low level. The E1 enable input must be set to logic high level to gate the ground key detector to the DET output. The Electrical characteristics table specifies the threshold level as a function of longitudinal resistance to ground.

The ground key detector threshold is pre-programmed and cannot be changed by external components.

**Ring Trip Detector**

Ring trip detection is accomplished by

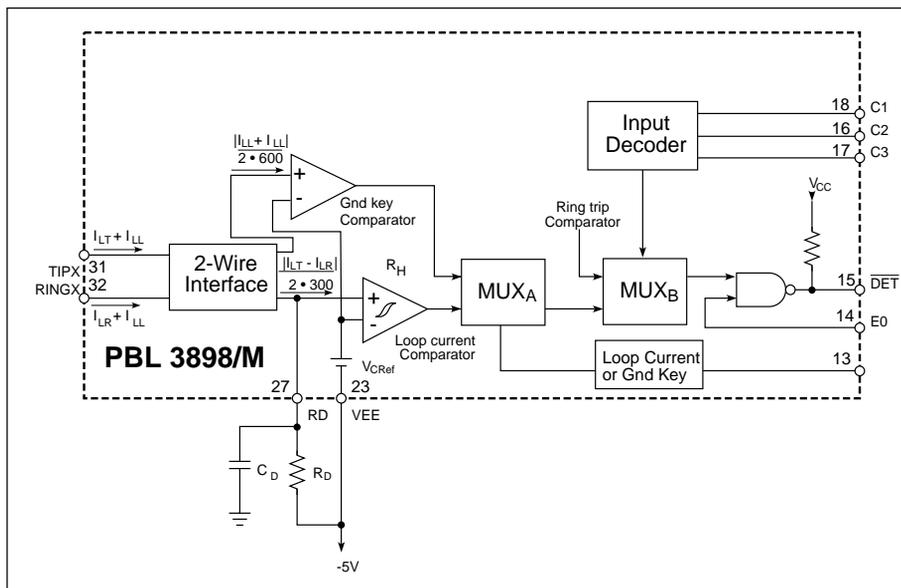


Figure 19. Loop current and ground key detector.

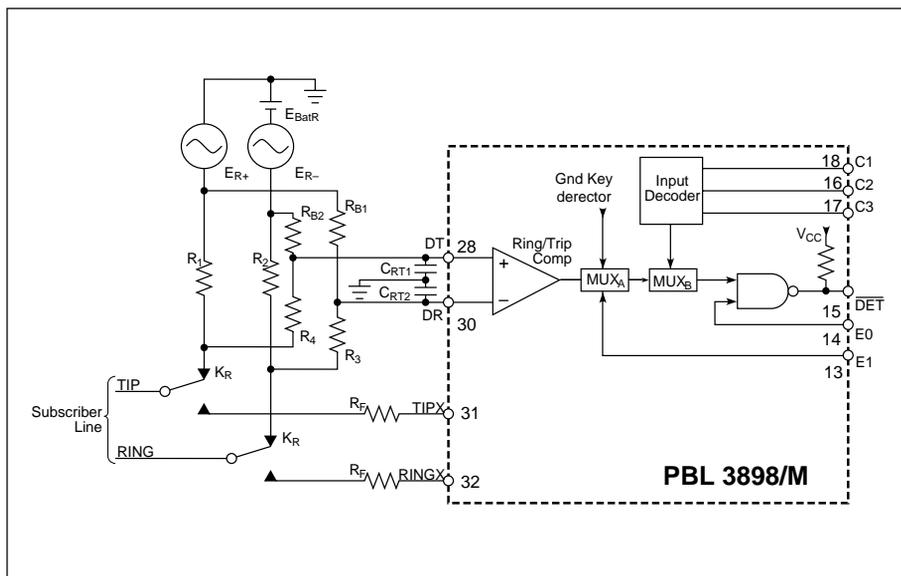


Figure 20. Ring trip network, balanced ringing.

monitoring the two-wire line for presence of dc current while ringing is applied. When the subscriber goes off-hook with ringing applied, dc loop current starts to flow. The comparator in the SLIC with inputs DT and DR detects this current flow via an interface network. The result of the comparison is presented at the  $\overline{DET}$  output. The ring trip comparator is automatically connected to the  $\overline{DET}$  output, when the SLIC control inputs are set to the ringing state (C3, C2, C1 = 0, 0, 1). When off-hook during ringing is detected, the line card or system controller will proceed to disconnect the ringing source (software ringtrip) by re-setting the control input logic states. Alternatively, the  $\overline{DET}$  output may be monitored by circuits on the line card, which perform the ringtrip function (hardware ringtrip).

