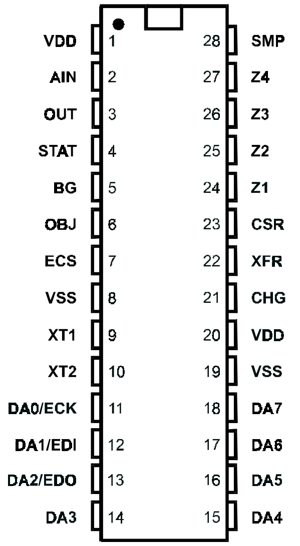
QProx™ QT9701B
CHARGE-TRANSFER CAPACITANCE SENSOR IC

- **Numerous auto-calibration modes**
- **Multistage internal digital filtering**
- **200µs response time**
- **200ns to 1.4µs selectable drive pulse width**
- **Psuedorandom burst mode**
- **Programmable sensitivity, hysteresis, response time, digital filtering, detection mode, drift compensation**
- **Post detection processing: event filtering, output stretch, auto recalibration timeout**
- **Analog sample gate control line**
- **Status indication output**
- **Shorted electrode detection**
- **Only one external mosfet required**
- **Uses cloned e^{2}prom setups from E2S board**
- **5 volt single supply operation**



APPLICATIONS

- **Fluid level sensing**
- **Security sensing**
- **Moisture detection**
- **Switch replacement**
- **Distance guaging**
- **Material properties analysis**
- **Human presence detection**
- **Collision avoidance**
- **Transducer drivers**

DESCRIPTION

The QT9701B is an advanced, high performance charge-transfer (QT) control and processing IC. With a few inexpensive external parts it becomes a complete sensor capable of detecting femtofarad capacitance changes while fully cancelling large background levels of ‘Cx’. Advanced signal processing permits robust detection while allowing a wide range of selectable built in operating modes. The QT principle delivers levels of performance clearly superior to other technologies.

The QT9701B includes a fast onboard ADC for signal acquisition and incorporates high speed digital signal processing to deliver up to 200µs response times. Virtually all internal processing function can be enabled, disabled, or altered to suit a specific application by the simple addition of an inexpensive 8-pin serial e^{2}prom. Without the external e^{2}prom, the QT9701B will operate in a default mode suitable for a great many sensing applications.

The QT9701B allows almost any metal-bearing surface to be made inherently sensitive to nearby mass; nonmetallic objects can be sensitized by simply attaching some metal. The field readily penetrates through solid surfaces, allowing most dielectric materials to become sensitive without modification; this is useful in sensing level through containers, for example. The IC supresses large load capacitances by using a 4-stage charge cancellation process, and does so automatically and transparently during a self-calibration procedure. When used with an external e^{2}prom, the resulting calibration point can be locked so that the sensor will immediately begin to function after each powerup without the need for recalibration. The QT9701B also incorporates a user-alterable drift compensation mechanism to track slow environmentally induced changes in signal level.

The QT9701B can perform a 'learn by example' autocalibration, where the object to be sensed is presented and ‘learned’ to create the proper thresold point. It is also possible to recalibrate the QT9701B remotely on demand via a control line or switch closure. The numerous autocal methods eliminate the need for potentiometer adjustments. Sophisticated threshold options allow detection on positive or negative signal swings, or both, and can incorporate preset time delays before final detection confirmation.

The IC is designed for use in creating high performance capacitance detection systems for industrial and commercial use, and may be embedded on the circuit board of another product. Because the unit employs digital pulse technology, it is more immune to radiated RFI than other sensor types, and in most applications does not require shielding. The IC and related circuitry require only a single +5 volt supply from a common 78L05 type regulator.

AVAILABLE OPTIONS

T_A	SOIC (S)	300 MIL DIP (D)
0°C to +70°C	QT9701B-S	QT9701B-D
-40°C to +85°C	QT9701B-IS	
-40°C to +125°C	QT9701B-ES	

Quantum Research Group Ltd.

R2.04/1100

1 - OVERVIEW

The QT9701B implements all charge-transfer (QT) control and signal processing functions necessary to make a highly sensitive and stable capacitance sensor. Only a few low cost external parts are required to make the unit fully functional; these can be readily selected for a specific range of capacitance detection.

A block diagram of the QT9701B hardware is shown in Figure 1-1. Figure 1-2 shows a typical sensor circuit employing the IC (see also Figs. 11-1, 11-2).

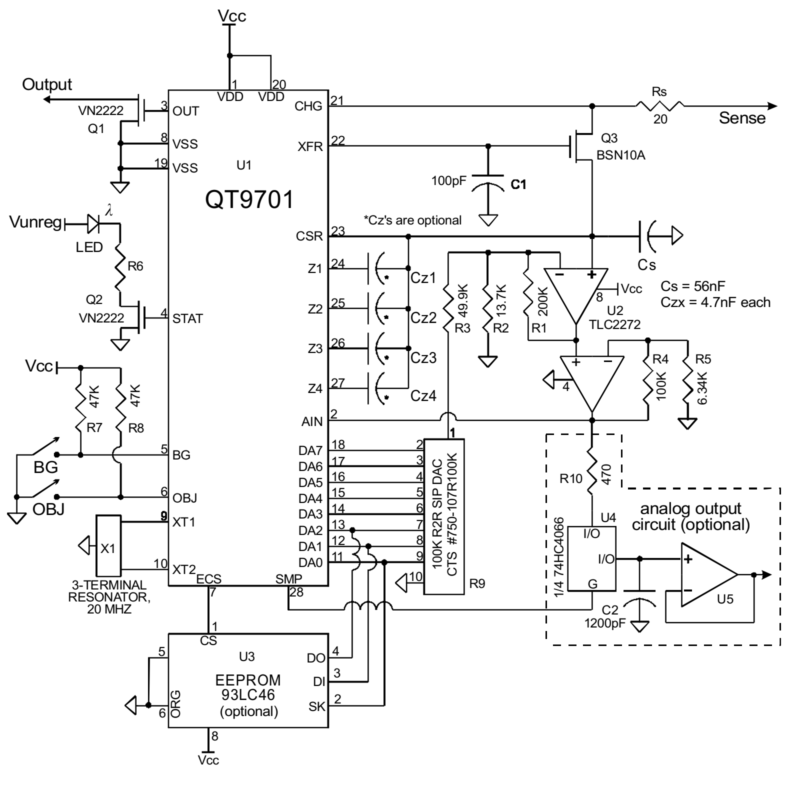
1.1 BASIC OPERATION

The QT9701B is a burst mode QT controller. QT cycles are executed via bursts of pulses on control lines CHG and XFR. CSR is provided to reset the charge detection capacitor Cs, and line SMP is provided to permit analog sampling of the amplifier signal, to create a direct analog output if desired. The number of pulses in each burst is controllable via e^{2}prom, or in the absence of an e^{2}prom, is set to 64 per burst. Timing information is found in Figure 10-1.

With each XFR control pulse, charge accumulates on cap Cs. The more transfer pulses within a burst, the higher the gain, but also the higher the accumulation of charge due to stray C. More transfer pulses also produce an averaging effect, with Cs acting as an integrator to produce an arithmetic mean of all charge accumulated within a burst. The voltage on Cs may become large enough to produce significant nonlinearities and cause mosfet Q3 back-diode reverse conduction; charge cancellation methods are used to 'buck' the accumulation of charge on Cs as described below.

At the end of each burst, the amplified signal from Cs is converted to digital in the QT9701B and further processed. Internally the IC contains several selectable processing paths which may be employed to filter noise, compensate for signal drift, and create different sensing effects. See Section 9 for more details on signal processing.

Figure 1-2 High Gain Circuit

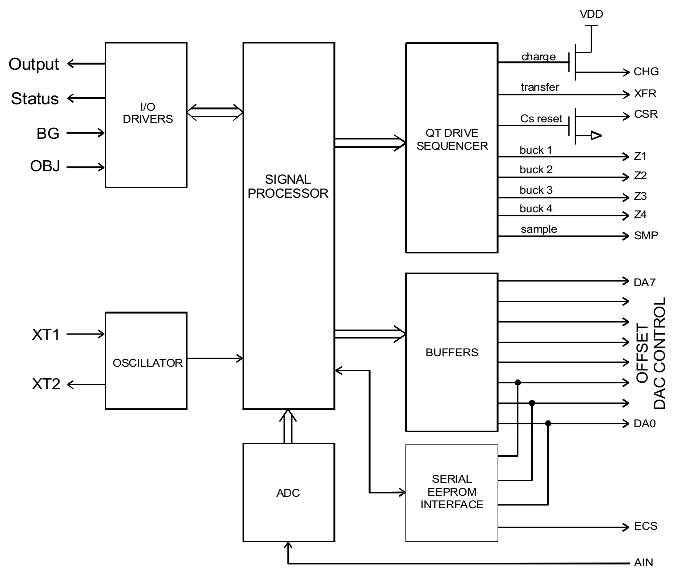


The sensor also provides a STAT pin which acts to indicate the current state of the sensor, and an active-high OUT pin which provides the primary output when the signal reaches a predefined criteria such as exceeding a specified signal level.

1.2 BACKGROUND Cx SUPPRESSION

Stray background 'Cx' is an extremely important factor in many sensor systems. For example, an attempt to convey the capacitance effect to a remote object often requires a shielded cable which will add an offset capacitance. There are many other possible sources of such loading, for example the electrode itself, which may be in close proximity with another surface. In most cases background 'Cx' is vastly greater than the signal to be observed, and without some compensating mechanism can swamp the sensor.

Figure 1-1 Block Diagram



As detailed also in documentation contained in the QProx E2S manual, the QT9701B employs two strategies for suppressing background C**.**

1.3 Cz CHARGE CANCELLATION

The first method of charge cancellation involves the use of external capacitors Cz1 through Cz4, and corresponding IC pins Z1 through Z4. Normally Z1...Z4 are held to VCC while CSR clamps Cs to ground. During the course of a burst, CSR is released, and one or more of lines Z1..Z4 may be driven to ground in sequence. Each burst is composed of 4 'sub-bursts' as shown in Figure 1-3; if the charge that accumulates on Cs is larger than about 0.37 volts, one of the Z1..Z4 lines will transition down to provide a charge cancellation effect, by creating a negative-going step on Vcs. The amount of charge so canceled should not produce a downward step of more than 0.35 volts by design, otherwise it is possible to inadvertently create non-acquireable gaps in the sensing range; the ADC cannot sense negative voltages, and too large a bucking step will potentially place the resultant final signal into negative territory. 1-3 shows a burst having 16 pulses contained in 4 sub-bursts of 4 pulses each; as the number of pulses per burst changes, the number of sub-bursts remains constant, while the number of pulses within each sub-burst is altered.

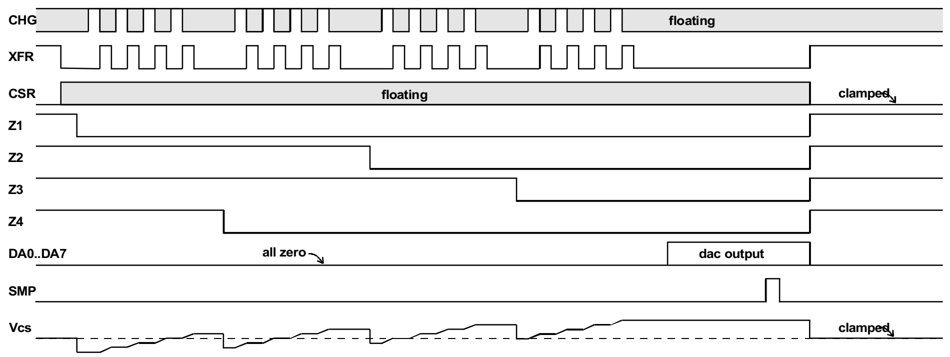


Figure 1-3 Burst Waveforms

The amount of each bucking step is easily computed by the ratio of the values of Cz to total capacitance:

$$[1] \quad V_Z = \frac{-Vcc \cdot C_Z}{C_S + 4C_Z}$$

where all Cz's are equal.

Four Cz's are not always required, and in lightly loaded systems none at all may be needed. In certain applications the background load may be quite predictable or limited to a maximum value, and so the number of Cz caps can be held to a minimum. Adding Cz caps reduces system gain unless Cs is reduced to compensate.

1.4 DAC CHARGE OFFSET CIRCUIT

The second way background C is accommodated involves an R2R ladder DAC driven via pins DA0 - DA7. After a burst has completed, but before the ADC conversion begins, this DAC is driven to a level calculated to bring the amplified signal to within a suitable portion of the ADC's range. The DAC value required to do this is iteratively determined during the self-cal process.

