QProx™ QTM1001AS

User Guide

QUANTUM

RESEARCH GROUP LTD

NOTICE: Use of this device for use any health or safety related application must be approved by an officer of the company in writing.

QUANTUM

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QUICK START

The QTM1001AS is pre-loaded with setups that make it easy to get started in one of two modes:

Basic BG mode (preset sensitivity):

1. Connect the QTM to a power source and a metal electrode via the connector. See output circuitry and connector pin list, next pages 5.

2. With power switched on and no object near the electrode (but it can be attached to a nonmetallic surface of your choice), press the button labeled 'BG' for at least 1.6 seconds and let go. After you let go the LED should glow solid for ¾ second and then flicker dimly.

Place your hand or an object near the electrode; the LED should flicker brightly when a detection is being made.

Basic OBJ mode (learn by example):

1. Connect the QTM to a power source and a metal electrode via the connector. See output circuitry and connector pin list, next pages5.

2. Place an object (or your hand) near the sense electrode at the point where you want the sensor to detect the object. Press the button labeled 'OBJ' for at least 1.6 seconds and let go. After you let go the LED should glow solid for ¾ second and then either flicker dimly or brightly (if not, push OBJ longer).

Take the object (or your hand) away. Now, whenever the object is restored to the position at which the calibration was made, it will sense it.

NOTE: If the LED stays on bright even when you remove the object, there was not enough signal to overcome the effects of hysteresis. This can be corrected by changing the hysteresis in the setups, or by simply moving the object closer to the electrode at the time the OBJ button is pressed.

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These two basic modes are the easiest to use. Also, the sensor is preset to remember the calibration settings obtained when the BG or OBJ button is pressed, even after power is lost; you do not need to recalibrate the sensor each time it powers up.

The QTM is capable of many, many other modes of operation; the above two are among the simplest and easiest to use.

OUTPUT CIRCUITRY

For a complete connector pin list, see next6.
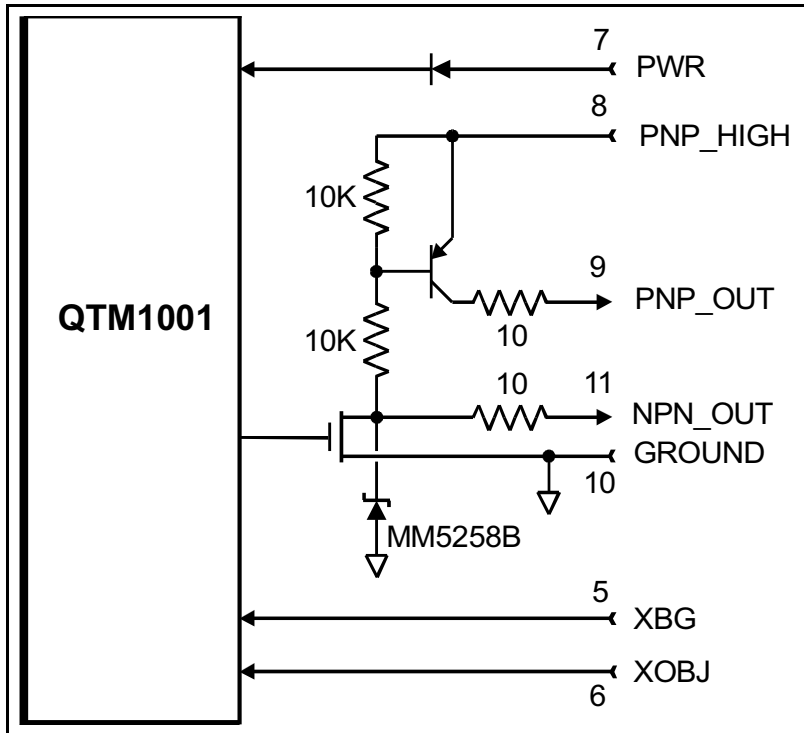
The QTM has simultaneous PNP and NPN outputs; the PNP high voltage (pin 8) is usually strapped to Power (pin 7), but in some cases, for example for logic level compatibility, it may be desirable to strap it to +5 or some other voltage.

While an external pullup can be used on NPN_OUT, the two 10K resistors can be used to make an internal pullup instead, thus saving an external part. Due to the clamping action of the emitter-base junction of the PNP, the pullup resistance is effectively much closer to 10K than to the sum of the two resistors, 20K.

Warning: Both PNP and NPN outputs have 10 ohm series resistances to provide some current limiting. But, the outputs are NOT rated for short circuit conditions and irreparable damage can be done by, for example, momentarily shorting PNP_OUT to ground or tying NPN_OUT directly to PWR.

The module has an internal series diode to prevent internal damage due to power reversal.

XBG and XOBJ mirror the two pushbuttons, and will work from +3 to +20 volts; they are "active high", that is, a high voltage will be the same as pushing the corresponding button. XBG and XOBJ should never be high at the same time. XBG and XOBJ can be fed from logic levels, especially from CMOS logic, or from relay contacts. If fed from TTL logic levels a pullup resistor of 1K to 4.7K connected from the control line to a +5 supply should be used to make sure the TTL level rises above +3 volts.

XBG and XOBJ can be activated by 100ms or longer pulses. In certain cases, for example when switching from BG/OBJ mode to BG mode, these lines should be held high for at least 1.6 seconds.

The 36V zener diode is present on unit serial numbers QT070157 upwards, and is removable.

CONNECTOR WIRING   - See also appendix A, PCB Dimensions
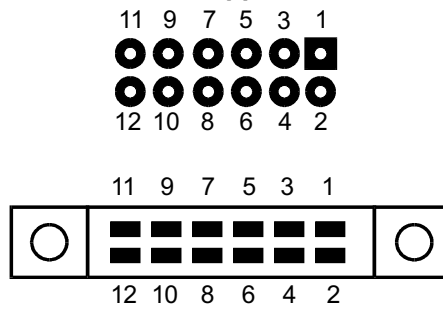
Top: Layout of the 12 hole user connector, possibly a user-installed IDC type.

Bottom: 12-pin edge connector, shown from wiring end of connector; topside of module is the top connector row shown. Some connectors will have pin numbering that conflicts with the numbering shown.

PIN	NAME	DESCRIPTION
1	SENSE	Sense lead to electrode
2	SHIELD	Signal ground (Use for coax shield if desired, else no-connect)
3	SHIELD	Signal ground (Use for coax shield if desired, else no-connect)
4	SHIELD	Signal ground (Use for coax shield if desired, else no-connect)
5	XBG	External Background cal (+3 to +20 volts causes BG cal)
6	XOBJ	External Object cal (+3 to +20 volts causes OBJ cal)
7	PWR	+7 to +20VDC at 50mA rating (25mA typical)
8	PNP_HIGH	PNP pull-up voltage (usually tie to POWER if using PNP out)
9	PNP_OUT	PNP output; clamps to PNP_HIGH when active
10	GROUND	Supply Ground
11	NPN_OUT	NPN output, clamps to GROUND when active
12	A_OUT	Analog output

Grounds

Shield grounds: These are strictly for use in connecting to the shield of a coax cable or other signal ground reference.

Corner hole grounds: The two corner holes near the connector are board ground. The two near the clone connector are isolated; this is intentional, and is designed to prevent ESD currents from traversing the pcb. The grounded corner holes should, if at all possible, be screwed down to a grounded metal chassis.

Outputs

Note that signal outputs NPN_OUT and PNP_OUT should be treated as logic drives only. They are rated at 100mA maximum and if coupled to an inductive load (a relay for example) should be protected from spikes via an external diode clamp, like a 1N4001, across the coil.

The analog output is a zero to +5 volt range signal buffered by a CMOS opamp; it should only be connected to a high impedance load to prevent inaccuracies in voltage.