The ringing source may be balanced or unbalanced, superimposed on the  $V_{Bat}$  supply voltage. The unbalanced ringing source may be applied to either the tip lead or the ring lead with return on the other wire. A ring relay, energized by the SLIC ring relay driver, connects the ringing source to tip and ring. For unbalanced ringing systems the loop current sensing resistor may be placed either in series with the ringing generator or in series with the return lead to ground.

Figures 20 and 21 show examples of balanced and unbalanced ringing systems. For either ringing system the ringtrip detection function is based on a polarity change at the inputs DT and DR

of the ringtrip comparator.

In the unbalanced case the dc voltage drop across resistor  $R_{RT}$  is zero as long as the telephone remains on-hook. With the telephone off-hook during ringing, dc loop current will flow, causing a voltage drop across  $R_{RT}$ . The  $R_{RT}$  voltage is applied to the comparator input DT via resistor  $R_3$ .  $R_4$  shifts the voltage level to be within the comparator common mode range.  $C_{RT}$  removes the ac component of the ringing signal.  $R_1$  and  $R_2$  establish a bias voltage at comparator input DR, which is more negative than DT when the telephone is on-hook and is more positive than DT when the telephone goes off-hook during ringing.

Complete removal of the ringing signal ac component at the DT input may not be necessary. Some residual ac component at the DT input may under certain operating conditions cause the  $\overline{DET}$  output to toggle between the on-hook and off-hook states at the ringing frequency. However, with the telephone off-hook the  $\overline{DET}$  output will be at logic low level for more than half the time. Therefore, by sampling the  $\overline{DET}$  output, a software routine can discriminate between on-hook and off-hook through examination of the duty cycle. Full removal of the ringing frequency from the DT input while maintaining ringtrip within required time limits (approximately < 100 ms) usually mandates a second order filter rather than the first order shown in figure 21. The software approach minimizes the number of line card components.

In the balanced ringing system shown in figure 20,  $R_1$  and  $R_2$  are the loop current sensing resistors. With the telephone on-hook, no dc loop current flows to cause a dc voltage drop across resistors  $R_1$  and  $R_2$ . Voltage dividers  $R_{B2}$ ,  $R_4$  and  $R_{B1}$ ,  $R_3$  bias the ringtrip comparator input DT to be more positive than DR. With the telephone off-hook during ringing dc loop current will flow, causing a voltage drop across resistors  $R_1$  and  $R_2$ , which in turn will make comparator input DT more negative than DR, setting the  $\overline{DET}$  output to logic low level, indicating ringtrip condition. Capacitors  $C_{RT1}$  and  $C_{RT2}$  filter the ring voltage at the comparator inputs. For 20 Hz ringing it is suitable to calculate these capacitors for a time constant of  $T = 50$  ms, i. e.

$$C_{RT1} = T \cdot \left( \frac{1}{R_{B2}} + \frac{1}{R_4} \right)$$

**Detector Output,  $\overline{DET}$**

The loop current detector, ground key detector and ringtrip comparator share a common output,  $\overline{DET}$ . The  $\overline{DET}$  output is open collector with internal pull-up resistor to  $V_{CC}$ . Via control inputs C1 through C3 and enable input E1 one of the three detectors is selected to be connected to the  $\overline{DET}$  output. With enable input E0 set to logic high level the  $\overline{DET}$  output is activated. In the  $\overline{DET}$  active state a logic low level indicates a triggered detector condition and a logic high level reports a non-triggered detector. With E0 set to logic low level, the  $\overline{DET}$  output is set to its