During the calibration process, the IC acts to find the optimum combination of Cz charge cancellation and DAC offset. It does so by first setting the DAC offset to a high value and then applying increasing amounts of Cz cancellation in successive steps until the signal is below 0.37 volts of Vcs, as required. Then, the value of the DAC offset is fine tuned to bring the analog signal into the desired range specified by the Reference Offset setting (Select 2 - see **Table 6.1**).

Cz cancellation and the DAC offset are fixed while the sensor runs. If an e^{2}prom is installed, these values of cancellation and offset can be stored for reuse on successive power-ups, otherwise a recalibration on each power up will be performed.

2 - CIRCUIT RECOMMENDATIONS

2.1 SAMPLER CAPACITORS

Charge sampler cap Cs and buck caps Czx should be high grade, stable parts for lowest thermal and long term drift. NPO or C0G ceramic, polycarbonate, and PPS film types are preferred in that order. Non-NPO, mylar, polyester, polyethylene, and "metallized film" caps are to be avoided; these have high dielectric absorption, high ESR, and/or poor temperature coefficients.

In cases where the background capacitive load is low, just a Cs capacitor can be used. If Cz caps are required, their number can be limited to less than 4 if loading is moderate.

2.2 TRANSFER MOSFETS

The transfer mosfet Q3 must be an n-channel enhancement device. The BSN10A is a reasonably good part for general purpose use. Lateral DMOS fets like the Temic/Siliconix SD211 are excellent devices; these have particularly low amounts of charge injection, although they have a higher on-resistance which may limit their use in some circumstances. When using DMOS parts like the SD211 with a substrate pin, be sure to connect the substrate pin to ground.

Q3 should be selected for a reasonable on-resistance with 5 volts on the gate. As long as electrode charge is fully transferred within the selected transfer pulse time, on-resistance will not affect accuracy. The QT method is surprisingly forgiving of on-resistance in most cases. If at least 11 RC timeconstants of transfer time expire, a timeconstant being defined as the greater of charge or transfer switch resistance, multiplied by load Cx, accuracy will not be materially affected at the resolution used in the digitally processed path.

The IC uses an internal 65 ohm p-mosfet to drive CHG, thus eliminating the need for an external p-mosfet. C1 is required for timing purposes to prevent switch cross-conduction by delaying the turn-on of Q3, and should be a 100pF NPO or C0G type.

2.3 SHORTER TRANSFER TIMES

Often it is desirable to use shorter transfer times than the QT9701B can produce on its own. The circuit of Figure 2-1 shows a simple way to create such a circuit from standard, inexpensive components. Transfer times as low as 20ns are easily achievable with this circuit, and even shorter times are possible with high speed logic gates and DMOS fets. Care should be taken to observe precautions involving ground return paths and signal lead inductances (see Section 14).

2.4 AMPLIFIER REQUIREMENTS

The external amplifier can be almost any moderate speed rail-to-rail output and ground-sensing input CMOS or JFET input device having a 2MHz GBW or better. Bipolar input opamps are to be avoided due to their higher input currents. Amplifiers in the same class as the TI TLC2272, Analog Devices AD822, and Burr Brown OPA2340 are all acceptable.

Two gain stages should be cascaded for the recommended gain of about 284; attempting to achieve this in one stage will result in settling time problems. If only a low gain is required, for example to create a low sensitivity QT sensor, then a single opamp may be more than sufficient (Fig. 11-2). Each opamp stage should be held to under a gain of 20 if possible with the above class of opamp. It is advisable to use opamp feedback resistor values of under 500K ohms to speed settling times, these should be placed very close to the opamp pins to reduce parasitic capacitances which slow down settling times.

There is generally no problem in using the same Vcc supply for the opamp as for the QT9701B, provided normal supply bypassing is performed.

2.5 R2R DAC REQUIREMENTS

An R2R ladder DAC is an inexpensive method of providing a subranging ADC system. The CMOS drive of the QT9701B functions as a perfect interface for this part, and no further buffering is required. The R2R should be 50K ohms or higher for best accuracy, and 8 bits in length. An 8-bit DAC IC with a buffered voltage output can also be used, but the expense and performance degradation of such a part compared to a simple R2R DAC makes this approach questionable at best. IC DACs have poorer settling times, require more power, and take up more space than a simple R2R ladder. R2R ladders also have a constant output impedance, making them ideal for creating the digitally controlled offset function required by the QT9701B. CTS 750-107R100K is a suitable part for this function. Note that some manufacturers specify a reverse pinout compared to the CTS part.

2.6 OUTPUT CIRCUITRY

The OUT and STAT lines are active high only, and they should not be loaded to any significant degree. Loading these lines will cause internal references inside the QT9701B to sag, adversely impacting signal acquisition. Mosfets and darlington transistors, the latter with a high base resistor, are suitable output buffers. The routing of currents from these transistors should not pass through any analog area; the supply voltages for these should also come from an independent source, not from the IC's Vcc supply, and the ground return should not share the same grounds as the rest of the sensor circuit.

Failure to observe these precautions can cause 'signal stiction' and other phenomena which are the result of inadequate loading and/or grounding precautions, causing induced feedback loops via disturbances on the power supply rail.

2.7 BG / OBJ INPUTS

These control inputs can be from any TTL or CMOS source. With pullup resistors to Vcc, contact closures to ground can be used. These inputs are active low, and should be pulsed low momentarily for at least the burst interval duration; thus, if the burst spacing is 1ms, the line should be held low for 1ms absolute minimum. To engage the BG or OBJ "mode override" functions the line should be evoked for >1.6 seconds prior to release. Note that if only a simple BG or OBJ recal function is desired, it is important to not hold the line low so long that this override feature is engaged.

2.8 E^{2}PROM

The external e^{2}prom should be a Microchip type 93L46A or comparable device having both byte-access and streaming modes. Many variants of this part are only word access or non-streaming and will not function. The eeprom's contents are described fully in Section 13. The e^{2}prom can be programmed using a commercial PROM programmer; a master can also be created using an appropriate QProx programmer board.

A plain blank e^{2}prom will be ignored. Refer to **Table 6.1** for modes which can be enabled and altered using the external e^{2}prom.

2.9 OSCILLATOR

Any 20MHz ceramic resonator will work fine. A quartz crystal will also function, but aside from a slight boost in accuracy, longer startup time, and increase in board space does not buy anything. The resonator should have two capacitors to ground on either side, of value 15pF. 3-pin devices having internal capacitors are available, saving considerable space and cost.

An external oscillator having CMOS drive levels may also be used, by connecting the oscillator to pin 9 and leaving pin 10 open. The oscillator should have a 50% duty cycle.

Lower frequencies may be used if desired for reduced power consumption, however all timing functions are slaved to the oscillator frequency and will thus slow down as well, including QT pulse widths, burst spacings, etc.

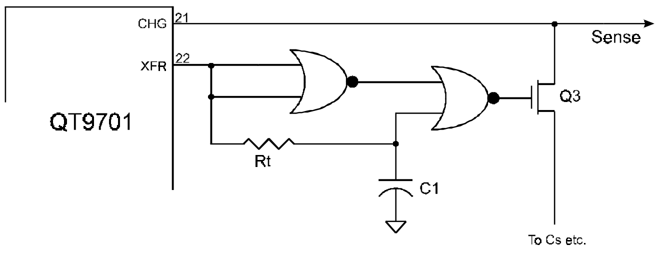
2.10 INPUT PROTECTION

The CHG drive and BG and OBJ lines are internally protected from ESD by clamp diodes, however, this should not be relied upon as a primary means of protection. It is highly recommended that any pins exposed to the outside world, including CHG, be clamped via two high speed, high conductance, low-C silicon diodes like type 1N4150, one from ground to the pin, and the other from the pin to Vcc or to a zener diode biased up to at least the level of Vcc, and that a resistor be placed between these clamp diodes and the CHG pin to further limit pin currents. See fig. 11-3. Silicon transient voltage suppressors (TVS) are basically heavy-duty zeners and should not be used directly on the CHG line. TVS diodes have extremely high levels of nonlinear junction capacitance and in some cases high leakage currents which can make the sensor drift prone and swamped with excess Cx.

Increasing Rs will assist in protecting the IC from ESD; Rs should be between the CHG pin and an external clamping circuit as described above for maximum effect. Rs will also help damp lead resonances which can adversely affect the QT process; so long as total (Rswitch + Rs) is not so large that at least 11 timeconstants can expire within the desired charge and transfer intervals, Rs will not adversely impact the sensor. If it does, the transfer pulse widths can also be increased to compensate.

In extreme ESD situations the CHG pin can be buffered via an external p-channel mosfet. Also, if the electrode is placed behind an insulating surface such as a piece of glass or plastic, ESD issues will be eliminated entirely.

Figure 2-1 Circuit for Short Transfer Times



Note that the QT9701B forces the XFR line high and clamps the CSR line low between bursts to self-clamp and dissipate ESD currents; however, when power is removed this feature obviously ceases.

2.11 SHORT CIRCUIT DETECTION

The QT9701B incorporates a circuit on CHG which can sense shorts to ground. When a short is detected, the OUT and STAT lines are forced high for the duration of the short. Short detection operates by monitoring output current through the internal p-mosfet device; external ESD circuits that include a series resistance can limit this current artificially, thus rendering the short detection system ineffective. Operation of the short detection circuit is not guaranteed under all conditions and should not be relied upon as a primary electrode failure detection system. Also, note that the circuit cannot determine open electrode conditions.

2.12 POWER SUPPLY AND PCB LAYOUT

The IC requires a stable, noise-free power supply. A low cost 78L05 class regulator will work fine for virtually all applications, but it should not be shared with devices that can produce transients or erratic loading. Designs should use a regulator specifically for the QT9701B if possible; testing can determine if the regulator might be shared with other circuitry.

The 78L05 should be properly bypassed on its input and output. Its input supply should also be relatively stable and noise-free so as to minimize feedthrough noise components via its pass transistor. A 22 µF tantalum or 100 µF low-Z aluminum capacitor is recommended on the output of the 78L05.

A ground or poured copper plane is highly recommended. Other circuits, including any output driver transistors, should not allow their currents to flow through the sensor's circuit area; grounds should always be led back to a common tie point at the point near the entry of the supply onto the PCB in accordance with customary "sensitive analog" practice.

Sense lead clamp diodes should shunt ESD currents back to earth via the most direct route possible, without traversing the area of the circuitry; ESD return currents should also not share a common ground path with the sensor circuitry. These clamp diodes should shunt as directly to a board mounting hole (or other major ground tie point) as possible. Positive clamped ESD currents are often neglected in designs; they should be shunted via a high quality low inductance bypass capacitor and/or zener back to the same ground tie point.

Component location is relatively unimportant and non-critical, with the above noted exceptions, and the circuit can easily be implemented on a 2-layer PCB.

2.13 ANALOG OUTPUT; SMP LINE

An analog output may optionally be obtained using a sample and hold circuit (Figure 1-2). The QT9701B provides a sample pulse (SMP) which is a positive-drive pulse timed to coincide with a stable portion of the output of the signal amplifier chain.

The sample and hold can be made of a 74HC4066 type switch and a 1nF ceramic capacitor, followed by a CMOS buffer amplifier.

When using a S/H circuit to obtain an analog output, avoid using a quad opamp instead of two separate dual packages. The slew rate and loading of the S/H buffer can produce major disturbances in other opamps on the same die.

The SMP line should never be routed near the Cs sample cap or the amplifier opamp chain, as this pulse can easily superimpose a severe transient on the signal at the exact moment where it should be stable.

3 - SENSOR RESOLUTION

The sensor's overall sensitivity is a function of several factors, including:

1. Total sampler capacitance, Cs + (Cz1 ... Cz4) = Ct
2. Burst length, N
3. Total amplifier gain, Av
4. ADC resolution, bits, n
5. Power supply voltage, Vs

Differential gain at the output of the operational amplifier is determined by:

$$[2] \qquad \frac{N\,Vs\,A_V}{C_T} \qquad \{\text{volts / Cx}\}$$

The ADC resolution is defined in terms of volts per level, resulting in the following overall sensitivity equation:

$$[3] \qquad \text{Sensitivity} = \frac{\text{ADC resolution}}{\text{differential gain}}$$

$$= \frac{V_S\,/\,(2^n - 1)}{N\,V_S\,A_V\,/\,C_T}$$

$$= \frac{C_T}{N\,A_V\,(2^n - 1)} \qquad \{\text{Cx per ADC level}\}$$

Given: Ct = 0.056 µF + 4 x 0.0047 µF = 0.0748 µF
N = 64, Av = 284, n = 8 bits

Then the overall sensitivity is about 16 femtofarads per ADC level. This can easily be adjusted by altering any of three parameters: N, which can be altered in the e^2prom setups, amp gain Av, and total sampler capacitance Ct.