Control Inputs

XBG and XOBJ replicate the onboard pushbuttons, and are 'active high'. These lines are sampled just after each burst; at the slowest burst rate the minimum activating pulse width on XBG and XOBJ should be 100ms minimum, preferably a little more.

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QTM1001AS FEATURES

- Fully programmable via cloning method from E2 evaluation board
- EEPROM permanent settings and calibration memory
- Instant-on mode
- Outputs:
  - Mosfet open-drain output
  - PNP transistor output
  - Analog output: raw or processed
  - LED status indicator
- Variable spread spectrum drive
- Variable pulsewidth drive
- Variable burst length
- Variable burst spacing

- Variable sensitivity
- Variable hysteresis
- Variable reference point offset
- Dual-path analog gain select
- Window or conventional detection thresholds
- Asymmetric thresholds
- Auto background drift compensation
- Auto timed calibration store
- Auto delayed recalibration
- Pushbutton background/object calibration
- Nonlinear & linear filtering:
  - Intrinsic boxcar filtering

  - Median filter
  - Digital boxcar filter
  - Event delay filter
- Pulse stretch output
- External calibration lines
- User-defined connectors
- Encapsulated for ruggedness
- 100% surface mount technology
- 2,500 pF load capacity
- Resolution to 5 femtofarads
- ESD protected drive output
- Moisture suppression or detection capability
- Immune to stray static fields

WHAT'S NEW IN THE QTM

The QTM1001AS has several features not found in the E2. These include:

1. Auto BG, BG/OBJ, and OBJ modes. It is no longer necessary to preprogram the setups to make the sensor operate in one of these modes; the key sequence of the two buttons makes that determination automatically.

2. Charge / Transfer pulse widths are digitally synthesized in 7 settings; no width-setting pots are required.

3. Operates with more functionality at the 200µs burst rate, including full detection mode processing options.

4. Auto calibration store to internal eeprom on a timed, as-needed basis, at a user-settable rate.

5. Asymmetrical threshold windows: the negative threshold can be set differently from the positive one.

6. Asymmetric *max on-duration* processing: negative threshold events can 'time-out' longer or shorter than positive threshold events.

7. Error handling facility:
   - can detect short circuits in a single burst and flag the output active or inhibited
   - can detect low signal levels and flag the output active
   - can force the output active during a recalibration, when the sensor is 'flying blind'.

8. Output pulse stretch to lengthen the output pulse for up to 10 seconds if desired.

9. HeartBeat[tm] output option for 'mission-critical' applications.

10. Analog output supports both raw analog and digitally processed (filtered) analog outputs, including 3 forms of computed analog: absolute, positive differential, negative differential, and absolute differential.

11. High stability (30ppm drift / $^\circ$C) of the signals is standard.

CONFLICT RESOLUTION AND THE QTM

The QTM does not perform the conflict resolution found on the E2. Care should be taken not to exceed guideline settings in certain combinations. While the QTM can recreate all modes of the E2 at all legal E2 settings, it can actually go beyond these. Normally, conflict resolution would prevent the E2 from being set to illegal combinations thus preventing you from taking advantage of the extra capability of the QTM. There is a way around this.

All E2's have a secret 'backdoor' feature that allows you to program in any illegal setup combination normally filtered out during conflict resolution. The backdoor forces the eeprom to accept the illegal settings; the eeprom can then be used to clone to the QTM.

To defeat conflict resolution:

1. Program the E2 to the combination you desire for the QTM1001AS.

2. Push the left button ("select") down and hold, and when the first long beep is heard, *keep holding* for about 4 seconds longer until you will hear another beep; the display will then show '0.*x*' where x is the setting for function '0'. The unit is now back in setups mode, and is <u>not</u> running as a sensor. If you desire you can now check all your setups by scrolling though with the 'Select' key - they are still there, unmodified.

3. De-power the E2 before it can exit setups and run.

4. Remove the eeprom from its socket.

5. The eeprom now holds the settings you programmed, uncensored from the E2's "conflict resolution" process.

The QTM1001AS does not perform the conflict resolution found on the E2. Care should be taken not to exceed guideline settings in certain combinations.

CLONING PROCESS

The QTM can be programmed from an E2S board via the 'cloning' process. The QTM has a superset of the available features of the E2; the new features are implemented by reusing some setups not applicable to the QTM, and via 'reserved' E2 functions. While most features of the QTM can be replicated on the E2 board, some, like asymmetric thresholds, cannot. The E2 can be thought of as a 'programmer' when setting up the QTM. It should be remembered that when setting the E2S up to program a QTM unit, the E2S itself may no longer function correctly if the new features of the QTM are enabled. This can be easily corrected by changing E2S setups to a combination that is valid for the E2S.

Cloning via eeprom removal

1. With power turned off, remove the eeprom from the E2 using an appropriate IC removal tool, and insert it into the socket on the cloning adapter, <u>making sure of IC orientation in the socket</u>. Detach the cloning cable from the clone adaptor if one is connected.

2. Mate the adapter to the cloning pads on the QTM and press so that all 6 spring loaded 'pogo' pins make firm contact with their corresponding metal contact pads.

3. With the clone adapter firmly pressed in place, quickly push then let go of the 'OBJ' button.

4. When the LED starts to blink remove the clone adapter.

If data is correctly cloned, LED will blink more slowly than normal for 4 to 6 times. The unit will then perform a reset and then run with the new setups. The unit may not be calibrated properly after a clone process, as old stored data will be used; if this is the case the sensor should be recalibrated using one of the BG, BG/OBJ, or OBJ modes.

The QTM cannot be displaying an error code when you clone; make sure it is running normally first.

When you are done you can place the eeprom back into the E2S if desired.

If the eeprom is reinserted into the E2 and the E2 is run, eeprom contents may alter during 'conflict resolution' by resetting to 'legal' combinations. Take care to review settings on the E2's LCD. ***In particular*** the serial port setup mode [F] may have changed ([F] = *"DRIFT STORE / DATA LOCKING / MOTION MODE"* on the QTM), preventing serial communications; recheck Setups [F] if this occurs.

The QTM may start in 'Data Lock' mode if that feature is selected ([F] - see <u>*QTM Setups Table*</u>, following this section) which means that the first stored data used will almost certainly not be correct. Pressing BG or OBJ in accordance with the instructions in 'Operating Modes' (later in this manual) will reprogram the QTM's stored data to make it run properly.

The Setup Table shows the functions of the QTM, most of which are the same as on the E2. Note the new functions been added over those found in the E2S.

Cloning via Cable Method

If your E2S has a clone port on board, you can clone to a QTM via the clone cable method. This method does not require that the eeprom be removed from the E2S.

1. Plug one end of the clone cable into the E2S, and the other end into the clone adaptor (later versions of the clone adaptor have a clone cable connector on them).

2. Make sure the E2S is powered on.

3. Set the E2S' setups to the desired combination for the QTM.

4. Place the E2S 'Select' (left) digit to '1' or higher, to prevent the E2S from timing out and running while you clone

5. Mate the adapter to the cloning pads on the QTM and press so that all 6 spring loaded 'pogo' pins make firm contact with their corresponding metal contact pads.

6. With the clone adapter firmly pressed in place, quickly push then let go of the 'OBJ' button.

7. When the LED starts to blink remove the clone adapter.

If data is correctly cloned, LED will blink more slowly than normal for 4 to 6 times. The unit will then perform a reset and then run with the new setups. The unit may not be calibrated properly after a clone process, as old stored data will be used; if this is the case the sensor should be recalibrated using one of the BG, BG/OBJ, or OBJ modes.