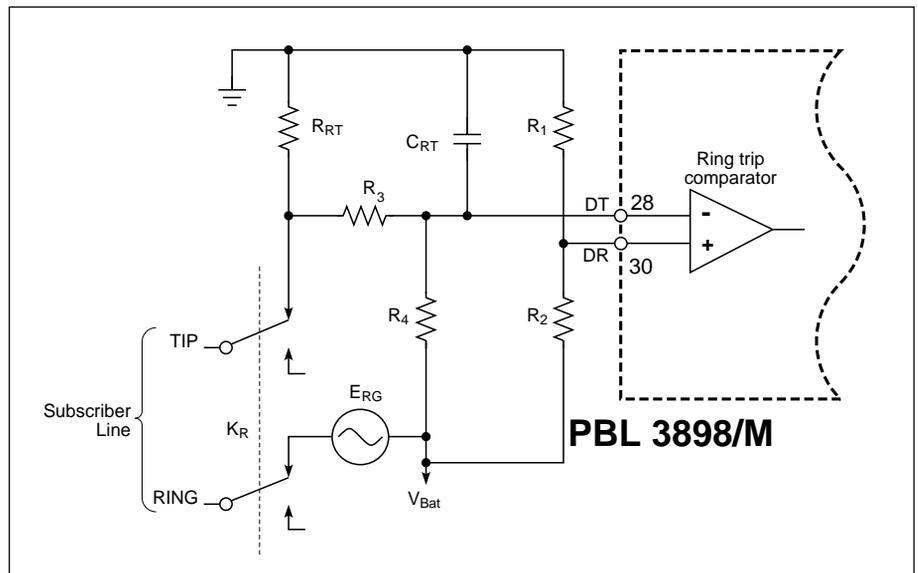


Figure 21. Ring trip network, unbalanced ringing.

high impedance state, i.e. connected to  $V_{CC}$  via the internal pull-up resistor.

### Relay Drivers

The PBL 3898/M SLIC contains two identical drivers for test and ring relays. The drivers are npn transistors in open collector configuration, sourcing up to 80 mA from the  $V_{CC}$  supply. Each driver has an internal inductive kick-back clamp diode. The relay coil may be connected to negative supply voltages ranging from ground to  $V_{Bat}$ . Control input C4 activates the test relay driver. Control inputs C1, C2 and C3 are used to operate the ring relay.

### Control Inputs

#### Overview

The PBL 3898/M SLIC has four TTL compatible control inputs, C1 through C4. A decoder in the SLIC interprets the control input logic conditions and sets up the commanded operating state. C1 through C3 allow for eight operating states. The C4 control input acts directly on the test relay driver.

The control inputs interface with programmable CODEC/filters, e.g. SLAC, SiCoFi, Combo II without any interface components. Via serial I/O ports on the programmable CODEC/filter devices a microprocessor can communicate with the

SLIC. In designs utilizing conventional CODEC/filters without control latches, the line card logic must contain the necessary latches for inputs C1 through C4.

Table 1 contains a summary description of the Control Inputs.

#### Test Relay Control (C4)

With C4 set to logic low level the test relay driver (TESTRLY) is activated. The active driver can source up to 80 mA from the  $V_{CC}$  supply. C4 set to logic high level causes the relay driver to be de-energized. The test relay driver is controlled exclusively by C4 and is independent of the C1, C2 and C3 logic levels.

#### Open Circuit State (C3, C2, C1 = 0, 0, 0)

In the Open Circuit State both the TIPX and RINGX power amplifiers present a high impedance to the line. The loop current and ground key detectors are not active in this state.

#### Ringling State (C3, C2, C1 = 0, 0, 1)

The ring relay driver (RINGRLY) is activated and the ring trip comparator is connected to the detector output ( $\overline{DET}$ ). The TIPX and RINGX terminals are in the high impedance state and signal transmission is inhibited.

#### Active State (C3, C2, C1 = 0, 1, 0)

TIPX is the terminal closest to ground potential and sources loop current, while RINGX is the more negative terminal and sinks loop current. Signal transmission is normal and the loop current or ground key detector is gated to the  $\overline{DET}$  output according to enable input E1 logic state.

#### Stand-by State (C3, C2, C1 = 0, 1, 1)

In the stand-by state the short circuit loop current is reduced to:

$$I_{Ldc} = 125 / (R_{DC1} + R_{DC2}).$$

The loop current or ground key detector is connected to the  $\overline{DET}$  output in accordance with the E1 input logic state.

#### TIPX Open Circuit State (C3, C2, C1 = 1, 0, 0)

The TIPX power amplifier presents a high impedance to the line. The RINGX terminal is active and sinks current. The loop current detector is connected to the  $\overline{DET}$  output for enable input E1 = 0. The detection threshold for the on-hook to off-hook transition is  $I_{LRTThOff0} = (1.55 \cdot 600) /$

| State # | C4<br>Note 1 | C3 | C2 | C1 | Operating State            | Active detector<br>Note 2  |
|---------|--------------|----|----|----|----------------------------|----------------------------|
| 1       | X            | 0  | 0  | 0  | Open circuit               | Ring trip                  |
| 2       | X            | 0  | 0  | 1  | Ringling                   | Ring trip                  |
| 3       | X            | 0  | 1  | 0  | Active                     | Loop current or ground key |
| 4       | X            | 0  | 1  | 1  | Stand-by                   | Loop current or ground key |
| 5       | X            | 1  | 0  | 0  | Tip open                   | Loop current, Note 3       |
| 6       | X            | 1  | 0  | 1  | Reserved                   | None                       |
| 7       | X            | 1  | 1  | 0  | Active polarity reversal   | Loop current or ground key |
| 8       | X            | 1  | 1  | 1  | Stand-by polarity reversal | Loop current or ground key |