Note that supply voltage Vs conveniently drops out of the equation - thus, the sensor is largely immune to slow changes in supply voltage, although it can be sensitive to transient supply excursions which do not equally affect all aspects of the acquisition process.

4 - OPERATIONAL MODES

4.1 BG, BG/OBJ, AND OBJ MODES

The QT9701B operates in either of two primary calibration modes:

1. 'Normal' mode: sensor makes use of the setting of Detect Threshold. This mode is the factory default setting. Evoking BG in 'normal' mode simply causes a recalibration to occur, that is, the reference point is recentered and with it the threshold level(s). 'Normal' mode *is* BG mode and is referred to as BG mode throughout.
2. 'Learn' mode: The sensor ignores Detect Threshold, and 'learns by example'. There are two variations of 'Learn' mode: BG/OBJ, and OBJ.

Switching modes: These modes can be entered into at will by the use of the BG and OBJ control lines as explained below.

Making the mode permanent: The selected BG, BG/OBJ or OBJ mode can be stored "permanently" into the external

e^2prom if present, but only if Data Locking [F.b] is on. The mode can be changed at any time and is automatically stored again into the e^2prom, overwriting the prior mode. If Data Locking is set to 0 or 9, or if the e^2prom is absent, the unit will always power up in BG mode and perform a full calibration on startup.

4.2 WHEN TO USE EACH MODE

Mode selection depends on the sensing effect desired.

OBJ: Use for detecting objects that generate large signals, and where little processing finesse is required. Evoking OBJ will trigger a “learn by example” and set the threshold automatically, and store that setting into the e^2prom if present. If no e^2prom is present, this mode must be entered and recalibrated after each power up by evoking OBJ.

BG/OBJ: For “learn by example” calibration with continuous background drift compensation. This mode can be thought of as a hybrid between the ‘pure’ BG and OBJ modes. It requires two input commands, one first on the BG line, then one on OBJ. If no e^2prom is present, BG/OBJ must be entered and recalibrated after each power up.

BG: BG mode is designed to allow more advanced processing functions like “prox trap” while also permitting drift compensation. BG only requires a single command to calibrate to the background level, but the threshold level must be set via the e^2prom and cannot be ‘learned’. BG will also permit maximized sensitivity with background reference drift tracking at all times. BG mode will also permit ‘motion’ detection processing, where motion in either direction will cause a detection. OBJ and BG/OBJ cannot provide these more sophisticated functions.

4.2 BG MODE DETAILS

In BG mode the threshold level(s) are taken from Detect Threshold [0], while hysteresis is defined by [1]. There are also some further issues related to Data Locking:

If Data Locking [F.b] is off or e^2prom absent, the unit will power up and perform a background calibration to set its initial reference point; the unit will *always* start out in BG mode if Data Locking is off or the e^2prom is absent.

If Data Locking is on (and e^2prom is present), unit will use stored e^2prom cal settings on powerup and not perform a BG cal. If the BG cal point has changed, it will be necessary to evoke the BG line to recalibrate, or wait until a Max On-Duration expires (if enabled and if a detection is in progress), or wait until drift compensation catches up to the error (if enabled).

Evoking BG if already in BG mode causes a full background recalibration; the unit will remain in BG mode. If Data Locking is on, evoking BG will cause the resulting cal data to be stored for reuse on next powerup.

Evoking BG if in BG/OBJ mode causes a background reference point recalibration, but the prior learned threshold levels will not be altered and BG/OBJ mode will remain in force. See “BG/OBJ Mode Details”, below.

If Data Locking is on, the calibration settings resulting from a prior BG evoke will be stored in the e^2prom for retrieval on any subsequent powerup.

Forcing to BG mode from OBJ mode: Evoking BG if the IC is in OBJ mode will take the IC out of OBJ mode and put it into pure BG mode, triggering a BG recal as well.

Forcing to BG mode from BG/OBJ mode: If IC is in BG/OBJ mode and it is desired to change the mode to “pure BG” mode: evoke the BG line for >1.6 seconds. After the BG line goes high, the STAT line will go “solid high” for ¾ second and the device will then recal. At this point it will be in “pure BG” mode. If STAT does not go “solid high”, the line was not evoked long enough.

4.4 BG/OBJ MODE DETAILS

To enter BG/OBJ mode:

1. Following a powerup, evoke BG when the known background signal level is present (object to be detected is absent). Evoking BG will make the IC recalibrate and finds its new background reference level.
2. Then, with a target signal present (target object placed at the furthest distance of desired detection) evoke OBJ. Unit then learns the correct threshold and sets hysteresis levels according to Select [1] (Hysteresis).

If Data Locking is on (and e^2prom is present), the resulting cal data will be stored for retrieval on any subsequent powerup. Then, when the IC subsequently powers up again it will use the stored e^2prom settings and immediately run with them, without performing a recalibration of any sort.

If the IC is already in BG/OBJ mode, step 1 will not take the unit out of BG/OBJ mode; instead, step 1 will simply cause a recal of the reference point, leaving the differential threshold value from a prior step 2 alone. A subsequent step 2 will then set the new threshold level exactly as might be expected.

If the IC is already in BG/OBJ mode, evoking OBJ thereafter (repeating step 2) will cause the unit to establish a new ‘learn by example’ threshold, while leaving the reference level alone. Thus, once you have entered BG/OBJ mode via the above 2-step process, you do not necessarily have to repeat step 1 to do a threshold recalibration; after evoking OBJ again it will remain in BG/OBJ mode and just properly recalibrate its threshold level.

If the IC is in OBJ mode, it is cleared in step 1; evoking BG when in OBJ mode will always put unit into “pure BG” mode.

BG/OBJ mode can be used only with settings 0, 1, 8, or 9 of Detection Mode [D]. If settings other than these are programmed into the e^2prom in error, the erroneous settings will be ‘moved’ to one of the legal numbers when BG/OBJ mode is entered.

4.5 OBJ MODE DETAILS

OBJ mode is entered by the following process:

If the unit has just powered up and is not in BG/OBJ mode:

- With a target signal present (target placed at the border of desired detection) evoke OBJ. Unit learns the correct threshold from the current signal level and enters OBJ mode.

If the unit has been running and BG had been evoked previously (unit already in either or BG or BG/OBJ mode):

- With a target signal present at the edge of the desired range, evoke OBJ for >1.6 seconds to clear out the BG mode and also to prevent the BG/OBJ mode from being entered. Unit enters OBJ mode and learns the correct threshold level.

If the unit is already in "pure OBJ" mode:

- Evoking OBJ will cause a new detection threshold point to be learned at the current signal level; unit remains in OBJ mode.

If in doubt, evoke OBJ for >1.6 seconds. The STAT line will go "solid high" for about ¾ second and then the device will recal in pure-OBJ mode. If STAT does not go "solid high", the line was not evoked long enough.

The hysteresis value is taken from the value of the Detect Threshold setting, or can be forced to zero hysteresis if Hysteresis setting [1] is set to '3' (0 hysteresis) via the e^{2}prom. If the e^{2}prom is absent, the hysteresis is set to 8 counts of signal.

If hysteresis is too large a value for the signal level, 'sticking' can occur: the sensor will detect an object (usually immediately after evoking OBJ) and not release. If expected signal levels are small, BG/OBJ mode is a better option than pure OBJ because BG/OBJ will set an amount of hysteresis proportionate to the signal level.

OBJ mode has no knowledge of the background reference level, and so cannot drift compensate for background level changes. OBJ sets a rigidly fixed trip point at an absolute signal level.

OBJ will only work with Detection Mode [D] set to 0 or 8. All other settings of [D] are 'truncated' to 0 or 8, whichever is closest in Table 6.1. Setting [D] to 8 can make the sensor respond to departing objects (an "absence detector").

If Data Locking is enabled, the resulting OBJ setting and trip point will be stored in the e^{2}prom for retrieval on subsequent powerup. Then, when the unit powers up it will use the stored e^{2}prom settings and immediately run without recalibrating.

Evoking OBJ mode with only a background level of signal present will usually cause the sensor to stick 'on', and is not advised.

4.6 DATA LOCKING & DRIFT STORE

Data locking allows the sensor to store reference calibration and threshold settings, as well as BG/OBJ and OBJ mode settings. If Data Locking is off (or the e^{2}prom is absent), the IC will forget its prior settings when power is interrupted, including the fact that it might have been in a BG/OBJ or OBJ mode. BG/OBJ and OBJ modes require that fixed information be saved to operate, and so need to be manually restored after each powerup if Locking was not enabled.

Data locking operates seamlessly with BG, BG/OBJ, and OBJ modes; once Data Locking is specified via the e^{2}prom setups nothing else needs to be done. The unit will save all cal data whenever BG or OBJ are evoked or whenever an automatic recalibration (due to a *Max On-duration* timeout, for example) occurs.

Drift Store mode makes the QT9701B periodically save to e^{2}prom the drift compensated reference level, so that if the unit is depowered it will remember its last known reference when next powered up. The *Drift Store* save operation can be specified to occur periodically, from one minute to 10 minutes of spacing. Note that many eeproms have a limited cycle life; this may have an impact on selection of the e^{2}prom update rate or the e^{2}prom type or make used.

The Drift Store operation takes 5 milliseconds to execute and interrupts sensing, but does not occur at all if the reference level has not changed. Thus, even with this mode enabled, in OBJ mode or if *Drift Rate* is set to "off", no e^{2}prom save will ever occur.

Setting setup [F] to '1' allows Data Locking but prevents Drift Store from occurring on a timed basis.

Motion mode disables both Data Locking and timed Drift Store. Motion mode is a purely transient mode.

5 - STAT OUTPUT

The STAT line acts as a multipurpose indicator that shows output state, error conditions, and input feedback. It is designed to drive an LED for meaningful operator feedback, but can also be monitored by a microprocessor. STAT will output as follows depending on sensor state:

Running and not detecting: STAT outputs a positive 10ms pulse at a 10Hz rate (10% duty cycle); on an LED this generates a low, very noticeable flicker.

Running and detecting: STAT outputs a positive 90ms pulse at a 10Hz rate (90% duty cycle); on an LED this generates a bright but flickering output.

When an input line (BG or OBJ) is evoked: STAT is forced low for the duration the input line is held low.

If BG or OBJ are evoked for >2secs: After input release, STAT will go "solid high" for ¾ second before the QT9701B enters the new mode.

While calibrating: STAT will be forced "solid low"; this usually takes well under a second.

If a CHG short to ground is detected: STAT will go "solid high" for the duration of the short.

On a calibration error: STAT will output a repeating error code, provided that Output Error Code [E.a] is 'on':

Single repeating pulse:	**CHG shorted to ground**
Double repeating pulse:	**Excess capacitive load**
Triple repeating pulse:	**Unstable signal, cannot calibrate**

The QT9701B will repeatedly try to recalibrate between each set of 'Morse code' outputs. If [E.a] is off, the recalibration attempts will be much quicker, since the STAT codes are not output.

The repeating STAT code pulses are 250ms in duration with a 250ms dead time between pulses; between coded pulse groups there is a minimum 750ms dead time.

TABLE 6.1 - QT9701B SETUPS

BOLD BOXES DENOTE DEFAULTS WHICH ARE USED IF E^2PROM IS ABSENT

SELECT	DESCRIPTION	SETTING									
		0	1	2	3	4	5	6	7	8	9
0	**Detect Threshold, counts**	62	40	32	25	19	14	11	**8**	6	4
1	**Hysteresis, % of Threshold**	50	**25**	12.5	0	‡	‡				
2	**Reference Offset (hex / decimal)**	0x10 / 16	0x20 / 32	0x40 / 64	0x60 / 96	**0x70 / 112**	0x80 / 128	0xA0 / 160	0xC0 / 192	0xE0 / 224	0xF0 / 240
3	**unused**										
4	**Pulse Width - ns**	200	400	600	800	**1,000**	1,200	1,400			
5	**Burst Length, pulses**	4	8	16	24	32	40	48	56	**64**	‡
6	**Burst Spacing**	200µs	500µs	1ms	**2ms**	5ms	10ms	20ms	50ms	100ms	‡
7	**Randomize Bursts, %**	**off**	12.5%	25%	50%	‡					
8	**Drift Rate, seconds/bit**	off	100	50	20	10	**5**	2	1	0.5	0.2
9	**Median Filter**	off	**on**	‡	‡						
A	**Boxcar Average, length**	off	2	4	8	16	**32**	64	‡		
B	**Detect Integrator, counts**	off	1	2	5	**10**	20	50	100	200	‡
C	**Max On-Duration, seconds**	infinite	100	50	**20**	10	5	2	1	0.5	0.2
D	**Detection Mode**										
D.a	Output on positive signals	**X**	X	X	X	X	X				
D.b	Output on negative signals					X	X	X	X	X	X
D.c	Max On-Duration engages on +/- crossing	**+**	+	+/-	+/-	+/-	+/-	+/-	+/-	-	-
D.d	Drift compensation during detect		X		X		X		X		X
E	**Calibration control**										
E.a	output error code if cal error	off	**on**	off	on	‡					
E.b	recal if ref drifts into boundary	on	**on**	off	off	‡					
F	**Drift Store / Data Locking / Motion**										
F.a	Drift store interval, minutes between saves	**off**	off	1	2	5	10	15	30	60	motion
F.b	Data locking	**off**	on	on	on	on	on	on	on	on	off
G	**unused**										
H	**unused**										
J	**unused**										
L	**Output Stretch, seconds**	**0**	0.1	0.2	0.5	1	2	3	5	7	10
N	**unused**										
P	**unused**										
U	**unused**										

6 - SETUP NOTES

[0] This setting is not used for detection threshold when in BG/OBJ or OBJ mode; OBJ mode makes use of the Detect Threshold table number to define an absolute level of hysteresis. BG/OBJ and OBJ modes use learned thresholds and do not use [0].