You can alter settings in the E2S using the Select and Set buttons and clone the settings over immediately without having to restart the E2S. In Setup mode, the E2S's eeprom is updated immediately after you change a setting, which allows you to clone to a module interactively. Just be sure the E2S does not time out from the Setups mode and start to run - cloning cannot occur while the E2S is running in Sense mode.

The QTM cannot be displaying an error code when you clone; make sure it is running normally first.

The QTM may start in 'Data Lock' mode if that feature is selected ([F] - see _QTM Setups Table_, following this section) which means that the first stored data used will almost certainly not be correct. Pressing BG or OBJ in accordance with the instructions in 'Operating Modes' (later in this manual) will reprogram the QTM's stored data to make it run properly.

The Setup Table shows the functions of the QTM, most of which are the same as on the E2. Note the new functions been added over those found in the E2S.

DATA VERIFY MODE

Units with serial numbers QT070173 and higher than have a new feature allowing the viewing of the contents of the internal setups table. The feature uses the on-board LED to 'spell out' the setups table, by counting out the settings in LED flashes.

TO ACTIVATE DATA VERIFY MODE: Turn module power off. With both buttons pressed simultaneously (or by asserting both XOBJ and XBG together) power the unit back up. Let go of both buttons (or de-assert XOBJ and XBG at the same time). After a 1.5 second delay the LED will begin to flash at a deliberate pace.

READING THE VERIFY FLASHES: The LED will 'count out' the current settings in the on-board setups table. If a setup is set to '6', the LED will flash 6 times, followed by a 1.5 second gap before the next setup parameter is displayed.

If the setting of a particular setup is zero ('0'), the LED does a distinct short, dim flicker.

ENDING VERIFY MODE: Verify mode is self-terminating. At the end of verify mode the QTM1001AS will reset itself and run. Verify mode can be terminated early by interrupting power briefly.

FORCING DEFAULT SETTINGS

Factory default settings can be forced into the module while in Data Verify Mode.

At any time while the LED is showing the Verify flashes, hold the OBJ button down (or assert the XOBJ line) for 2 seconds, then let go. The QTM will reset itself and run using factory default settings, thus overriding all prior settings. This default setups will be written into the onboard eeprom.

QTM1001AS SETUP TABLE   bold boxes denote factory defaults

select	description	0	1	2	3	4	5	6	7	8	9
						setting					
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	**amp gain**	low	high								
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	display error code if calibration error	off	on	off	on	‡					
e.b	recalibrate if reference drifts into boundary	on	on	off	off	‡					
F	**drift store / data locking /**										
f.a	drift store interval, mins. 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	**asymmetrical windows (n, p**	no	yes	‡	‡						
H	**unused**										
J	**error handling**										
j.a	output active if shorted electrode during run	x		x		x		x		‡	‡
j.b	output active on very low signal during run			x	x			x	x	‡	‡
j.c	output active during recalibration	x	x	x	x					‡	‡
L	**output stretch, seconds**	0	0.1	0.2	0.5	1	2	3	5	7	10
N	**detect threshold (-), counts**	62	40	32	25	19	14	11	8	6	4
P	**max on-duration (-), seconds**	infinite	100	50	20	10	5	2	1	0.5	0.2
U	**analog output mode**	raw	synth	+synth	-synth	|synth|					

Setup Notes

Note: Asterisk (*) items are those that deviate from the E2.

‡   Reserved function; do not use.

0   This setting is not used for detection threshold when in BG/OBJ or OBJ mode; OBJ mode makes use of this number to define the level of hysteresis. BG/OBJ and OBJ modes use 'learn by example' thresholds.

1   Percentages shown are relative to the differential between the 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, provided Hysteresis is set to 0, 1, or 2. If in OBJ mode Hysteresis is '3', there will be no hysteresis whatsoever.

2   Reference offset is internally forced to 0x70 if OBJ mode is entered. Numbers are hexadecimal (example: 0x20 = 32 decimal).

3   *Amp gain affects both the internal readings and the analog output.

4   *Pulsewidths are digitally synthesized and are within 0.5%.

5   *No onboard 'Conflicts Resolution' is performed. Maximum permissible Burst Lengths to be used are:

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

	Randomization			
	off	12.5%	25%	50%
200us	24	-	-	-
500us	64	48	32	24
1ms & up	64	64	64	64

(Burst Spacing is the row label)

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

	Randomization			
	off	12.5%	25%	50%
200us	16	-	-	-
500us	56	40	24	16
1ms & up	64	64	64	56

(Burst Spacing is the row label)

Care must be taken not to exceed the above table limits for burst length. These limits are beyond that found in the E2 from which the settings must be cloned. Conflicts resolution on the E2 can be circumvented - see earlier section, '*Conflict Resolution'* for details.

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 at 200 µs burst spacing should be disabled, else timing errors will occur.

A   *Boxcar Averaging can remain functional even at 200us 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   *Detection Mode is fully functional at all settings of Burst Spacing, even 200 µs.

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

E   *Display Error code if calibration error*, if 'on', will flash the LED in a repeating code if a calibration or recalibration error occurs. If no error, no code is displayed. The code is:

Single Repeating Flash:	**Electrode wire shorted to ground**
Double repeating flash:	**Excess capacitive load**
Triple repeating flash:	**Unstable signal, cannot find cal point**

After each coded flash the sensor again tries to recalibrate. Turning Error Display 'off' will prevent this display, which takes additional time and will add delay to when the sensor will finally calibrate.

Recalibrate if reference drifts into boundary, if on, tells the 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 *The sensor can store drift and cal parameters into its onboard eeprom at a timed interval as defined by 'F'. 'F' also sets Data Locking, the ability to remember the last calibration point on a cold start.

Setting to '0' will prevent both drift store and data locking.

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 compensation data 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, the eeprom will not be written. The save timing interval 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.

Important Note to E2 users: *'F' settings used for the QTM can conflict with settings for the baud rate and protocol on the E2. After setting up the E2 and cloning from it, be sure to reset setup 'F' properly if you want to use the serial communications port again. This is an unfortunate compromise on the road to greater functionality for the QTM - we hope you understand!*

G *If 'G' is set to 'yes', the sensor will use asymmetric threshold processing, the negative set being defined by functions 'N' and 'P'. Setting 'G' to 'yes' and setting 'N' and 'P' to duplicate the settings of '0' and 'C' is identical to the way the E2 functions, and identical to leaving 'G' on 'no'.

J *Defines the output from the sensor when an error occurs.

Setting *'output active if shorted electrodes during run'* to boxes without an 'x' will actually *inhibit* the output if a short circuit occurs. This is important to know because function 'D' can otherwise be set to generate an output on a low signal level. The setting of 'D' with regard to negative signals is overridden by the safety aspects of 'J'.

Short detection occurs within each burst, and so is a fast way of detecting a short circuit.

"*Output active on very low signal during run"* uses the signals processed through the digital filters, and may take some time to respond. If this option is set, an the output will become active if the actual signal level falls below the usable level of the sensor's current 8-bit "window". Low signal can also be caused by a short, or by some other factor such as an intermittent electrode connection, a bad recalibration point, or excessive signal drift.

"Output active during recalibration" forces the output active during a recalibration cycle, no matter the reason. During recalibration the sensor is momentarily "flying blind" and cannot process signals. Forcing an output during this interval may be desirable in some applications.

L *Output stretch adds a post-processing function - the ability to create a 'retriggerable one-shot' effect on the output. Setting to '0' turns the stretch function off. Stretch does not lengthen outputs caused by conditions related to function 'J'; it only stretches real signal detection 'events'.

N Negative signal (with respect to the reference level) threshold, used when 'G', 'Asymmetrical Windows' is enabled. This threshold is NOT used in BG/OBJ or OBJ mode, regardless of 'G'. Also this setting does not influence hysteresis in OBJ mode (see notes for [1], above).