#### Notes

- Control input C4 logic state (X) affects only the test relay driver and does not change the SLIC operating state. C4 at logic low level activates the test relay driver. C4 at logic high level turns the test relay driver off.
- Enable input E1 must be set to select between loop current and ground key detector.
- The ground key detector is not functional in the tip open circuit state

Table 1. PBL 3898/M operating states.

| Enable state # | E0 | E1 | $\overline{DET}$ output state | Active detector                  |
|----------------|----|----|-------------------------------|----------------------------------|
| 1              | 0  | X  | High impedance                | None                             |
| 2              | 1  | 0  | Active                        | Loop current or ringtrip. Note 1 |
| 3              | 1  | 1  | Active                        | Ground key                       |

#### Notes

- The loop current detector or the ring trip comparator is selected via C3, C2, C1 (state# 1 or 2 selects the ringtrip comparator).

Table 2. Enable inputs E0 and E1.

R<sub>D</sub>. For E1 = 1 the ground key detector is connected to the  $\overline{\text{DET}}$  output. Note that the ground key detector is not functional in the tip open circuit state.

**Reserved State (C3, C2, C1 = 1, 0, 1)**

This state has no assigned function.

**Active Polarity Reversal State (C3, C2, C1 = 1, 1, 0)**

TIPX and RINGX polarity is reversed from the Active State: RINGX is the terminal closest to ground and sources loop current while TIPX is the more negative terminal and sinks current. Polarity reversal transition time is 10 msec. The loop current or ground key detector is connected to the DET output in accordance with the E1 input logic state. Signal transmission is normal.

**Stand-by Polarity Reversal State (C3, C2, C1 = 1, 1, 1)**

Polarity Reversal as described under state C3, C2, C1 = 1, 1, 0 and Stand-by as described under state C3, C2, C1 = 0, 1, 1.

**Enable Inputs**

E0 sets the  $\overline{\text{DET}}$  output to active state, when at logic high level and to high impedance state when at logic low level. E1 selects the loop current detector to be gated to the  $\overline{\text{DET}}$  output, when at logic

**Metering**

**Metering Injection**

The metering injection block (see figure 12) represents an external circuitry for injection of the 12 or 16 kHz metering signal to the receive path on the four wire side of the SLIC. A suggested injection circuitry with a smooth ramping of the metering signal is shown in figure 22. For components values see table 3.

The R<sub>M1</sub> resistor value can be calculated from the equation

$$R_{M1} = \frac{Z_T \cdot V_{MG}}{V_{Meter} \cdot \left( \frac{Z_T}{100} + G_{2-4S} (Z_{LM} + 2R_F) \right)} \quad (4)$$

where

V<sub>Meter</sub> is the wanted metering voltage between the TIP and RING terminals.

Z<sub>LM</sub> is the line impedance seen by the 12 or 16 kHz metering signal.

|                 |                          |  |
|-----------------|--------------------------|--|
| R <sub>M1</sub> | Resistor                 | Value according to equation (4), 1%, 1/4 W |
| R <sub>M2</sub> | Resistor                 | 200 kohm, 1%, 1/4 W                        |
| R <sub>M3</sub> | Resistor                 | 301 kohm, 1%, 1/4 W                        |
| R <sub>M4</sub> | Resistor                 | 301 ohm, 1%, 1/4 W                         |
| R <sub>M5</sub> | Resistor                 | 909 kohm, 5%, 1/4 W                        |
| C <sub>M1</sub> | Capacitor                | 220 nF, 10%, 10V                           |
| C <sub>M2</sub> | Capacitor                | 47 nF, 10%, 10V                            |
| D <sub>M1</sub> | Diode                    | 100V, 100 mA, 10 ns, e g 1N4148            |
| M <sub>1</sub>  | N Channel MOS transistor | BS170 or equivalent                        |

Table 3. Part list for metering injection circuit.