[1] Percentages are relative to difference between reference and threshold levels. If set to '3', no hysteresis is used, even in OBJ mode. In OBJ mode the table value of Detect Threshold [0] is used for hysteresis, if Hysteresis is set to 0, 1, or 2.

[2] Reference offset is internally forced to 0x70 if OBJ mode is entered. Numbers are shown in both hexadecimal and decimal.

[3] Unused.

[4] Pulsewidths are digitally synthesized and are within 0.5%.

[5] No onboard 'Conflicts Resolution' is performed. Maximum permissible Burst Lengths vs. pulse widths are:

TABLE 6.2 Permissible Burst Lengths and Randomization - 1000ns pulse width or less

		off	12.5%	25%	50%
Burst Spacing	200 µs	24	-	-	-
	500 µs	64	48	32	24
	1ms & up	64	64	64	64

TABLE 6.3 Permissible Burst Lengths and Randomization - 1200ns and 1400ns pulse widths

		off	12.5%	25%	50%
Burst Spacing	200 µs	16	-	-	-
	500 µs	56	40	24	16
	1ms & up	64	64	64	56

Care should be taken not to exceed the above limits.

[8] Drift is disabled if OBJ mode is selected regardless of this setting. BG/OBJ mode does not, on its own, disable drift.

[9] Median Filter should be disabled at 200 µs burst spacing, otherwise timing errors will occur.

[A] Boxcar Averaging can remain functional even at 200 µs burst spacing, at all settings of averaging.

[C] Max On-Duration is fully functional in BG/OBJ mode but is disabled in OBJ mode.

[D] All Detection Mode settings are usable at all settings of Burst Spacing, even 200 µs.

Detection Mode is forced to one of 0, 1, 8, or 9 in BG/OBJ or OBJ mode. Select one of these settings if using BG/OBJ or OBJ mode. 'Window' thresholds are not possible in BG/OBJ or OBJ.

[E] [E.a]: Outputs an Error Code on 'STAT' if a calibration error, if [E.a] is 'on'.

[E.b]: "*Recalibrate if reference drifts into boundary*", if on, tells sensor to auto recalibrate if the permissible 8-bit signal 'window' has been exceed by the signal reference in either + / - directions. If off, the signal reference will stop drift compensating when a window edge has been reached.

[F] [F.a]: Sensor can store drift and cal parameters into an e^2prom at a timed interval as defined by [F.a]. If e^2prom is absent, default is off.

[F.b]: Sets Data Locking, the ability to remember the last calibration point on cold starts. If e^2prom is absent, default is off.

Setting to '1' will enable Data Locking, but the unit will only store full calibration results, not incremental drift compensation changes on a periodic basis.

Setting to '2' through '8' will do both, storing full calibration results when they occur, and the drift compensated reference level at the timed intervals (in minutes) noted. The store process can take up to 5ms to perform and interrupts the acquisition cycle by that amount of time. If the unit has not sensed any drift in the prior interval, the e^2prom will not be written. The timing interval for saves resynchronizes with each recalibration or powerup event.

Setting to '9' will enable the special 'fast-recalibration' or 'motion' mode, but data store and locking are both disabled.

[L] Output stretch adds the ability to create a 'retriggerable one-shot' output effect.

Setting [L] = 0 turns stretch off. A forced output due to a detected short circuit on CHG will not cause an output stretch.

7 - SETUP PROGRAMMING; CONFLICTS

7.1 SETUPS VIA AN EVAL BOARD

The QT9701B's operating modes can be set by copying an e^{2}prom from a QProx eval board (like the E2S or E97S), and hardwiring the copy to the QT9701B as shown in Figure 1-2. The copy can be created using a commercial PROM duplicator. Not all the settings available on the eval board may apply to the QT9701B, and there may be some settings that the QT9701B uses that are not described in conjunction with the eval board.

Most of these issues relate to operable features and settings at short burst spacings. On the E2S eval board for example, there is a 'conflicts resolution' process that will 'correct' certain combinations of erroneous settings. The E2S does, however, allow the setting of illegal combinations (illegal to the E2S) into its e^{2}prom which can then be copied over to the QT9701B, provided that the E2S does not actually run as a sensor first. On the E2S, the conflicts resolution process only occurs at the time it begins to operate as a sensor, after it has exited the setups mode; while programming the sensor in setups mode it is possible to freely create any desired combination of settings.

The key to transferring setups from the E2S to the QT9701B is to program the E2S to the settings desired for the QT9701B using the E2S's buttons, *not* by using QTWinView, then unpower the E2S before it enters its sense mode.

When reinserting the e^{2}prom back into the E2S be aware that the settings you have programmed may cause problems in the E2S - for example, lack of serial comm port function if [F] is altered; PC software may no longer function if [F] is not reset to its default, manually, using the two buttons.

In general, be sure the e^{2}prom being duplicated contains what you need according to Table 6.1 even if the combination of settings is 'illegal' on the eval board.

7.2 SETUPS VIA PROM PROGRAMMER

It is also possible to use a PROM programmer to enter the setup information for the QT9701B by following the information contained in Section 13.

Note that many programmers fail to automatically recognize the byte mode required of the 93LC46A device; it is very difficult to program this part in 16-bit mode.

Important: Be sure that the combination of settings chosen for the e^{2}prom does not violate the setup restrictions of the QT9701B, particularly in regard to the combination of features (such as randomization) chosen in conjunction with short burst spacings.

8 - FUNCTION DESCRIPTIONS

The following details only differences with the E2S board; for more operation details please refer to the E2S manual as well.

[0]
DETECT THRESHOLD

This is one of 4 items that can affect sensitivity (others are Burst Length, amplifier gain, and under certain conditions Drift Rate). Threshold establishes the 'trip point' above (or below, in the case of negative thresholds) which a detection is determined. During calibration the unit establishes a reference level; deviations from this reference are compared against a level based on the reference plus (and/or minus) Detect Threshold. Setting 9 represents the highest sensitivity since only 4 counts of signal deviation are then required to trip. If negative signal detection is in effect (see Detection Mode), the negative threshold is the mirror image of the positive one (e.g. a setting of '6', value '11', can create a positive threshold at +11 and another at -11 from the reference).

In OBJ mode, the Detect Threshold value may be used instead to create hysteresis, and is not used for threshold purposes; In OBJ mode, the threshold is determined at the time of the button push and is an arbitrary value corresponding to the current signal level at the time OBJ is evoked. See ***OBJ Mode*** section (4.5) for details.

[1]
HYSTERESIS

The sensor has several hysteresis options. In conventional signal detection mode, a hysteresis of 50, 25, or 12.5% of threshold value can be selected, which applies to positive and negative thresholds alike (depending on which are active: see [D], Detection Mode). Thus if Hysteresis is set to 25%, a detection at a signal deviation of +8 will be released only when the signal falls below +6. Hysteresis is only applied after the Detection Integrator has concluded there is a valid detection. If the Detection Integrator function is switched off, no detection will be performed and the Hysteresis setting becomes irrelevant.

In OBJ mode the Hysteresis setting is ignored, unless set to '3' (0 hysteresis); after the OBJ button push the hysteresis is taken from the table value of Detect Threshold, and the signal threshold is obtained from the recording of the actual signal level at that time. See ***OBJ Mode*** section (4.5) for details.

[2]
REFERENCE OFFSET

Reference Offset determines where the sensor establishes a calibration point. The offset numbers are given in Table 6.1 both as hexadecimal ("0x20") and decimal ("32"). Normally, centering the reference at mid-scale of the 8-bit (0 - 255) ADC range is a reasonable location to calibrate to, as this will allow an equal amount of headroom both above and below the reference to accommodate long term drift and signal swings. However, in many situations signal and/or drift swings are largely unilateral, e.g. positive, and so maximum headroom in the positive direction is desired. In this case, Reference Offset might be set to a low number, like 0x10 or 0x20. Conversely, largely negative excursions would indicate a need for a high value of Offset, for example when ‘missing mass’ is being detected (example: detecting gas bubbles or voids in a fluid within a tube or pipe, theft detection, or as a web break detector). Centering the Reference Offset at 0x70 is suitable for most applications.

In OBJ mode the reference offset will be forced to 0x70 (setting 4) when the OBJ button is pushed.

[4]
PULSE WIDTH

The settings are digitally synthesized and can be selected as shown. Pulse Width applies equally to both the charge and transfer times. Alternate pulse widths (for example, below 200ns) can be generated with the help of some low cost, external timing gating circuitry (see Figure 2-1). When using short pulse widths, be careful of inductive lead effects which can cause anomalous behavior (see Section 14).

[5]
BURST LENGTH

Affects the number of QT cycles within a burst (see Section 1.1, Figure 10-1). Bursts occur at a rate determined by Burst Spacing. Burst length can be set from 4 to 64 pulses per burst; the larger burst length is the more sensitive the sensor becomes, in direct proportion, but the less its ability to compensate for and suppress background capacitance loading. Higher Burst Lengths produce more intrinsic averaging for a given desired sensitivity level, and thus can help suppress electrical noise effects, provided the Threshold value is desensitized proportionately to compensate for the increased gain.

At 200 µs and 500 µs this setting may need to be reduced; see Tables 6.2 and 6.3 in Setup Notes. No conflict resolution is performed internally, so erroneous operation in the form of timing errors will occur if the limitations in these tables are violated.

[6]
BURST SPACING

Affects the timing between successive bursts. Longer time equates to lower sample rates, and hence slower response time. At low spacings (200 µs and 500 µs) the burst length may need to be reduced; see Tables 6.2 and 6.3 in Setup Notes, and comments in [5] above. Longer burst spacings are useful in the presence of strong alternating electric fields, for example power line interference, especially in conjunction with Median filtering [9] and Averaging [A] in order to suppress the interference. Longer burst spacings also reduce average emitted RFI and can help with emissions issues, especially when large free-space electrodes are used.

Burst Spacings can also be randomized to skip around interfering noise impulses. See [7] below for more information on this feature.

[7]
RANDOMIZE

Sets the degree to which the Burst Spacing is randomized. Percentages shown in the table are percents of burst spacing time; thus, randomization of 25% at a burst spacing of 1ms will cause bursts to be spaced anywhere from 750µs to 1.25ms apart. Bursts are randomized using a short length psuedo-random number generator. Randomness helps to spectrally spread RF emissions, and reduces the chance of false detections due to correlated electrical noise. Randomization literally 'skips around' repetitive noise and greatly reduces the odds that a long string of acquisition bursts will sample repeatedly on a repetitive noise pulse. The use of Median filtering [9] and Averaging [A] will act to suppress the effects of the remaining corrupted bursts.

Note the limitations on Randomize according to Tables 6.2 and 6.3 in Setup Notes.

[8]
DRIFT RATE

Drift Rate, or perhaps more accurately Drift Compensation Rate, sets the rate at which the sensor’s baseline reference point can track slow ambient changes (drift) in signal level. In many sensing environments the signal will fluctuate due to varying moisture levels, temperature, dirt accumulation, or other uncontrollable variables. Such fluctuations can cause the sensor to lose its calibration point, resulting in the sensor appearing to gain or lose sensitivity, or cause false detections. The drift compensation process operates by permitting the reference level to increment or decrement by 1 count every 'X' seconds in the direction of the signal deviation; 'X' is the setting of Drift Rate.

Drift Rate should be set to as slow (leftwards in the table) a rate as possible; fast drift compensation may cause the sensor to track real objects and thus appear to lose sensitivity.

Drift compensation is usually made to occur only when a detection is not being made; it should normally occur only when detectable objects are not present, otherwise the baseline reference will accumulate an error which can cause problems with future object detections. Detection Mode [D] can be set to either permit or prevent drift compensation during detection events.