P The maximum on-duration prior to a recalibration can be set differently for signals that go below a negative threshold, if the corresponding function is set in Detection Mode 'D'. 'P' will function only when 'D' is set to 2 and above (i.e. when negative excursion detection is enabled).

U The analog output mode can be selected to one of 5 options: [0] Raw, which is the raw analog signal from the acquisition front end; [1] Synth, which is a digitally synthesized output corresponding to the filtered raw signal in span; [2] +Synth, which is the rectification of the difference between the actual signal and the internal reference level (signal - reference); [3] -Synth, which is the rectification of the difference between the internal reference level and the actual signal (reference - signal); [4] |Synth|, which is the absolute value of the difference between the signal level and the reference level.

All synthesized analog signals have 8 bits of resolution from 0 to +5V out, although in the case of the difference signal options ([2, 3, 4]) the span of the analog output may not encompass all 8 bits..

OPERATING MODES

BG, BG/OBJ, AND OBJ MODES

The QTM operates in either of two primary calibration modes:

'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.

'Learn' mode: The sensor ignores Detect Threshold, and 'learns by example'. There are two variations of 'Learn' mode: BG/OBJ, and OBJ.

On the E2, BG/OBJ and OBJ modes had to be specified in the setup procedure; this was required because of the dual use of the LCD display: the right button could be used either for scrolling the LCD function or for the OBJ function, but not both. In the QTM1001AS there is no LCD and so a separate mode is not required.

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

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 internal eeprom.

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.

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 eeprom 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.

BG MODE DETAILS

BG mode is identical to the mode that the QProx E2 runs in if 'Buttons Mode' is set to '0'. 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, 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.

If Data Locking is on, unit will use stored eeprom cal settings on powerup and not perform a BG cal. If the BG cal point has changed, it will be necessary to evoke BG 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 eeprom for retrieval on any subsequent powerup.

Forcing to BG mode from OBJ mode: Evoking BG if the QTM is in OBJ mode will take the QTM 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 QTM is in BG/OBJ mode and it is desired to change the mode to "pure BG" mode: evoke BG for >1.6 seconds. After the BG evoke, the LED will come on "solid" for ¾ second and the device will then recal. At this point it will be in "pure BG" mode. If the LED does not go "solid on", the line was not evoked long enough.

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 QTM 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, the resulting cal data will be stored for retrieval on any subsequent powerup. Then, when the QTM subsequently powers up again it will use the stored settings and immediately run with them, without performing a recalibration of any sort.

If the QTM 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 QTM 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 QTM 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 eeprom in error, the erroneous settings will be 'moved' to one of the legal numbers when BG/OBJ mode is entered.

In the E2, BG/OBJ mode disables the Max On-Duration feature to 'infinite'. This is not true in the QTM1001AS. If 'infinite' is desired, you must set Max On-Duration to 'infinite' via the eeprom setting.

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 LED will go "solid on" for about ¾ second and then the device will recal in pure-OBJ mode. If the LED does not glow "solid", 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) in the cloned setups.

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 the Setups Table. 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 for retrieval on subsequent powerup. Then, when the unit powers up it will use the stored 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.

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, the QTM 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 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 QTM1001AS periodically save 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 once every minute to 10 minute spacings. Note that the internal eeprom has a rated life of 1 million writes; this may have an impact on selection of the drfit store update rate chosen.

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 Drift Store enabled, in OBJ mode or if *Drift Rate* is set to "off", no 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.

LED FUNCTION

The LED is a multi-purpose indicator that shows signal health, output state, error conditions, and pushbutton feedback.

Running and not detecting: the LED will noticeably flicker, but dimly.

Running and detecting: the LED will flicker brightly (flickering is a little harder to notice).

When a button is pushed: the LED is forced off.

If a button is pushed long: (to forcibly revert to a different operating mode) the LED will, after button release, come on brightly for 3/4 second before proceeding with the new mode.

While calibrating: the LED will usually be off; this usually takes well under a second. If *Error Handling* [J] is set to 0 through 3 (*output active during recalibration*), the LED will be on solid during the recalibration.

If an error occurs during operation: for example a short circuit or low signal condition when the appropriate error mode is enabled (see *Error Handling, [J] description, next section)*, the LED will glow solid with no flicker.

If a clone operation is performed: the LED will blink slowly for 1 second (about 5 blinks) to indicate that the data has been cloned successfully, and the clone adapter can be removed. The LED will then turn off for ½ to 1 second while the sensor resets itself and starts over.

On a calibration error: the LED will flash an error code, provided that Error Display [E] is 'on':

Single Repeating Flash:	**Electrode wire shorted to ground**
Double repeating flash:	**Excess capacitive load**
Triple repeating flash:	**Unstable signal, cannot find cal point**

The unit will repeatedly try to recalibrate between each set of 'Morse code' flashes. If [E] is off, the recalibration attempts will be much quicker, since the LED flashes are not performed.

FUNCTION DESCRIPTIONS

The following details differences with the E2 board. For more details please refer to the E2 manual.

[0]

DETECT THRESHOLD (SENSITIVITY)

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).

This control functions identically to that of the E2, with the exception that in BG mode it is possible to have asymmetric thresholds and processing if 'G' is on. If G is on and Detection Mode D is set to 8 or 9, Detect Threshold [0] has no effect at all unless used to form the hysteresis level (see [1] below).

The table threshold value is in counts of signal from the current reference level: the lower the number, the higher the sensitivity.

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 then-signal level.

[1]

HYSTERESIS

The QTM1001AS has several hysteresis options. In conventional signal detection mode, a hysteresis of 0, 50, 25, or 12.5% of threshold value can be selected, which applies to positive and negative thresholds alike. 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.

If set to '0', there is no hysteresis and output chatter can easily occur. In OBJ mode the amount of hysteresis is expressed in counts of signal swing, as set by Detect Threshold [0], which is 'hijacked' by the hysteresis function - in OBJ mode the detect threshold is 'learned by example' and so Detect Threshold is not used for threshold purposes. In OBJ mode [1] is ignored unless set to 0, in which case there is no hysteresis at all.

[2]

REFERENCE OFFSET

Reference Offset determines where the sensor establishes a calibration point. The offset numbers are given in both hexadecimal ("0x20") and decimal ("32"). Normally, centering the reference at mid-scale (0x70) of the 8-bit 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 it can be anticipated that signal and drift swings are largely unilateral, e.g. positive, and so maximum headroom in the positive direction would be 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).

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

[3]

AMPLIFIER GAIN

Amp Gain determines which gain path the sensor controller takes its signal from. There are 2 paths: low gain, and high gain which has a 17.55x higher gain. Unlike the E2, Amp Gain in the QTM does affect the output analog signal path gain as well.

Low gain is useful where very large signal excursions are expected, or to desensitize the sensor intentionally, for example to create touch switches.

[4]

PULSE WIDTH

There are no adjustment pots on the QTM. The settings are digitally synthesized and can be selected as shown in the table.

[5]	Affects how many QT cycles are made during a burst. Bursts occur at a rate determined by Burst Spacing (see below). Burst length can be set from as few as 4 pulses per burst to 64; the larger the burst length the more sensitive the sensor becomes, but the less is its ability to compensate for and suppress background capacitance loading. The most sensitive the sensor can be is Burst Length = 8, Threshold = 9, and Amplifier Gain = 1. 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 due to Burst Length.
BURST LENGTH	

At 200 μs and 500 μs burst spacings this setting may need to be reduced; see table in *Setup Notes*.

[6]	Affects the duration 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
BURST SPACING	reduced; see table in *Setup Notes*.