|                  |                       | 12 kHz               | 16 kHz               |           |
|------------------|-----------------------|----------------------|----------------------|-----------|
| R <sub>MF3</sub> | Resistor              | 5,11 kohm            | 4,02 kohm            | 1%, 1/4 W |
| R <sub>MF4</sub> | Resistor              | 5,36 kohm            | 5,62 kohm            | 1%, 1/4 W |
| R <sub>MF5</sub> | Resistor              | 22,1 kohm            | 22,1 kohm            | 1%, 1/4 W |
| R <sub>MF6</sub> | Resistor              | 36,5 kohm            | 27,4 kohm            | 1%, 1/4 W |
| R <sub>MF7</sub> | Resistor              | 2,15 kohm            | 2,26 kohm            | 1%, 1/4 W |
| R <sub>MF8</sub> | Resistor              | 9,09 kohm            | 9,09 kohm            | 1%, 1/4 W |
| C <sub>MF2</sub> | Capacitor             | 1,0 nF               | 1,0 nF               | 5%, 10V   |
| C <sub>MF3</sub> | Capacitor             | 1,0 nF               | 1,0 nF               | 5%, 10V   |
| U <sub>1</sub>   | Operational amplifier | µA 741 or equivalent | µA 741 or equivalent |           |

Table 4. Part list for 12 and 16 kHz notch filter. Note that all component values are user programmable and may be altered to suit the application.

V<sub>MG</sub> is the voltage of the signal at the metering generator, e g 1V<sub>rms</sub>.

G<sub>2-4S</sub> is the transmit gain through the SLIC, i e 0,51 (-5,85dB).

12) represents an external 12 or 16 kHz low pass or notch filter to reduce the metering level in the transmit path in order to prevent an overload of the codec or combo input. A suggested metering filter circuit, shown in figure 23, is a notch filter centered at 12 or 16 kHz. For components values see table 4.

**Metering Filter**

The metering filter block (see figure

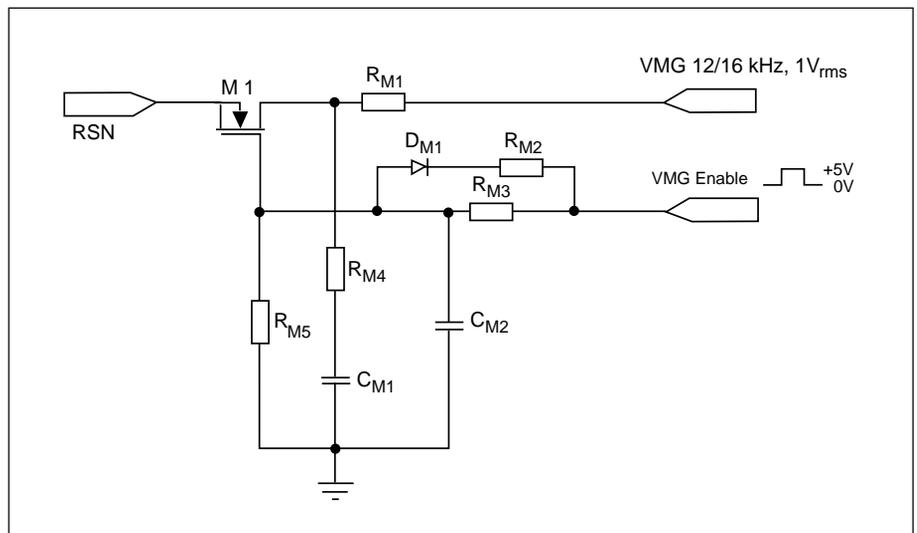


Figure 22. Metering injection circuit.

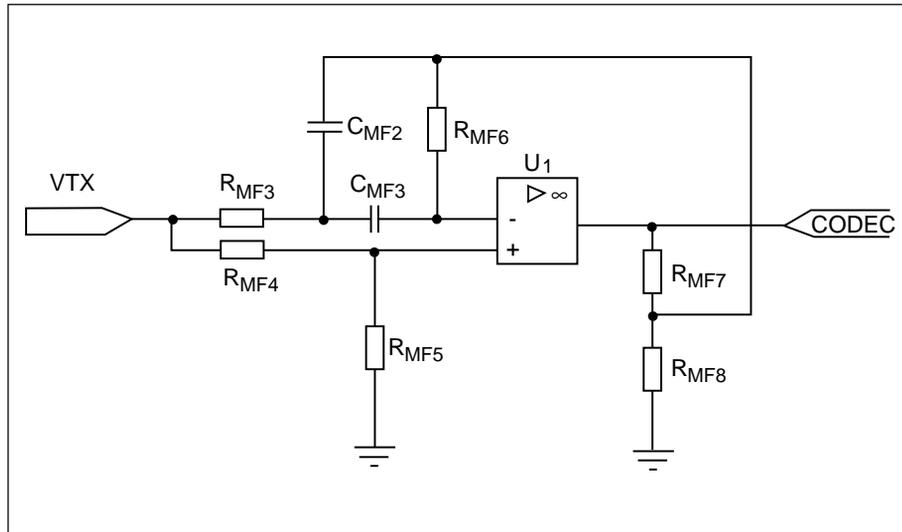


Figure 23. Metering notch filter

low level and the ground key detector when at logic high level.