Drift is not permitted in OBJ mode and will be disabled when the OBJ button is pushed; see Section 4.5, OBJ Mode Details for further information.

If the reference level drifts into the boundary of the 8-bit signal window, so that [reference level +/- threshold level] exceeds the valid signal range, one of two things can happen:

1. Drift ceases, if "*recalibrate if reference drifts into boundary*" (see [E.b]) is off.
2. The unit performs a recalibration to reset the signal "window", if "*recalibrate if reference drifts into boundary*" [E.b] is on. This automatic recalibration attempts to reset the signal's reference point so that it conforms to the setting of [2], Reference Offset.

Analog Output and Drift Compensation: Since the analog output (if implemented) is split from the sensor prior to signal processing, drift compensation cannot be made to apply to it.

[9]
MEDIAN FILTER

This is a filter that strongly acts to limit electrical impulse noise errors. A median filter selects the median, or center value of an odd group of sample data. The QT9701B's median filter uses 5 pipelined signal samples. Because it takes the center value, impulse induced spurious signals are eliminated from further processing within the signal path, no matter how erroneous. If enabled, this filter is the first digital filter in the signal path.

Median filtering is best explained by showing its effects on a data stream. Given the data set:

105, 101, 93, 99, 223 (where the 'real' signal = 100)

The average if the above set is (105+101+93+99+223) / 5 = 124.2. The median is the center value of the set, or 101, which is a much more accurate representation of the 'real' signal. Because they can be very effective on short data sets, median filters are generally more efficient than linear filters.

The median filter is based on a pipeline of data length 5; after every burst new data is shifted in, the oldest is discarded, and the median of the resulting pipe of data is taken; this ensures the fastest update rate possible, i.e. one update after every QT burst.

Due to timing constraints, median filtering should not be employed at 200µs Burst Spacing.

[A]
BOXCAR AVERAGING

This is a simple linear digital FIR (finite impulse response) filter which follows the median filter. It performs a boxcar average of length 'n'. In general for every doubling of length, noise is suppressed by 3dB or by 0.71 in amplitude. Thus a boxcar of 16 has a noise improvement of about 12dB or a reduction to 0.25 in amplitude. Averaging's downside is a slowdown in response time, which is more evident with a long (slow) Burst Spacings. Averaging compounds with the intrinsic sample averaging which occurs naturally in the sample process, as set by Burst Length. Averaging can be used alone or following the Median Filter, in which case it acts to clean up residual low level noise.

The averager is based on a pipeline of length 'n' (where 'n' is from 2 to 64); after every burst new data is shifted in, the oldest is discarded, and the average of the resulting pipe of data is taken; this ensures the fastest update rate possible, i.e. an one result after every QT burst.

[B] DETECTION INTEGRATOR

This post-detection filter acts to integrate or count the duration of a detection event prior to an actual output. This allows the sensor to suppress large transient events by real objects, as well as noise induced transients; thus, it can supplement the actions of the Median and Boxcar filters.

The DI is implemented as an up/down counter controlled by the threshold comparator. If a detection is in progress, the DI will count up once after every burst in which an event has been detected. When no detection event is in progress, the DI counts down again. If the DI reaches the prescribed count level as defined in the Setups, a 'real' detection is finally assumed and the Out line is activated.

Important Note: If the DI is set to zero, it is disabled and Out cannot turn on, and [C], [D], and [L] have no effect. If set to 1 count, Out activation occurs after a single threshold detect. The DI can also be seen as a continuous-time ‘majority vote’ filter, since over a period of time there needs to be a greater than 50% detection ‘hit’ rate for the DI to reach its count limit.

Setting [B] to ‘off’ is useful to suppress detections for test purposes, or if a sampled analog output path is all that is required.

[C] MAX ON-DURATION

This is a post-detection function that determines how long a detection is permitted to exist before an automatic recalibration is performed.

There are two recalibration methods which can be selected:

1) Default - the sensor performs a full recalibration involving both coarse and fine offsets;
2) Motion - the sensor keeps coarse and fine offsets the same, and merely resets the reference level to whatever the current signal strength happens to be at that moment.

(2) is selected by setting [F] to 9 ('Motion'). All other settings of [F] are slower but safer from the standpoint of establishing a true reference level; although faster to respond, ‘Motion’ [F.9] can lock up the Out line for the duration that the signal strength falls outside the ADC’s 8 bit signal range.

[C] interacts with Detection Mode [D]: [D] can be set to permit Max On-Duration to start timing towards recalibration even if no output is being generated. This can occur if a threshold level is crossed even if that threshold level is set to not activate Out. An example of this is if [D] is set to [D.2]; this setting will cause outputs if the signal exceeds the positive threshold, but though a negative threshold is also established (symmetrically spaced across the Reference level from the positive one) negative signal excursions will not generate an activation of Out; but, with [D.2] negative excursions that fall below the negative threshold will cause Max On-Duration to start to run. The negative threshold appears to act as a ‘phantom threshold’ in this case, and when the [C] counter times out, a recalibration will be performed.

‘Infinite’ setting disables Max On-Duration, and no timeout will occur.

The duration counter is reset to zero any time a detection ceases, or if the signal polarity changes (crosses from + to - or vice versa even if a detection appears to be continuous, for example in a ‘window’ detection threshold mode, e.g. [D.4]).

In OBJ mode Max On-Duration is effectively switched to infinite; the actual setting of [C] is ignored.

Max On-Duration is also fully operable in BG/OBJ mode.

If [B] is set to ‘off’, [C] is ignored; also, if [B] is off, drift compensation will occur continuously at the rate specified by [8].

[D] DETECTION MODE

Defines what constitutes a detection, and determines what happens to some other functions during a detection. [D] can allow the detection of signals that are increasing and/or decreasing; it can also allow Drift Compensation [8] to occur during a detection event or not, and can permit the Max On-Duration timer [C] to run even if no output is generated but a ‘hidden’ threshold level is exceeded.

In particular note the interaction with Drift [8] and Max On-Duration [C] functions; see also the explanations of these interactions in notes for these functions, above.

[D.a]: Output on positive signals - If [D.a] is set to a setting with an 'X' in the box, the sensor will generate an Out activation if the filtered signal rises above the upper threshold level, and [B] is set to [B.1] or higher.

[D.b]: Output on negative signals - If [D.b] is set to a setting with an 'X' in the box, the sensor will generate an Out activation if the filtered signal falls below the lower threshold level, and [B] is set to

[B.1] or higher. Setting to [D.4] or [D.5] will create a detection 'window' that will activate Out if the signal deviates enough from the reference level in either the + or - directions.

[D.c]: Max On-Duration engages on +/- signal crossing - See [C] for further information on Max On-Duration. Boxes denoted by (+) will cause the Max On-Duration timer to count towards a timeout if the signal rises above the positive threshold level. Boxes denoted by (-) will cause the Max On-Duration timer to count towards a timeout if the signal falls below the negative threshold level. The (+) or (-) threshold levels do not necessarily need to generate an activation of Out, and can instead be 'phantom' threshold(s) whose only purpose is to trigger the [C] timer.

[D.d]: Drift compensation during detect - An 'X' in the selected box will cause the drift compensation mechanism of [8] to operate even if a detection is in process. A detection is defined as a crossing of the (+) or (-) thresholds, as enabled in [D.c], (*not* [D.a] or [D.b]) provided also that the Detect Integrator {B] is enabled (set to at least [B.1]). Conversely, if an 'X' is <u>not</u> present in the selected box, Drift Compensation will be disabled during a detection (usually the most desirable mode).

[D.0] is the most common mode associated with prox sensors.

[D.4] and [D.5] are useful for creating a ‘prox trap’ where an object that is in the sense field when the unit calibrates will create a detection no matter whether it is moved closer or further away. A demonstration of this is to set up the sense electrode with an object (like your hand) close by, then let the QT9701B calibrate on it by evoking the BG input. Any movement towards or away from the electrode will cause a detection. The width of the detection window is governed by the sensor’s overall gain (see Burst Length [5]) and the Detect Threshold setting [0]). This type of detection will work in both the BG or BG/OBJ modes, but not OBJ mode.

Note that ‘hidden’ detections can be created that will make the Max On-Duration counter run towards a Max On-Duration recalibration timeout, without generating an actual activation of the Out line. This is useful in clearing a “stuck sensor” condition quickly, for example if a stationary object near the electrode is unexpectedly removed, creating a large, fast, and undesirable negative signal deviation. If set to [D.2] and the unit is in BG or BG/OBJ mode, this negative swing can be made to trigger a full recalibration after the Max On-Duration period has timed out, without causing an actual Out activation.

In OBJ mode: Detection Modes other than [D.0] or [D.8] are ignored; the closest setting, either [D.0] or [D.8], is used instead.

All [D] settings are available at all burst rate settings, without restriction.

[E] CALIBRATION CONTROL

There are two options under Calibration Control:

[E.a]: output error code if calibration error - This controls whether the STAT line will output an error code if during a calibration the sensor detects an error. Since this ‘Morse code’ takes time to output and slows up the QT9701B’s ability to automatically try to recalibrate, it may be desirable to disable this.

[E.b]: recalibrate if reference drifts into boundary - Controls what happens when sensor drift compensation [8] moves the reference level enough so that it runs into the edge of the allowable reference range. If this happens, it may be desirable to recalibrate the sensor completely to achieve a better centering of the signals within the 8-bit signal range. Turning this ‘on’ allows this form of recalibration.

The allowable reference range is that required to accomodate the reference level plus the threshold level(s), (+) and (-), within the 8-bit ADC range. For example, if the threshold is set to 14 counts, and positive detection is enabled via [D.c], then the signal space is limited on the positive side to:

255 - 14 - 1 = 240

The '-1' is required to allow the signal to exceed the threshold by one count for detection purposes.

[F]
DRIFT STORE / DATA LOCKING / MOTION MODE

[F] controls three things:

1. Whether the sensor will store calibration data in e^{2}prom (if installed) for reuse on subsequent power-ups, thus preventing the need for another recalibration;
2. Whether the sensor will also store the reference drift data if Drift Rate is enabled;
3. Whether the sensor processes in ‘motion’ mode, whereby recalibration occurs very quickly but does not involve altering the charge cancellation amount (via Cz's) or the DAC offset value.

[F.a]: Drift store interval - If [F.a] is set to one of the intervals shown, reference drift data will be saved to the e^{2}prom at the intervals shown (in minutes). Note that [F.a] is irrelevant in OBJ mode or if Drift Rate [8] is off. OBJ does not make use of a reference level, and so there is nothing to store.

[F.a]: Motion mode - Motion mode will recalibrate very quickly, in a single cycle, but at an interval defined by [C]. No storage of cal data or drift compensation information occurs if motion mode is enabled.

[F.b]: Data Locking - [F.b] is useful in all modes except 'motion' mode. [F.b] stores the calibration data into e^{2}prom every time there is a full calibration. If [F.a] is enabled, the calibration data from [F.b] will be incrementally updated into the e^{2}prom.

[L]
OUTPUT STRETCH

The output can be made to ‘stretch’ longer than normal using this setup. After a signal detection ceases, the output can be prolonged by the number of seconds indicated in Table 6.1. Setting to zero prevents stretch entirely and lets the output behave normally. Note also that settings of Detection Integrator [B] can also make outputs appear to stretch, but [B] also causes a delay in the *onset* of output activation as well.

‘Stretch’ has no effect on activations made due to a detected short circuit on CHG.