[7]	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 spectrally spreads RF emissions, and reduces the chance of false detects due to correlated electrical noise.
RANDOMIZE	

Note that Randomize can be extended to faster burst rates than on the E2 according to the table in *Setup Notes*.

[8]	Drift Rate, or more accurately Drift *Compensation* Rate, sets the rate at which the sensor's baseline reference is itself allowed to drift to track slow ambient changes. In many sense environments the
DRIFT RATE	sensed signal level will fluctuate due to varying moisture levels, temperature, dirt accumulation, or other variables. Such fluctuations can cause the sensor to lose its calibration point, resulting in the sensor appearing to gain or lose sensitivity, or even to cause false detections. Drift Rate sets the rate at which the sensor is permitted to track these baseline fluctuations. 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 deviation; 'X' is the setting of Drift Rate.

Drift Rate should be set to as slow a rate as possible; fast drift compensation will cause the sensor to track real objects and thus appear to lose sensitivity. Setting too slow can prevent the sensor from keeping up with signal drift.

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.

Analog Output and Drift: The Raw analog output mode is split from the sensor prior to signal processing, so drift compensation cannot be made to apply to it.

Synthesized analog modes which are expressed as a difference from the reference level (Analog modes [U.2,3,4]) will compensate for drift, reflecting the operation of the internal drift compensation mechanism.

Drift compensation is not permitted in OBJ mode and will be disabled when the OBJ button is pushed; see **BG/OBJ Modes** section.

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

1. Drift ceases, if "*recalibrate if reference drifts into boundary*" (see [E]) is off.

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

[9]
MEDIAN FILTER

This is a nonlinear filter that acts to limit electrical impulse noise errors. A median filter selects the median, or center value of an odd group of sample data. The filter uses 5 signal samples. Because it takes the center value, impulse induced spurious signals are eliminated from further processing within the signal path, no matter how deviant. If selected this filter is the first digital filter in the signal path. See *Signal Flow* section.

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

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

The 'boxcar' average (the sum divided by 5) is 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 can be more efficient than linear filters. Their downside is that they leave a residue of low level noise, but this is easily cleaned up by a simple linear filter.

The median filter is based on a shift register of data of 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.

Median Filter should be switched off if burst rate is set to 200 μs, otherwise serious timing error can occur.

[A]
BOXCAR AVERAGING

This is a 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. When coupled with a long (slow) Burst Spacing, the sensor can seem to take forever to respond. Boxcar Averaging compounds with the intrinsic sample averaging which occurs naturally in the sample process, according to Burst Length. Boxcar Averaging can be used alone or following the Median Filter, in which case it acts to clean up any residual noise left by the Median filter.

The boxcar averager is based on a shift register of data of length 'n' ('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 update 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 unit to suppress large transient events by real objects, as opposed to signals induced by noise or drift. This filter comes in handy when only detections of a minimum duration are desired to be sensed. It can also act as a noise filter, supplementing the actions of the Median and Boxcar filters.

The DI is implemented as an up/down counter controlled by the threshold comparator (see *Signal Flow* section). If a detection is in progress, the DI will count up once after every burst in which an event has been detected. When no event is in progress, the DI counts down again. If the DI reaches the prescribed count level as set during Setups, a real detection is finally assumed and the output transistor is activated.

Important Note: If the DI is set to zero, it is disabled and the output *cannot* turn on , and so the functions [C], [D], [G]. [L], [N], and [P] do nothing. If set to 1 count, it is as though DI were bypassed since no integration is performed; activation is after a single 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 the DI to 'off' is useful to suppress detections for test purposes, or if the analog output is employed alone.

[C]
MAX ON-DURATION

This is a post-detection function that determines how long a detection is permitted to exist before a recalibration is forced. After the specified duration, the sensor seeks out a new reference level based on existing signal strength. Coarse and fine offsets may be affected during recalibration. A short Max On-Duration turns the unit into a *motion detector*, causing outputs only when signal strength increases (and/or decreases - see Detection Mode, 'd').

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. Motion mode is selected by setting [F] to 9; in this mode, recalibration will be very fast (within a single burst). The default mode ([F] is anything but '9') is slower but safer from the standpoint of establishing a true reference level; 'Motion' can lock up the sensor's output for the duration that the signal strength falls outside the ADC's 8 bit signal range.

Max On-Duration interaction with Detection Mode: Detection Mode 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 generate an output. An example of this is if Detection Mode is set to 2; this setting will cause outputs if the signal exceeds the positive threshold, but though a negative threshold is also established (symmetrically to the positive one) negative signal excursions will not generate an output; but, 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.

'Infinite' disables Max On-Duration.

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

In BG/OBJ mode, unlike the E2S board, Max On-Duration is usable.

If [B] (Detect Integrator) is set to 'off', [C] is ignored, and drift compensation will occur continuously at the rate specified by [8] (drift compensation rate).

If Asymmetrical Windows [G] is turned on, the setting of Max On-Duration for negative-going signals can be made different than for positive-going signals using [P]. If Detection Mode [D] is set to 8 or 9, [C] is completely ignored if [G] is on.

See Detection Mode [D] and Asymmetrical Windows [G] below for more details.

[D] **DETECTION** **MODE**	Defines what constitutes a detection, and determines what happens to some other functions during a detection. Detection Mode can allow the detection of signals that are increasing and/or decreasing. It can also allow drift compensation to occur during a detection event or not, and can permit the *Max On-Duration* timer to run even if no output is generated but a 'hidden' threshold level is exceeded.

Detection mode 0 is the most common and most associated with prox sensors. Modes 4 and 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 sensor with an object (like your hand) close by, then let the unit calibrate on it. In Modes 4 or 5, either bringing the object closer or removing it will cause a detect, leaving only a narrow window of non-detection. The narrowness of the window is defined by the sensor's overall gain (see *Burst Length, Amp Gain*) and the *Detect Threshold* setting.

Detection Mode functions largely the same as in the E2S, except that all [D] functions are available even at the 200 µs burst rate (the E2S was limited to settings 0 or 8 at 200 µs).

Note that 'phantom' or 'hidden' detections can be created that will make the Max On-Duration counter run towards a timeout, without generating an actual output. 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 negative signal swing. If [D] is set to 1, and the unit is in BG mode, a negative signal swing can trigger a full recalibration after the Max On-Duration period has timed out, even though no actual output transistor activation ever occurred.

This feature also works in conjunction with Asymmetric Windows, [G], whereby the negative threshold can be set differently than the positive one, and the timeout associated with Max On-Duration can be set differently for the negative threshold as well (see [N], [P]).

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

[E]

CALIBRATION CONTROL

There are two options under Calibration Control:

display error code if calibration error - This controls whether the LED will flash an error code (see *Setup Notes* and *LED Function* section, prior pages) if, during a calibration or recalibration, the sensor detects an error. Since this 'Morse code' takes time to display and slows up the QTM's ability to try recalibrating again, it may be appropriate to disable this.

recalibrate if reference drifts into boundary - Controls what happens when the sensor drift compensation moves the reference level enough so that it runs into the edge of the allowable signal space. 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 recalibration.

[F]

DRIFT STORE / DATA LOCKING / MOTION MODE

This controls three things:

1. Whether the sensor will store calibration data in the onboard eeprom 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 will process in a rapid "motion" mode, whereby signal reference recalibration occurs very quickly, but is not a full recalibration involving both coarse and fine offsets in addition to the signal reference level.

If Data Locking is on, the eeprom will be used for recalibration data storage.

If Drift Store is set to one of the intervals shown, the drift data will be saved to the eeprom as well at the intervals shown. Note that Drift Store is irrelevant in OBJ mode, or if Drift Rate is off. OBJ does not make use of a background reference level, and so there is nothing to drift compensate with as the background signal level is unknown.