Table 2 summarizes the above description of the Enable Inputs.

## Overvoltage Protection

The PBL 3898/M SLIC must be protected against overvoltages on the telephone line caused by lightning, ac power contact and induction. Refer to Maximum Ratings, TIPX and RINGX terminals, for maximum allowable continuous and transient voltages that may be applied to the SLIC. The circuit shown in figure 12 utilizes series resistors together with a programmable overvoltage protector (e.g. Texas Instrument TISPPBL2), serving as a secondary protection.

The TISPPBL2 is a dual forward-conducting buffered p-gate overvoltage protector. The protector gate references the protection (clamping) voltage to negative supply voltage (i.e. the battery voltage,  $V_{Bat}$ ). As the protection voltage will track the negative supply voltage the overvoltage stress on the SLIC is minimized. Positive overvoltages are clamped to ground by a diode. Negative overvoltages are initially clamped close to the SLIC negative supply rail voltage and the protector will crowbar into a low voltage on-state condition, by firing an internal thyristor.

A gate decoupling capacitor,  $C_{TISP}$  is needed to carry enough charge to supply a high enough current to quickly turn on

the thyristor in the protector. Without the capacitor even the low inductance in the track to the  $V_{Bat}$  supply will limit the current and delay the activation of the thyristor clamp.

The fuse resistors  $R_F$  serve the dual purposes of being non-destructive energy dissipators, when transients are clamped and of being fuses, when the line is exposed to a power cross. Ericsson Components AB offers a series of thick film resistors networks (e.g. PBR 51-series and PBR 53-series) designed for this application.

Also devices with a built in resettable fuse function is offered (e.g. PBR 52-series) including positive temperature coefficient (PTC) resistors, working as resettable fuses, in series with thick film resistors. Note that it is important to always use PTC's in series with resistors not sensitive to temperature, as the PTC will act as a capacitance for fast transients and therefore will not protect the SLIC.

## Over-Temperature Protection

A ring lead to ground short circuit fault condition, as well as other improper operating modes, may cause excessive SLIC power dissipation. If junction temperature increases beyond 140°C, the temperature guard will trigger, causing the SLIC to be set to a high impedance state. In this high impedance state power dissipation is reduced and the junction

temperature will return to a safe value. Once below 130 °C junction temperature the SLIC is returned back to its normal operating mode and will remain in that state assuming the fault condition has been removed.

## Power-Up Sequence

The voltage at pin VBAT sets the substrate voltage  $V_{QBat}$  (supplied internally from  $V_{Bat}$  through a resistor), which must at all times be kept more negative than the voltage at any other terminal. This is to maintain correct junction isolation between devices on the chip. To prevent possible latch-up, the optimal power-up sequence is to connect ground and  $V_{Bat}$ , then other supply voltages and signal leads.

The  $V_{Bat}$  voltage should not be applied at a faster rate than  $dV_{Bat}/dt = 4 \text{ V}/\mu\text{sec}$ , e.g. a time constant formed by a 5.6 ohm resistor in series with the VBAT pin and a 0.47 microfarad capacitor from the VBAT pin to ground. One resistor may be shared by several SLICs.

## Printed Circuit Board Layout

Care in PCB layout is essential for proper function. The components connecting to the RSN input should be placed in close proximity to that pin, such that no interference is injected into the RSN terminal. A ground plane surrounding the RSN pin is advisable. The  $C_{HP}$  capacitor should be placed close to terminals HPT and HPR to avoid unwanted disturbances.

The switch mode regulator components must be located near the pins to which they connect. It is particularly important that the catch diode and the inductor are connected via shortest possible trace lengths.

Ground terminals GND1 and GND2 should be connected via a direct PCB trace at the device location.

## Ordering Information

| Package     | Temp. Range | Part No.     |
|-------------|-------------|--------------|
| PLCC 32 pin | 0 to 70°C   | PBL 3898/MRN |



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