9 - SIGNAL PROCESSING

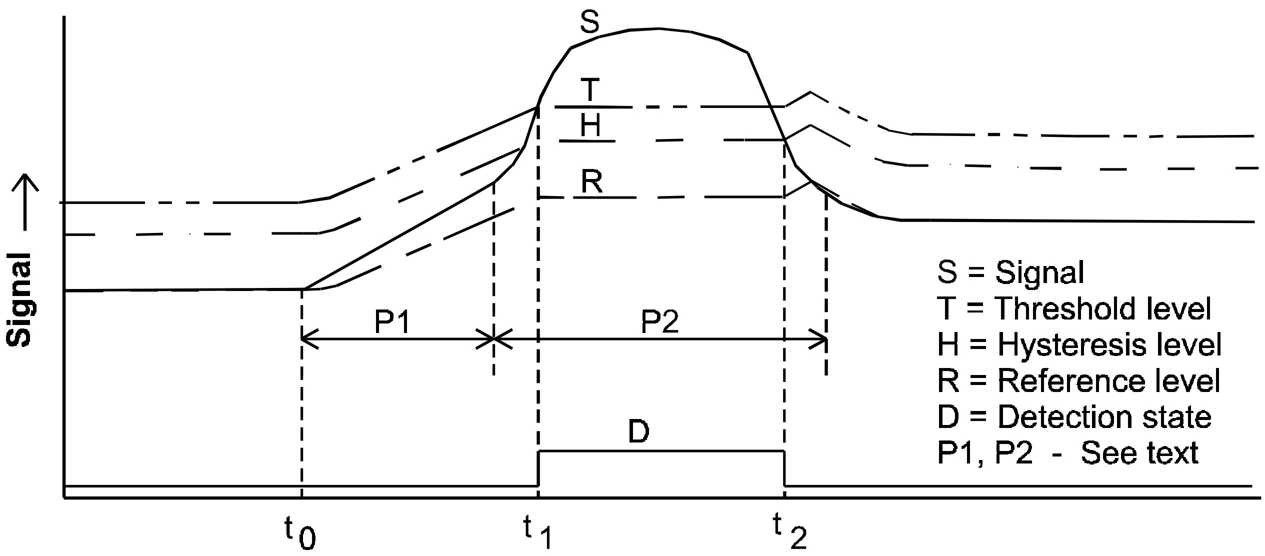
9.1 DRIFT COMPENSATION AND DETECTION

Figure 9-1 shows how the reference level, thresholds and hysteresis interact with the drift compensation mechanism. Prior to time t0, the sensor is shown as being quiescent; Reference and Signal have the same value. During interval P1 the signal begins to rise slowly, perhaps due to environmental factors or a slow moving inbound object; the reference level 'drift compensates' upwards at the selected rate limit to try and track the slow Signal changes. Because threshold 'T' is tied to 'R', no detection occurs yet since 'T' also rises. Then, during interval P2 an object enters the field rapidly and causes the signal to rise much faster than can be compensated for by 'drift compensation'; at time t1 a detection event 'D' occurs.

'S' falls as the object recedes, and the signal finally drops through the hysteresis level 'H' at time t2, causing 'D' to cease. The reference level once again tries to keep up with changes in the signal, even spiking upwards briefly while the signal is still higher than the 'real' background level.

Negative signal swings and negative threshold work in exactly the same manner and are simply the mirror image of the diagram shown.

Figure 9-1 Drift Compensation and Threshold Detection



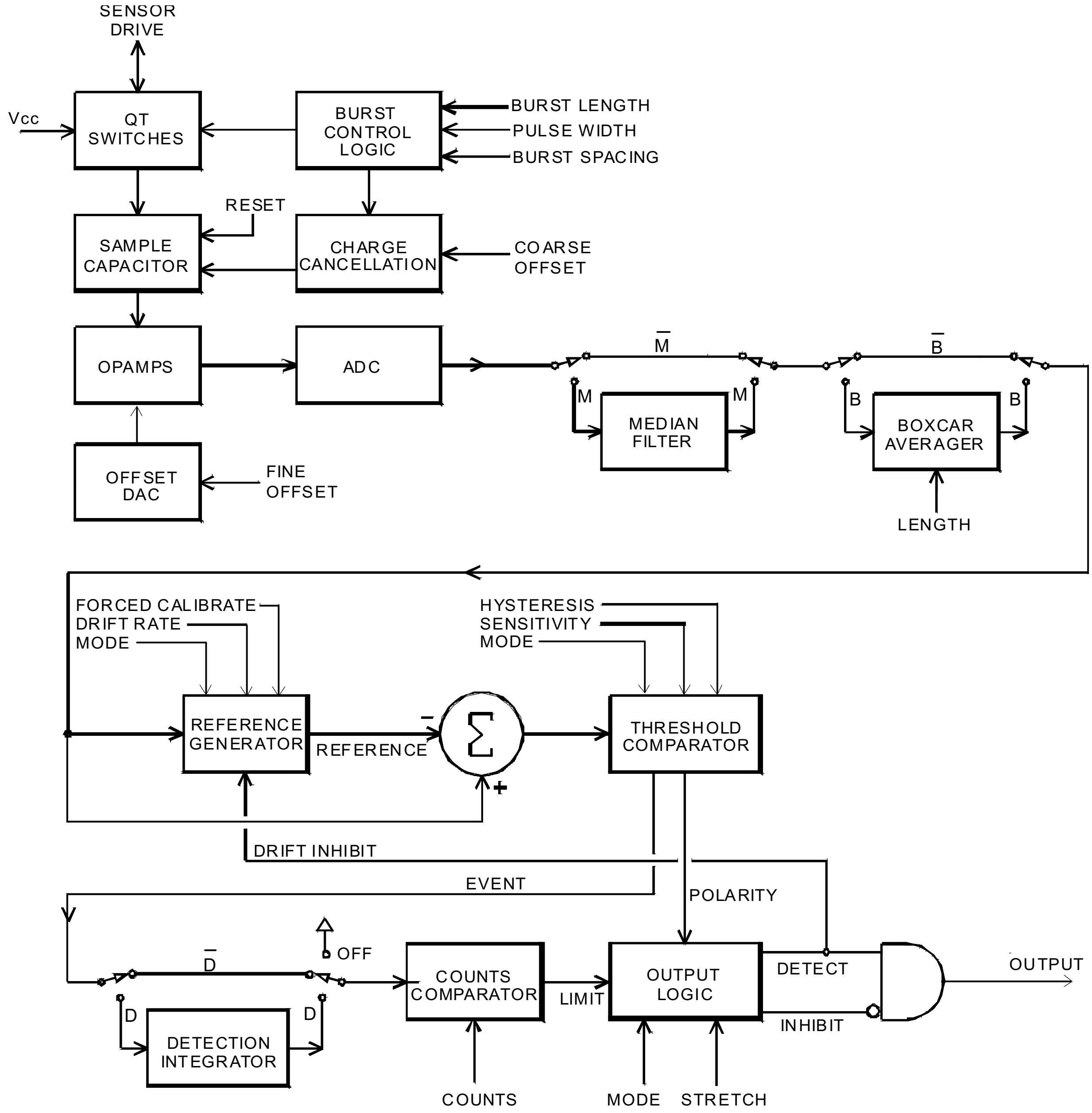
9.2 SIGNAL FLOW

Figure 9-2 shows the overall signal flow diagram, including both hardware and signal processing elements.

Most blocks shown are incorporated inside the QT9701B, except for the n-mosfet transfer switch, charge cancellation caps, charge sampler cap, amplifier, and offset DAC. Note that the output is not necessarily activated upon detection; various modes may intentionally inhibit the output, while internal processing continues.

Of particular note is the summing junction S used to form the difference signal. The reference generator is an algorithmic block which can allow reference 'drift' or forcible recalibration to reset the reference; reference drift compensation is usually inhibited by a detection event.

Figure 9-2 Signal Flow



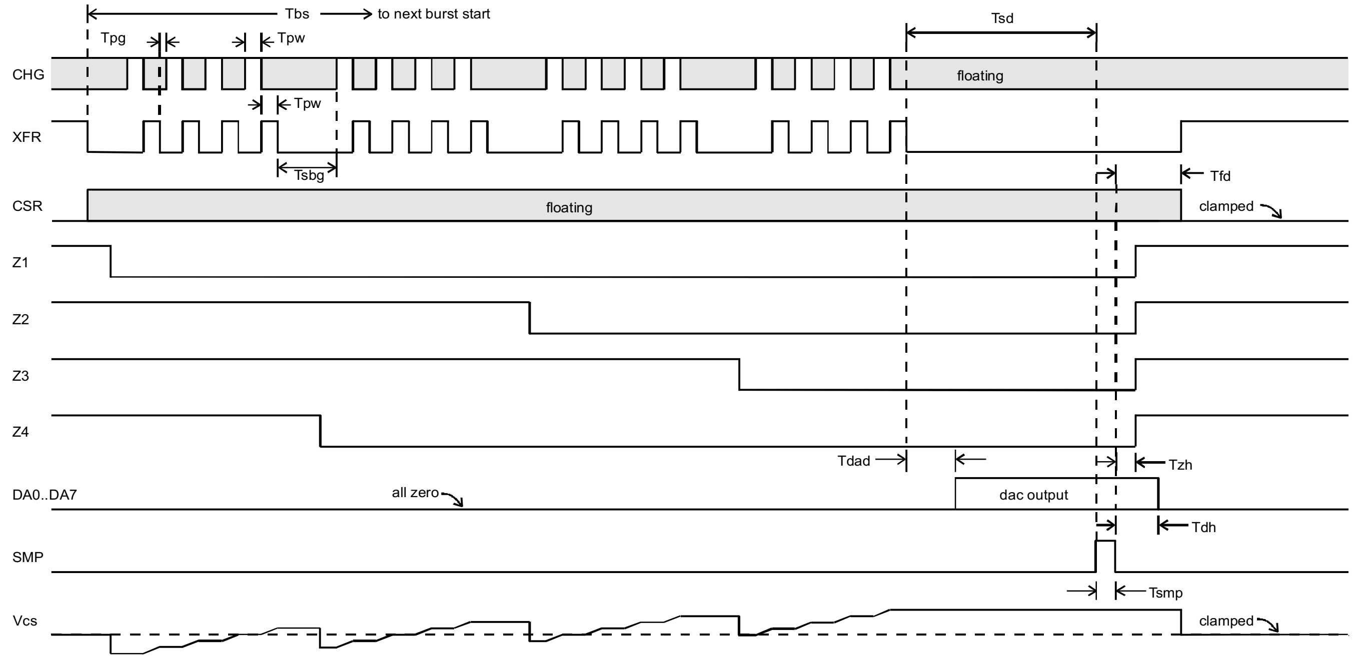
10.1 ABSOLUTE MAXIMUM SPECIFICATIONS

Operating temp	as designated by suffix
Storage temp	-55°C to +125°C
VDD	-0.5 to +7.0 V
Max continuous pin current, any control or drive pin	±25mA
Short circuit duration to ground, CHG line	infinite
Short circuit duration to VDD, CHG line	infinite
Short circuit duration to ground, any other pin	5 secs
Voltage forced onto any control or drive pin	-0.6V to (Vdd + 0.6) Volts

10.2 RECOMMENDED OPERATING CONDITIONS

VDD	5.0 ±0.2V
Supply ripple+noise	5mV p-p
Load capacitance	0 to 1,000pF
R2R dac value	100K ohms
Cz values	7% of (Cs + Cz), max, each Cz, if used
Cs value	22nF to 100nF

FIGURE 10-1 TIMING DIAGRAM



10.3 AC SPECIFICATIONS Fosc = 20MHz, Vdd = 5.0, TA = recommended operating range

Parameter	Description	Min	Typ	Max	Units	Notes
Fosc	Oscillator frequency	0		20	MHz	Crystal, resonator, or external source
Fduty	Oscillator duty cycle	45		55	%	
Tpw	Pulse width	200		1,400	ns	Selectable; see Table 6.1
Tbs	Burst spacing interval	0.2		100	ms	Selectable; see Table 6.1
Tpg	Pulse gap	200		1,600	ns	Tpw dependent; see table 10.4
Tsbg	Sub-burst interpulse gap	5.6		10.4	µs	Tpw dependent; see table 10.4
Tsd	Burst end to sample delay		19		µs	
Tdad	DAC output delay		2.4		µs	
Tsmp	Sample pulse width		4.6		µs	
Tdh	DAC hold time	600			ns	
Tzh	Zx hold time	400			ns	
Tfd	CSR/XFR float delay	2.8			µs	
Br	Burst randomization			± 50	%	% of Tbs, burst spacing interval
Temin	BG/OBJ evoke duration	Tbs		1.4	s	Normal recalibration function only
Teforce	BG/OBJ mode change	1.6			s	Forced mode change

Note 1: Timings shown assume burst length = 16. There are always 4 sub-bursts within a burst; as burst length increases, the number of QT cycles in all sub-bursts increases equally.

Note 2: Charge cancellation lines Z1..Z4 are sequenced as shown when all four are required. When only one is required, only Z1 transitions; when 2 are required, Z1 and Z2 transition; when 3 are required, Z1, Z2, and Z3 transition. Non-transitioning Zx lines always remain high. Points of possible transition for each Zx line are fixed as shown.