Data Locking is useful in all modes except motion. Motion mode is a very "here and now" mode, and storage of motion mode calibration data is fairly pointless.

'F' settings for QTM may conflict with the E2's settings for baud rate and protocol, which will affect PC display software. We apologize for this re-use of function 'F' and the resulting inconvenience.

[G]

ASYMMETRICAL WINDOWS

This setup controls whether the negative processing features of [N] and [P] are used. If [G] is on, and [N] and [P] are set identically to [0] and [C], it is as though [G] were off; processing is indistinguishable in these cases from the E2, which does not have asymmetric processing. The same holds true if Detection Mode [D] is set to 0 or 1, or if the unit is in OBJ mode.

Asymmetric signal processing opens up numerous possibilities for auto recalibration under certain conditions, and for creating 'prox traps' with more sophistication. Asymmetric Windows can operate whenever Detection Mode [D] is set to 2 or above. See notes under [N] and [P] for more details.

[H]

UNUSED

This setup is unused because of feature conflicts with the E2. "Buttons Mode" on the QTM is not necessary, as the BG, BG/OBJ and OBJ modes operate without requiring any special setup.

[J]

ERROR HANDLING

There are three 'error' conditions that can trigger an active output:

shorted electrode: if the electrode lead is shorted to ground, the unit can be made to generate an active output. Conversely, the output can be forced *inactive* when the electrode is grounded. Setting [J] to 1, for example, and shorting the electrode lead while the sensor is normally running will prevent the output from going active, even if the Detection Mode [D] is set to 4 or 8 (negative swings create output).

low signal level: if desired the output can be forced active if the signal level, as processed by any internal digital filters, falls to under 9 counts of signal within the current 256-level signal space. Very low signals can indicate a failed electrode connection, in which case it may be desirable to activate the output as a safety measure.

recalibration in progress: if desired, the sensor can output can be forced active while the unit is in a calibration or recalibration cycle. During this moment the sensor is 'flying blind', and so it may be desirable to make the output active as a safety feature.

The LED will glow solid without flicker during an above error handling 'event'. See *LED Function* section for details.

Note that Output Stretch [L] does not stretch error-induced output activations.

[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 the table. 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 these will also cause a delay in the onset of output activation as well.

'Stretch' has no effect on activations made due to an error condition (see [J]).

[N]

DETECT THRESHOLD (-)

This functions similarly to Detect Threshold [0], except operates only with negative-going signals, and then only if:

1. Detect Integrator [B] is set to 1 or higher, and,
2. Detection Mode [D] is set to 2 or higher, and,
3. Asymmetrical Windows [G] is on, and,
4. Unit is in BG mode (will not work in BG/OBJ or OBJ modes)

Negative hysteresis in BG mode if [N] is in use is set according to the percentage specified in Hysteresis [1], as a percentage of the negative threshold.

[P]

MAX ON-DURATION (-)

This functions similarly to Max On-Duration [C], except operates only with negative-going signals, and then only if:

1. Detect Integrator [B] is set to 1 or higher, and,
2. Detection Mode [D] is set to 2 or higher, and,
3. Asymmetrical Windows [G] is on, and,
4. Unit is in BG mode (will not work in BG/OBJ or OBJ modes)

This feature can, among other things, be used to create a powerful auto self-cal where the sensor will automatically reset its reference very quickly if objects are removed from the field of the electrode; this is accomplished by setting [P] to 0.2 secs, and [N] to a suitably low threshold like 9 (4 counts). This feature is useful in situations where 'real' signals go positive, but after debris has collected around the electrode and the sensor has drift-adapted to that debris, but then the debris is suddenly removed, the sensor will adapt to the sudden drop in signal with a quick recalibration in the negative direction.

Exactly the reverse effect is also possible.

[U]

ANALOG MODE

This function controls the analog output pin function as follows:

(1) Raw Analog. The analog pin outputs the sampled, raw signal from the front end. This mode is exactly like the E2S' analog output.

(2) Synth. This outputs a synthesized analog signal that represents the output of the last stage of internal filtering, including both Median and Boxcar if enabled. The offset and span of this signal are identical to Raw Analog.

(3) +Synth. This is the positive differential, or half-wave rectification, of {signal - reference}, where 'reference' is the internal signal reference level, which can be drift compensated. If Signal falls below Reference, the output is zero volts. The +Synth output is fully filtered by any enabled filter stage(s).

(4) -Synth. This is the negative differential, or half-wave rectification, of {reference - signal}, where 'reference' is the internal signal reference level, which can be drift compensated. If Signal rises above Reference, the output is zero volts. The -Synth output is fully filtered by any enabled filter stage(s).

(5) |Synth| This is the absolute value of the differential, or full-wave rectification, of {signal - reference}, where 'reference' is the internal signal reference level, which can be drift compensated. The |Synth| output is fully filtered by any enabled filter stage(s).

The Synth signals all are reconstituted using an 8-bit DAC. if a difference mode is used (i.e. [U] is set to 3, 4, or 5) the output may not encompass full scale 0 to 5 volts, but will only rise by the number of counts of differential. Thus, if +Synth is selected, and the reference level is currently 153, then the Analog output signal can only rise by 255-153= 102 counts, resulting in 5*(102/255) = 2 volts.

HEARTBEAT™ OPTION

The HeartBeat™ option provides a way of ensuring proper operation by allowing host equipment to monitor the following sensor functions:

1. Sensor DSP operation
2. Sensor hardware functionality in real time, from front to back including the output transistor
3. Electrode integrity, including opens and shorts
4. Proper sensing signal range

The HB option operates by issuing narrow pulses on a regular basis if the sensor is running properly.

Operation

The HeartBeat (HB) signal is a narrow, $5\mu s$ pulse superimposed on the output line, spaced 10ms to 15ms between pulses. It pulses continuously while the sensor is operating properly, regardless of output state. With the output high, the HB is a negative pulse, and conversely with the output low, the HB pulse is positive. The HB pulse is too short to interfere with electromechanical loads such as relays.

When interfacing to logic input devices, the HB pulse can be readily filtered out using a simple RC lowpass network that will insert only a negligible response delay. The HB pulse can be split off into a pulse detector which can be monitored separately by the host equipment.

Example HB Splitter Circuit

The circuit shown demonstrates one way to split off the HB signal from the sensor output.

U1A buffers the NPN_OUT signal; the R2/C2 filter is further buffered by U1B to create an HB-stripped output. C1/R3 forms a pulse delay which in conjunction with exclusive-or U1C creates a positive double-pulse for every $5\mu s$ HB pulse detected. The first of these triggers U2A, and further gating within U2B triggers the second monostable only when a another pulse is detected within $8\mu s$ of the first one, i.e. whenever a short pulse is output from the QTM of either polarity. The output of U2B will go low 15ms after the last HB pulse, should the HB pulses cease; so long as HB pulses are sensed, its output will remain high.

The circuit shown is but one implementation that can verify HB operation; it can also be emulated in a state machine. QTM's output can also be fed directly into an accumulating counter within a host controller, with the transitions counted to verify HB operation.

Software can reliably determine the detection level state without interference from the HB pulses, by sampling the QTM's output 3 times equally spaced over a $15\mu s$ or more duration, then doing a majority vote. At least two such samples are guaranteed to miss any HB pulse that may occur at the time of sampling.

Enabling the HB Signal

The HeartBeat™ (HB) signal option is a full-time signal and cannot be separately enabled or disabled. Units having the HB option will always be in HB mode. Specific items monitored by HB include:

1. Firmware health: Using triple-redundant internal checks, any disturbance in the operation of the firmware will cause the HB signal to cease. Also, the HB signal does not start after a power-on until the sensor is running stably.

2. Normal sensing disturbances: If the sensor enters a calibration cycle, a control line is evoked, or any other action occurs which momentarily makes the sensor 'blind', the HB signal will cease.

3. Short circuits: If the signal lead is short circuited to ground, HB ceases.

4. Signal range: If the internally processed signal falls below the sensing window (below 8 counts of signal) the HB ceases. This can occur if the electrode or its connection fails open-circuit.

5. Output transistor checks: If the output transistor becomes faulty, either failing shorted or open, the HB will cease, since the HB signal is superimposed on the actual output line.

Note also that Setup [J], Error Handling, can output an active low signal when the sensor is 'blind', for example during low signal conditions, recalibrations, and when the sense line is shorted to ground. The normal output signal when used with [J] can be the primary indication of both a safety detection and a fault, for example when used in conjunction with a panic switch application. A signal fault detected via [J] will also cause a 'panic output', while the HB pulses can be used to provide a redundant 'panic' indication if the sensor fails.
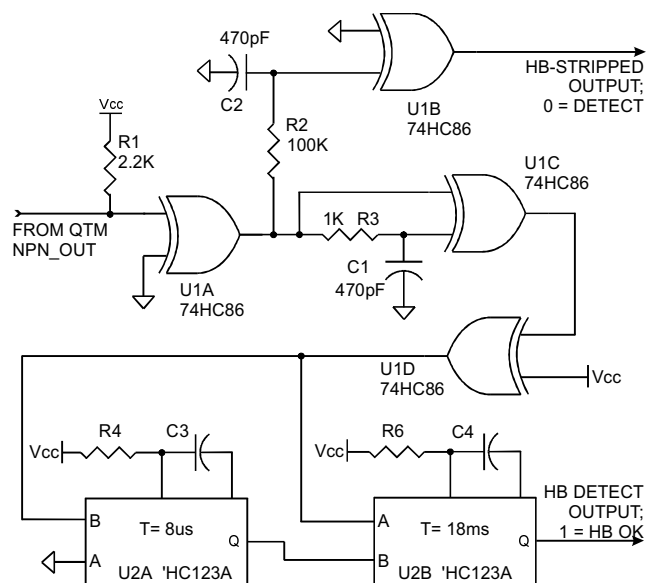
The HeartBeat signal can be used to monitor electrode failure even if the failure is a disconnect of a small portion of a large electrode, by connecting a suitable value of dummy capacitor to the far end of the electrode, to ground. If the electrode fails open even at its far end, for example if the electrode is a wire and the wire is cut near the end, the disconnection of the dummy cap will create enough of a signal drop to register as a 'low signal' detection. If [J] is set properly not only will the HB signal cease, but the output will go active low as well.

In critical applications the designer should be certain that possible failure modes are accounted for. Even the HB splitter circuit (or comparable software) should be designed for real-time periodic functional tests. This may take the form of the host machine simulating faults or exercising the HB splitter circuitry to be certain that it, too, is functional.

SIGNAL FLOW

The figure below shows the overall signal flow diagram, including both hardware and signal processing elements.

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 Σ 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.

More information can be found in the E2 user manual.
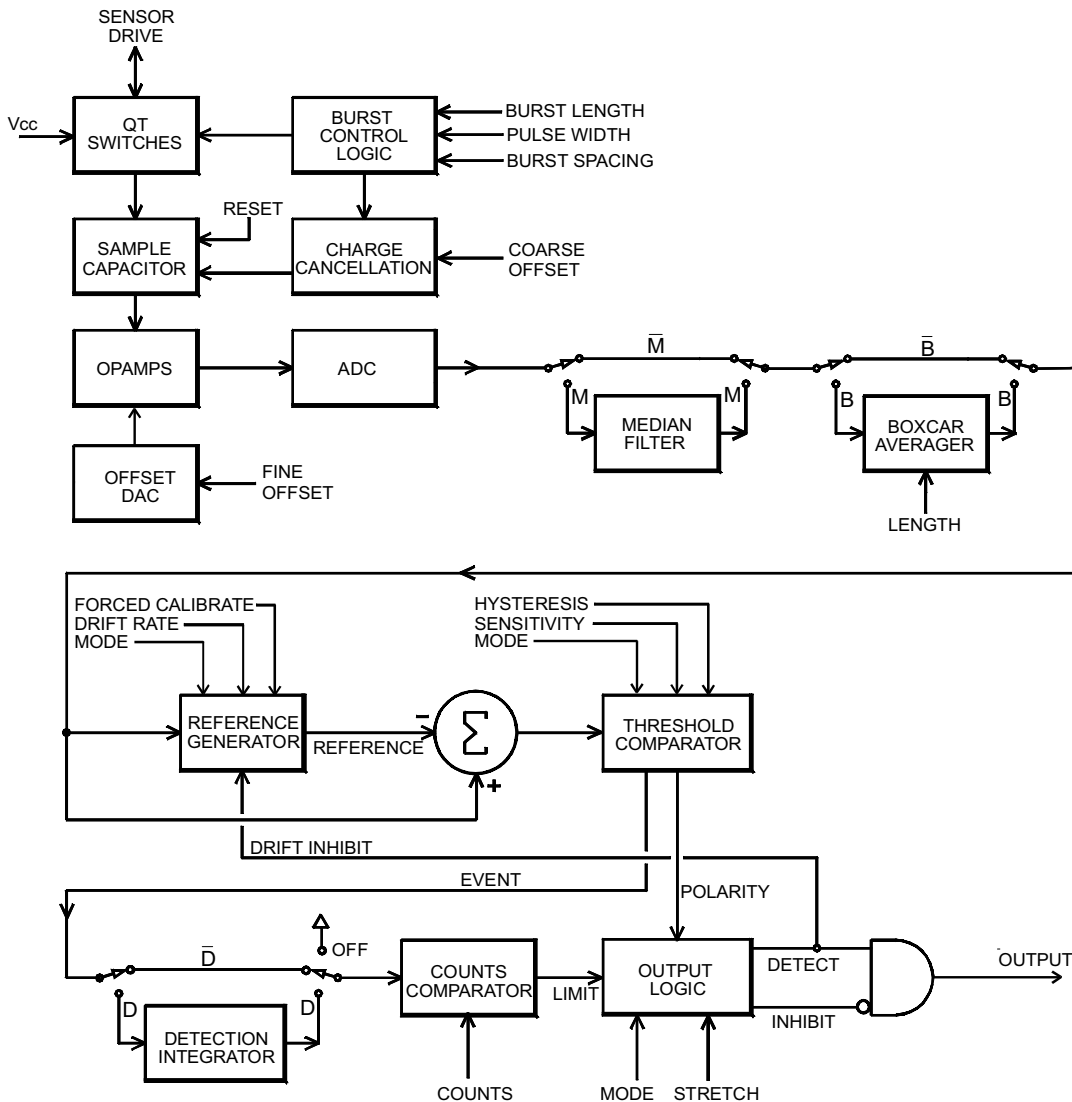
APPENDIX A - PCB DIMENSIONS

Dimensions in cm / (inches).