10.4 BURST TIMING VS. TPW

Parameter	Tpw							Units	Notes
	200ns	400ns	600ns	800ns	1000ns	1200ns	1400ns		
Tpg	1600	1000	800	200	200	200	200	ns	
Tsbg	10.4	10.0	9.0	8.0	7.2	6.4	5.6	µs	

10.5 SIGNAL PROCESSING

Description	Min	Max	Units	Notes
Threshold differential	4	62	counts	Note 1, 2
Hysteresis	0	50	%	Note 1
Median filter length	-	5	samples	Note 3; pipelined
Boxcar filter length	2	64	samples	Note 1, 3; pipelined
Burst randomization, % of burst spacing	±12.5	±50	%	Note 1, 3; See also tables 6.2, 6.3
Drift compensation rate	100	0.2	secs/level	Note 1, 3
Post-detection integrator length	2	200	counts	Note 1, 3
Post-detection recalibration timer duration	0.2	100	secs	Note 1, 3
Pulse stretch duration	0.1	10	secs	Note 1, 3
Drift cal store to e^{2}prom interval	1	60	mins	Note 1, 3

Note 1: For possible presets see Table 6.1

Note 2: Value can be made arbitrary in BG/OBJ or OBJ learn modes.

Note 3: This feature can be disabled.

10.6 DC SPECIFICATIONS 20MHz, Vdd = 5V, T_A = recommended range, unless otherwise noted

Parameter	Description	Min	Typ	Max	Units	Notes
V_{DD}	Supply voltage	4.5	5	5.5	V	
I_{DD}	Supply current		10	20	mA	
V_{DDS}	Supply turn-on slope	70			V/s	Required for proper startup
V_{IL}	Low input logic level			0.8	V	BG, OBJ, XT1, DA0, DA1, DA2
V_{HL}	High input logic level	4.4			V	BG, OBJ, XT1, DA0, DA1, DA2
V_{OL}	Low output voltage			0.15	V	OUT, STAT, ECS, DA0 - DA7 (Note 1)
V_{OH}	High output voltage	Vdd-0.15			V	OUT, STAT, ECS, DA0 - DA7 (Note 1)
V_{AIN}	AIN input range	0		Vdd	V	
I_{OUT}	OUT, STAT pin current			50	µA	Recommended limit, source or sink
I_{DAC}	DAC pin currents			100	µA	Recommended limit, source or sink
I_{IL}	Input leakage current			±1	µA	
R_{CHG}	CHG source resistance		65		Ω	$0 \le I_{CHG} \le 10$mA
R_{CS}	CHG short resistance	15	35		Ω	Note 2
I_{CHG}	CHG limiting current		36		mA	$V_{CHG} = 0$
C_X	Load capacitance range	0		1,000	pF	
I_X	Load shunt conductance	0		250	µA	Conductance across Cx
C_{ZMAX}	Cz limit			0.02	µF	Per Cz
C_{SMAX}	Cs limit			0.2	µF	
A_R	Acquisition resolution			8	bits	
A_L	Acquisition linearity			±1	lsb	
Av	Amp gain, recommended		284		V/V	Note 3
S[1]	Sensitivity - digital path		16		fF/lsb	Note 3
S[2]	Sensitivity - analog output		0.82		fF/mV	Note 3

Note 1: Sourcing or sinking 1mA current
Note 2: Resistance to ground on CHG that can be automatically detected as a short
Note 3: Using circuit of figure 11-1
All specifications subject to improvement.

10.7 - GAIN CHART

Gains computed at Vcc = 5.0, circuit of Figure 11-1 for both High Amp Gain and Low Amp Gain, but Low Amp Gain with Av = +16.93 (first gain-stage only of Figure 11-1 circuit). An Excel spreadsheet program which allows easy recalculation of gains with component changes, Gaincalc.xls, can be found on the Quantum website at http://www.qprox.com/users.htm.

HIGH AMP GAIN

	In order of descending burst length								
	64	56	48	40	32	24	16	8	4
pF / V	0.823	0.941	1.097	1.317	1.65	2.19	3.29	6.58	13.17
V / pF	1.22	1.06	0.91	0.76	0.608	0.456	0.304	0.152	0.076
fF / bit	16.1	18.4	21.5	25.8	32.3	43.0	64.6	129.1	258.2
% of Full Gain	100.00%	87.50%	75.00%	62.50%	50.00%	37.50%	25.00%	12.50%	6.25%

LOW AMP GAIN

	In order of descending burst length								
	64	56	48	40	32	24	16	8	4
pF / V	13.80	15.78	18.41	22.09	27.61	36.81	55.22	110.44	220.9
mV / pF	72.4	63.4	54.3	45.3	36.2	27.2	18.1	9.1	4.5
fF / bit	271	309	361	433	541	722	1083	2165	4331
% of Full Gain	5.96%	5.22%	4.47%	3.73%	2.98%	2.24%	1.49%	0.75%	0.37%

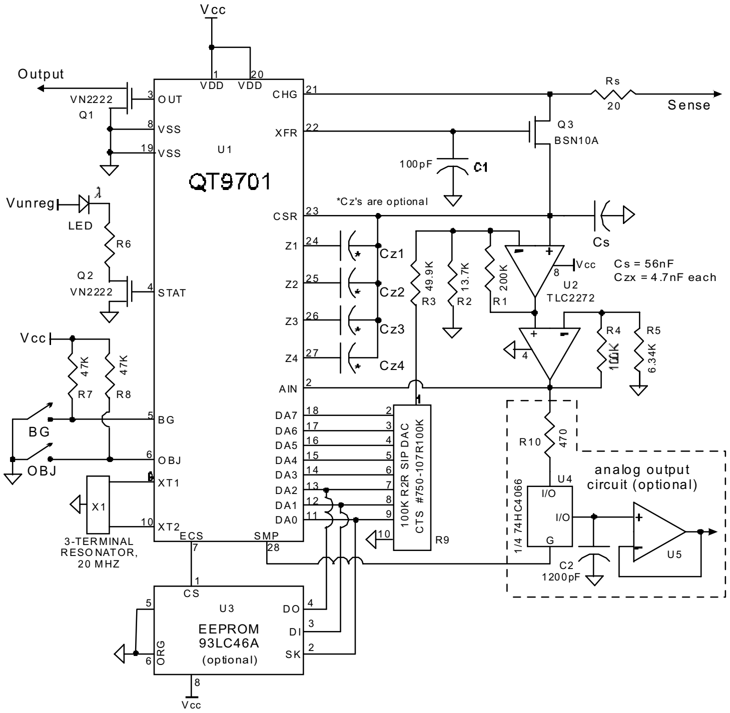


FIGURE 11-1

Full circuit - 0.016pF resolution

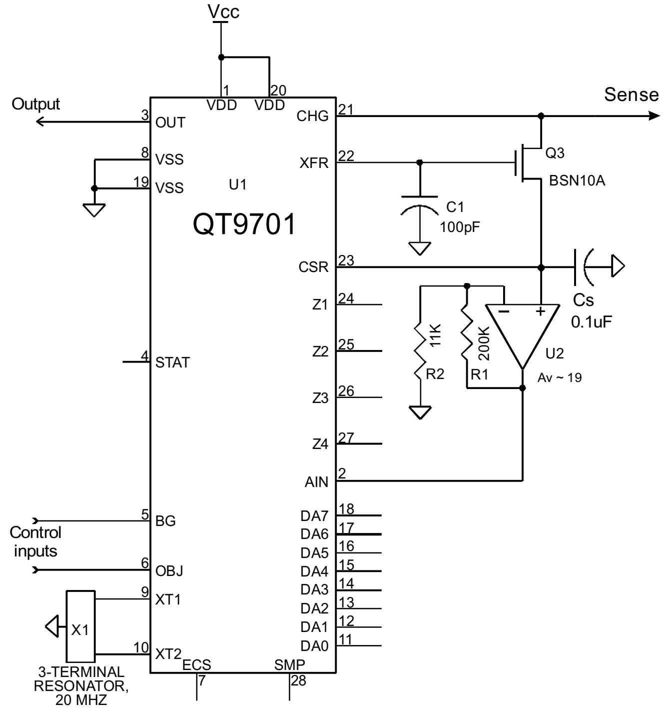


FIGURE 11-2

Low gain minimal circuit - 0.32pF resolution

11 - ESD NETWORK

The network of fig. 11.3 is suggested to shunt ESD currents without significantly loading the sense lead with unwanted parasitic capacitance. Care should be taken that the sense lead does not overshoot or ring during QT pulses, causing conduction into one of the two clamp diodes; such conduction currents can lead to a marked drop in QT efficiency, and can also cause a strong thermal dependency due to the thermal coefficients of the diodes. These effects are most pronounced when the ringing occurs at the transfer edge, i.e. when Q3 turns on from the leading edge of XFR. Raising the two 22 ohm resistors will damp resonances while simultaneously increasing ESD protection. Resonances can also be reduced by making the sense wire short, running the sense wire through coaxial cable, or running the sense wire along a grounded metal plane such as a piece of sheet metal.

The presence of ringing can be tested for without an oscilloscope by simply heating one of the clamp diodes and watching the analog signal level. If no ringing-induced diode clamping is occurring, the signal will suffer only negligible drift.

The two diodes and zener should be placed very close to the sense lead, and physically configured so that the diode clamping currents return to earth ground without traversing the remaining portion of the PCB. This calls for a robust, very direct chassis ground connection near the sense lead connection, and <u>all</u> other ground-referenced connections including power and control I/O lines coming from the same side of the PCB as the sense lead. Where this is not possible, the return ground path for ESD currents should be made very heavy and be routed away from the remaining sensor circuitry via an independent path back to the nearest chassis connection.

ESD can also be controlled by limiting access to the sense electrode, for example by covering the electrode with plastic or placing it behind a nonconductive surface.

Note that the resistors in the ESD circuit can adversely affect the CHG short circuit detection feature by limiting current flow out of CHG.

Ferrite beads: Ferrite beads and similar lossy inductors can sometimes be used to slow the edges of the QT pulses while simultaneously slowing ESD transients. Great care should be taken to ensure that the resulting circuit is properly damped to eliminate ringing for the above mentioned reasons. Additional damping can be had by further increasing series resistance.

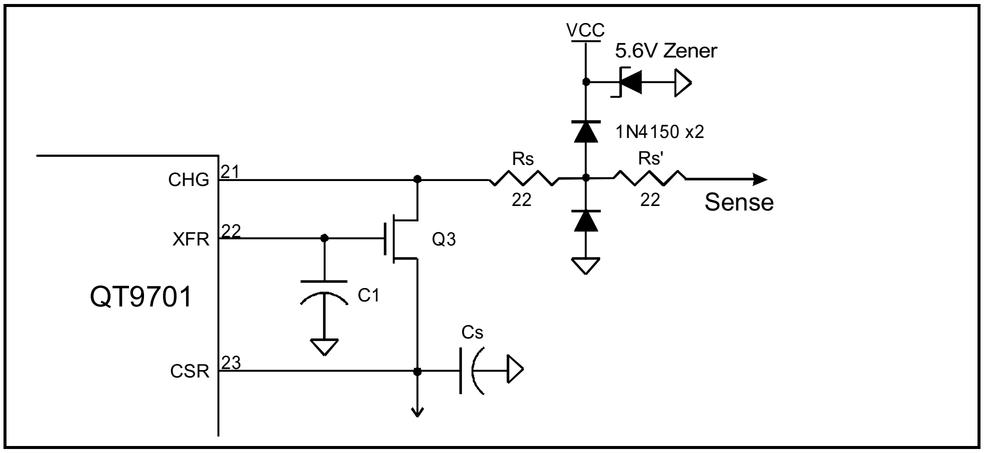


FIGURE 11-3 Recommended ESD Protection Network

12 - CUSTOMIZATION

The QT9701B can be mask-customized for various applications to suit. For example, more specific timing and signal processing parameters may be incorporated, or the defaults can be altered so as to eliminate the need for an external e^2prom. If customized defaults are used, they can still be overridden by means of an external e^2prom in case requirements change.

It is also possible to incorporate entirely new features into the device for a specific application. Consult Quantum for further details on customization options.

13 - 93LC46A SERIAL E^{2}PROM CONTENTS

Note that the Microchip 93LC46A uses byte-mode boundary addressing. Many prom programmers will refuse to recognize this structure and will default to word (16 bit) mode. Consult your prom programmer manufacturer for details or upgrade requirements.

Address	**Select item**	**Parameter**	**Valid range (decimal)**	**Comments**
0	0	sensitivity	0..9	
1	1	hysteresis	0..3	
2	2	reference offset	0..9	
3	3	unused	-	
4	4	pulse width	0..8	
5	5	burst length	0..8	
6	6	burst spacing	0..8	
7	7	randomization	0..3	
8	8	drift rate	0..9	
9	9	median filter	0..1	
10	A	boxcar averaging	0..6	
11	B	detect integrator	0..8	
12	C	max on-duration	0..9	
13	D	detection mode	0..9	
14	E	calibration control	0..3	
15	F	drift store / data locking	0..9	
16	G	unused	-	
17	H	unused	-	
18	J	unused	-	
19	L	output stretch	0..9	
20	N	unused	-	
21	P	unused	-	
22	U	unused	-	
23	-	Cz store	0..4	cal store for Cz charge cancellation capacitors
24	-	offset store	0..255	cal store for R2R DAC
25	-	reference store	0..255	cal store for reference, incl. periodic [F.a] store
26	-	threshold store	0..255	for (+) threshold only; (-) threshold is a lookup
27	-	unused	-	
28	-	mode flags	0..255	see chart below
29	-	check byte	85..89	must be 85 (0x55 - 0x59 hex) for e^{2}prom to be recognized

Mode Flag Bits

Bit	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**0**
Function	*	-	*	*	*	*bg	bgobj	obj

\- Unused
* Bits used for internal processing; the state of these are ignored, even though written
Note: All process flags are all ignored on powerup if 'data locking' [F.b] is off
e^{2}prom is read only once on power up;e^{2}prom will be reread and a recalibration induced if pin 1 is held low for 10us minimum.