8.13 (3.20)

0.381 φ
(0.15 φ)
(4)

BG

clone pads

3.05 (1.20)

1.73 (0.68)

3.81 (1.50)

OBJ

1

8.66 (3.41)

5.72 (2.25)

0.927 (0.365)

7.37 (2.90)
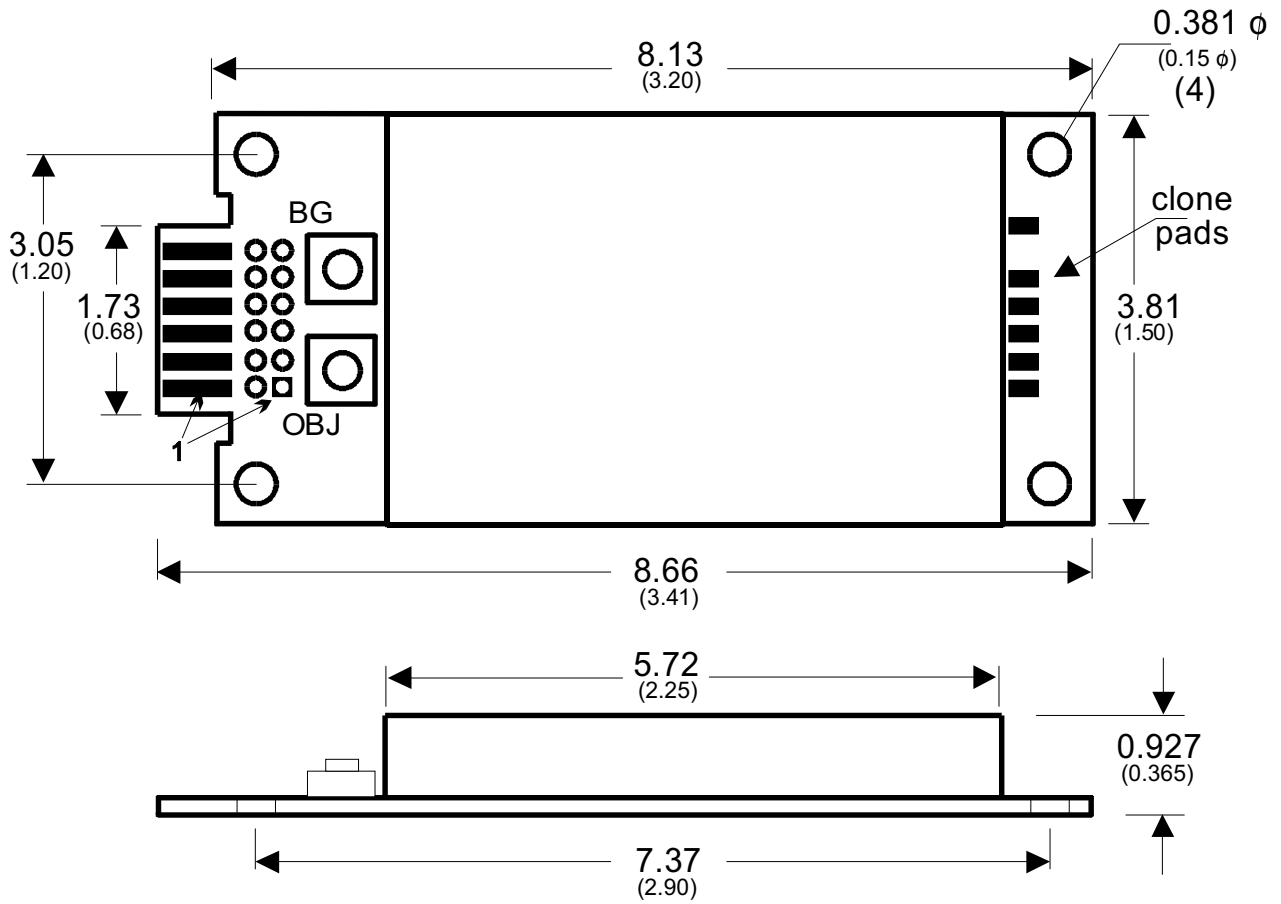
APPENDIX B - SPECIFICATIONS

ABSOLUTE MAXIMUM RATINGS

Operating temp . . . . -20 to +70°C
Storage temp . . . . -40°C to +100°C
Vsupply . . . . -50 to +30 V
Max continuous sense line current (forced) . . . . ±100mA
Short circuit duration to ground, sense line . . . . infinite
Input voltage on BG, OBJ lines . . . . ± 30V
Output current, NPN_OUT, PNP_OUT . . . . ±100mA
Voltage forced onto any control or drive pin . . . . -0.6V to (Vdd + 0.6) Volts

RECOMMENDED OPERATING CONDITIONS

V$_{DD}$ . . . . 7 to 20V DC
Supply ripple+noise . . . . 100mV rms
Load capacitance . . . . 0 to 2,500pF

CIRCUIT DETAILS

Cs value . . . . 12nF PPS film, thermally compensated
Cz value . . . . 56nF PPS film, thermally compensated
Amp gain, high . . . . 360 ±4%
Amp gain, low . . . . 22.5 ±2%
Charge voltage . . . . 5.0V ±0.1

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
Drift compensation rate	100	0.2	secs/lsb	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 eeprom interval	1	60	mins	Note 1, 3

Note 1: For possible presets see QTM Setups Table
Note 2: Value can be made arbitrary in BG/OBJ or OBJ learn modes.
Note 3: This feature can be disabled.

GAIN CHART

The following chart shows the gains of the QTM1001AS at various burst lengths and at both amp gain settings.

Gain Chart, QTM1001A

HIGH AMP GAIN

	In order of descending burst length							
	64	56	48	40	32	24	16	8
V / pF	1.69	1.48	1.27	1.06	0.85	0.64	0.42	0.21
fF / bit	11.6	13.2	15.4	18.5	23.1	30.9	46.3	92.6
% of Full Gain	100.00%	87.50%	75.00%	62.50%	50.00%	37.50%	25.00%	12.50%

LOW AMP GAIN

	In order of descending burst length							
	64	56	48	40	32	24	16	8
mV / pF	105.7	92.5	79.2	66.0	52.8	39.6	26.4	13.2
fF / bit	186	212	247	297	371	495	742	1485
% of Full Gain	6.24%	5.46%	4.68%	3.90%	3.12%	2.34%	1.56%	0.78%

DC SPECIFICATIONS   Vdd = 12V, Ta = recommended range, unless otherwise noted

parameter	description	min	typ	max	units	notes
V_S	Supply voltage	7		20	V	
I_{DD}	Supply current		20	30	mA	No sense or output loads, not detecting
V_{IL}	Low input logic level			0.8	V	XBG, XOBJ
V_{HL}	High input logic level	3			V	XBG, XOBJ
V_{OL}	Low output voltage, NPN			0.15 1.2	V	NPN_OUT, no load NPN_OUT, 100mA load
V_{OH}	High output voltage, PNP	Vs - 0.15 Vs - 1.2			V	PNP_OUT, no load PNP_OUT, 100mA load
R_{OUT}	NPN_OUT, PNP_OUT source resistance			20	Ω	
V_{AOUT}	Analog output range	0.02		4.98	V	Unloaded, full scale
R_{AOUT}	Analog output impedance		75	100	Ω	DC load
R_S	Sense lead series resistance			60	Ω	
I_S	Sense limiting current		55	90	mA	Pulse current
C_X	Load capacitance range	0		2,500	pF	
A_R	Acquisition resolution			8	bits	
A_L	Acquisition linearity			±1	lsb	
D_L	Differential linearity		1	1.5	lsb	
T_{CG}	Tempco of analog output, gain		±25	±45	ppm / $^{\circ}$C	
T_{CO}	Tempco of analog output, offset		3	6	mV / $^{\circ}$C	at full gain

MECHANICAL

description		units
dimensions overall	3.41l x 1.50w x 0.365d	inches
mounting hole pattern	2.90l x 1.20w x 0.15ϕ	inches
weight	32	grams
connector*	2 x 6, 2.54mm (0.1") pitch, 6.7mm depth	

*Sullins EZC06DREH or equivalent

CUSTOMIZATION

The QTM1001AS can be 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 cloning. If customized defaults are used, they can still be overridden by means of the cloning process.

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

Quantum Research Group Ltd

Patents and patents applied for

Notice: This device expressly not for use in any medical or human safety related application without the express written consent of an officer of the company.