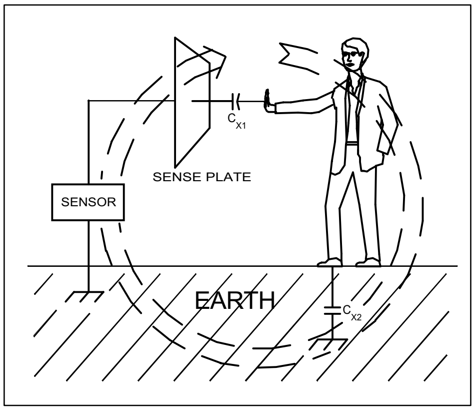
Flag bits:

	obj	1 = unit in 'pure' obj mode
	bgobj	1 = unit in 'bgobj' mode
	bg	1 = unit in bg mode (stored to e^{2}prom but not read back)

Notes: if obj & bgobj are both 0, unit is presumed to be in pure 'bg' mode
If any e^{2}prom location between address 0 and 21 is out of a 0..9 bound, or if the check byte (address 28) is not 0x55, the e^{2}prom is ignored and default settings are used instead.

14 - USAGE NOTES

Earth Grounding; Kirchoff's Current Law



In open plate sensing situations (e.g. human prox detection) where an earth ground is relied upon, and if the sense element has a large background Cx, a good earth connection is imperative. Short, heavy wiring is called for especially to the ground connection.

Remember that as in all capacitive sensing, Kirchoff's current law applies, meaning that the electrostatic field flows must return as currents via a conductive path. In all cases, this is a ground return path. Long, inductive or resistive return paths will reduce efficiency of operation and can cause anomalous operation due to inductive ringing and settling time problems. In closed-cell sensing (e.g. within a transducer) the ground return path is immediately adjacent to the emitting electrode, and problems rarely arise.

While experimenting, an oscilloscope is invaluable in detecting adverse ground and signal ringing.

See below for additional comments on signal ringing.

Sense Wire and Signal Ringing

Ordinary wire can be used to connect the QT9701B to the electrode. However, this will make for an inductive connection which can adversely affect performance, especially if the wire is long, the capacitive load is high, and short QT pulses are used. In practice 3-4 meters of unshielded wire works fine with long pulses assuming a decent ground connection is made and total load is under a few hundred pF. Keep in mind that unshielded wire itself is a sensor, and that any motion around the wire can cause a detection. A simple wire can *intentionally* be the sense element, for example to implement a ‘touch strip’ embedded within a wall (to replace a light switch for example).

If inductive ringing effects are found to be large even with long pulses (1.0us - 1.4us), a series resistor can be installed to dampen ringing. The resistor should not be too large; if possible allow at least 8 timeconstants to expire during both the charge and transfer phases of a QT cycle, as measured with a scope; 11 timeconstants are preferable.

Electrode Stability

Mechanical stability is an important issue. With an electrode having a large value of intrinsic ‘Cx’, say 1,000pF, and a desired sensitivity of 0.1pF, any slight motion of the electrode can generate far in excess of 0.1pF. The electronics may get blamed for being ‘unreliable’ when in fact the stability of the sense surface is to blame: a mechanical shift resulting in only 0.01% change in Cx will cause a detection! Thermal expansion alone can cause this with only a fraction of a degree. Be sure the electrode is solid, especially when used at high sensitivity, before looking for other factors. In some cases you may need to scale down your objectives for sensitivity, look at using a different operating mode, or use a higher *Drift Rate* [8] setting.

Isolation

Make sure the electrode is electrically isolated from surrounding metal surfaces or any earth ground. While this will not damage the sensor, it will prevent it from functioning and will cause an error code during self-calibration. Conductance to ground can affect readings, but less so in short pulse mode. Considerable conductance to ground can often be tolerated if stable enough or if overall sensitivity requirements are not high. Each application is different, and experimentation is often required.

Sensitivity

Capacitive proximity relies on opposing surface areas to operate; the larger the areas the more sensitivity can be achieved; as such QProx and the QT effect obey the laws of physics which dictate a 1/r relationship between distance and capacitance. If only touch sensing is required, sensitivity can be set low and surface area is not a great concern. Experimentation may be called for to determine the proper size of the electrode.

Adjacent surfaces of grounded metal will decrease sensing range, since the metal will tend to bend the emitted field lines back and thus reduce the field intensity. On the other hand, a non-conductive surface to which an electrode is bonded will tend to enhance range, as the material will conduct the field laterally and then emit it from a larger 'virtual surface' area.

Long vs. Short Pulses - Moisture Suppression, Interference Effects

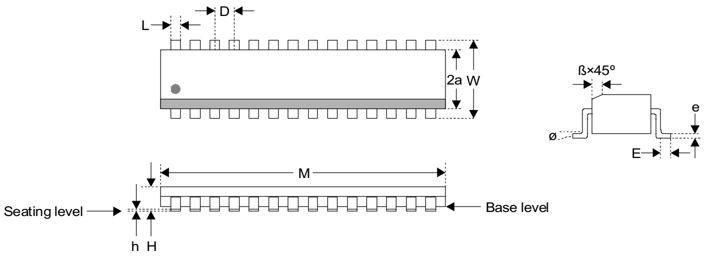
Use longer QT pulses unless you have a compulsory need for a shorter pulse. Among other reasons, use shorter pulses (<500ns) when you have a wet environment and desire to suppress the detection of ionic films, for example from water. Short pulses do not completely eliminate moisture detection; they do suppress it greatly over longer pulses, however. Shorter pulses can also assist in reducing electrical noise effects, as the sensor's 'window time' is made narrower. The duration of transfer switch S2 can be thought of as a 'window of exposure', an opportunity for stray electric fields to inject themselves into the sample cap Cs; the shorter S2's duration of closure the less signal interference is likely.

With longer pulse lengths, interference effects can be reduced by adding series resistance to the sense lead, thus forming a low-pass filter composed of Cs and the added resistance.

Electrode Load Limits

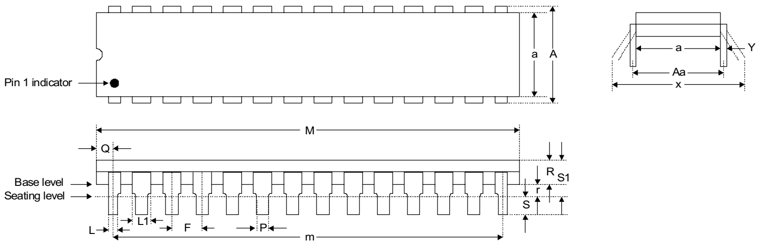
If the electrode is too large or too close to a grounded surface the sensor may saturate and be unable to cancel the acquired charge. If the sensor does not calibrate due to excess load, reduce the *Burst Length* [5] parameter. If loading is a factor, you should also consider using longer pulse widths (1.0 to 1.4us) to reduce the effects of wiring inductances and to improve settling. With shorter pulses, higher loads are less tolerated due also to the finite resistance of the mosfet switches, which may become unable to fully transfer the charge to and from the load; high loads will also exacerbate inductively induced ringing problems unless damped.

15 - PACKAGE OUTLINE - QT9701B-S



Package type: 28-pin SOIC						
SYMBOL	Millimeters			Inches		
	Min	Max	Notes	Min	Max	Notes
M	17.703	18.085		0.697	0.712	
W	10.007	10.643		0.394	0.419	
2a	7.416	7.595		0.292	0.299	
H	2.362	2.642		0.093	0.104	
h	0.101	0.3		0.004	0.012	
D	1.27	1.27	BSC	0.050	0.05	BSC
L	0.355	0.483		0.014	0.019	
E	0.406	1.143		0.016	0.045	
e	0.241	0.318		0.009	0.013	
ß	0.381	0.762		0.015	0.03	
Ø	0°	8°		0°	8°	

16 - PACKAGE OUTLINE - QT9701B-D



Package type: 28pin Dual-In-Line						
SYMBOL	Millimeters			Inches		
	Min	Max	Notes	Min	Max	Notes
a	7.112	7.493		0.28	0.295	
A	7.874	8.382		0.31	0.33	
M	34.163	35.179		1.385	1.395	
m	33.02	33.02	BSC	1.3	1.3	BSC
Q	0.584	1.22		0.023	0.048	
P	0.406	0.559		0.016	0.022	
L	0.203	0.508	4 places	0.008	0.02	4 places
L1	1.016	1.651	Typical	0.04	0.065	Typical
F	2.54	2.54	BSC	0.1	0.1	BSC
R	3.175	3.556		0.125	0.14	
r	0.381	-		0.015	-	
S	3.175	3.683		0.125	0.145	
S1	3.632	3.632		0.143	0.18	
Aa	7.874	7.874		0.31	0.31	
x	8.128	9.906		0.32	0.39	
Y	0.203	0.203	Typical	0.008	0.013	Typical

17 - PCB LAYOUTS FOR E9701 EVAL BOARD

Note: This board is no longer in production; artwork is provided here for archival reference only. Please use the E97S board to evaluate the functionality of the QT9701B via the QT9701B2 superset.

Figure 17-1 Silk screen layer

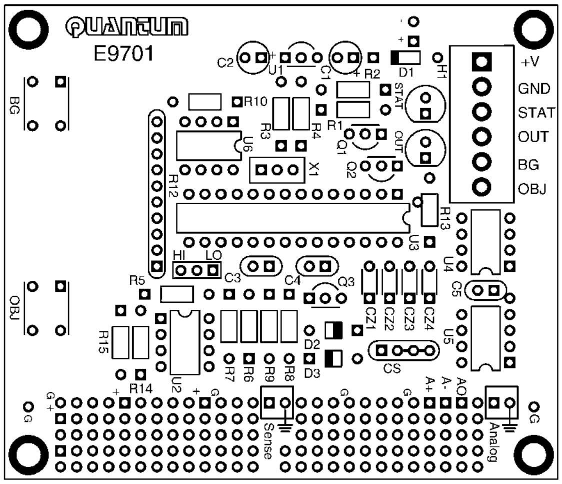


Figure 17-2 Component Layer

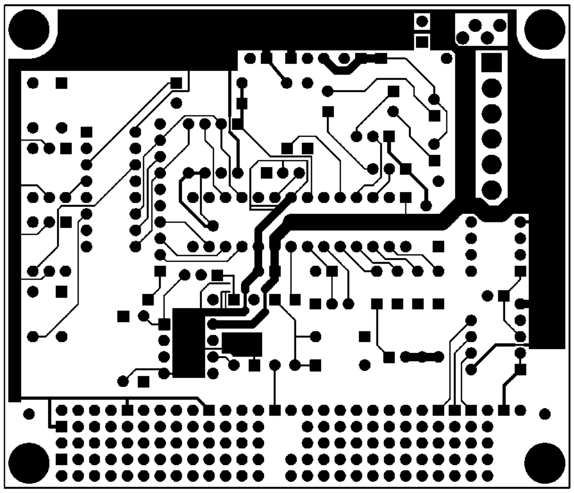
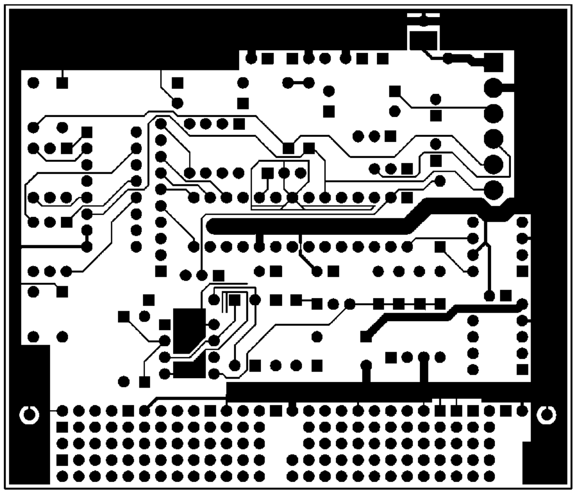


Figure 17-3 Solder Layer



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