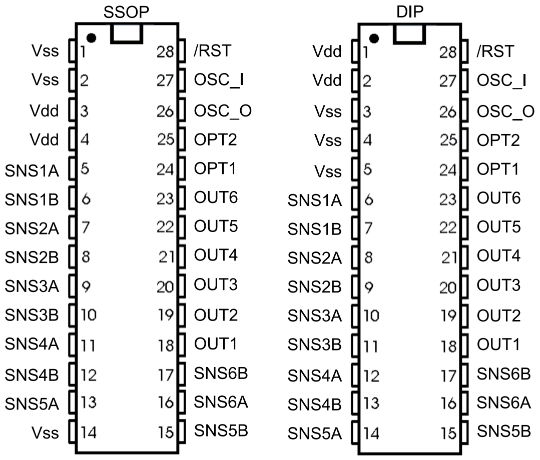
QProx™ QT160 / QT161
6 KEY CHARGE-TRANSFER QTOUCH™ SENSOR IC

- 6 completely independent touch circuits
- Individual logic outputs per channel (active high)
- Projects prox fields through any dielectric
- Only one external capacitor required per channel
- Sensitivity easily adjusted on a per-channel basis
- 100% autocal for life - no adjustments required
- 3-5.5V, 5mA single supply operation
- Toggle mode for on/off control (strap option)
- 10s, 60s, infinite auto-recal timeout (strap options)
- AKS™ Adjacent Key Suppression (QT160)
- Less expensive per key than many mechanical switches
- Eval board with backlighting - p/n E160
- Pb-Free package available (QT160-ASG)



NOTE: Pinouts are not the same!

APPLICATIONS

- PC Peripherals
- Backlighted buttons
- Appliance controls
- Security systems
- Access systems
- Pointing devices
- Instrument panels
- Gaming machines

QT160 / QT161 charge-transfer (“QT’”) QTouch ICs are self-contained digital controllers capable of detecting near-proximity or touch from up to 6 electrodes. They allow electrodes to project 6 independent sense fields through any dielectric like glass, plastic, stone, ceramic, and wood. They can also make metal-bearing objects responsive to proximity or touch by turning them into intrinsic sensors. These capabilities coupled with continuous self-calibration can lead to entirely new product concepts, adding high value to product designs.

Each of the 6 channels operate independently of the others, and each can be tuned for a unique sensitivity level by simply changing its sample capacitor value.

The devices are designed specifically for human interfaces, like control panels, appliances, gaming devices, lighting controls, or anywhere a mechanical switch or button may be found; they may also be used for some material sensing and control applications. The option-selectable toggle mode permits on/off touch control, for example for light switch replacement.

The devices require only a common inexpensive capacitor per channel in order to function. The QT160 also offers the unique adjacent key suppression (AKS™, patent pending) feature which suppresses touch from weaker responding keys and allows only a dominant key to detect, for example to solve the problem of large fingers on tightly spaced keys.

In most cases the power supply need only be minimally regulated, for example by an inexpensive 3-terminal regulator.

The RISC core of these devices employ signal processing techniques pioneered by Quantum; these are specifically designed to make the device survive real-world challenges, such as ‘stuck sensor’ conditions and signal drift.

By using the charge transfer principle, these parts deliver a level of performance clearly superior to older technologies yet are highly cost-effective.

AVAILABLE OPTIONS

T_A	DIP-28	SSOP-28	Notes
0°C to +70°C	QT160-D	-	
-40°C to +105°C	-	QT160-AS	
-40°C to +105°C	-	QT160-ASG	Pb-Free
0°C to +70°C	QT161-D	-	
-40°C to +105°C	-	QT161-AS	

1 - OVERVIEW

QT160/161 is a 6-channel burst mode digital charge-transfer (QT) sensor designed specifically for touch controls; they include all hardware and signal processing functions necessary to provide stable sensing under a wide variety of conditions. Only a single low cost, non-critical capacitor per channel is required for operation.

Figure 1-1 shows the basic circuit using the device. See Tables 7-1 and 7-2 (page 11) for pin listings. **The DIP and SOIC pinouts are not the same and serious damage can occur if a part is mis-wired).**

1.1 BASIC OPERATION

The devices employ bursts of charge-transfer cycles to acquire signals. Burst mode permits low power operation, dramatically reduces RF emissions, lowers susceptibility to RF fields, and yet permits excellent speed. Internally, signals are digitally processed to reject impulse noise using a 'consensus' filter that requires three consecutive confirmations of detection. Each channel is measured in sequence starting with channel 1.

The QT switches and charge measurement hardware functions are all internal to the device (Figure 1-2). A 14-bit single-slope switched capacitor ADC includes both the required QT charge and transfer switches in a configuration that provides direct ADC conversion. The ADC is designed to dynamically optimize the QT burst length according to the rate of charge buildup on Cs, which in turn depends on the values of Cs, Cx, and Vdd. Vdd is used as the charge reference voltage. Larger values of Cx cause the charge transferred into Cs to rise more rapidly, reducing available resolution; as a minimum resolution is required for proper operation, this can result in dramatically reduced apparent gain. Conversely, larger values of Cs reduce the rise of differential voltage across it, increasing available resolution by permitting longer QT bursts. The value of Cs can thus be increased to allow larger values of Cx to be tolerated. The IC is responsive to both Cx and Cs, and changes in Cs can result in substantial changes in sensor gain.

Option pins allow the selection of several timing features.

1.2 ELECTRODE DRIVE

The devices have 6 independent channels. The internal ADC treats Cs on each channel as a floating transfer capacitor; as a direct result, the sense electrode can be connected to either SNS1A or SN1B with no performance difference. In both cases the rule Cs >> Cx must be observed for proper operation. The polarity of the charge buildup across Cs during a burst is the same in either case.

It is possible to connect separate Cx and Cx' loads to SNS1A and SNS1B simultaneously, although the result is no different than if the loads were connected together at SNS1A (or SNS1B). It is important to limit the amount of stray capacitance on both terminals, especially if the load Cx is already large, for example by minimizing trace lengths and widths so as not to exceed the Cx load specification and to allow for a larger sensing electrode size if so desired.

Unused channels: If a channel is not used, a dummy nominal 1nF sense capacitor of any type must be connected to the SNS pins ensure correct operation.

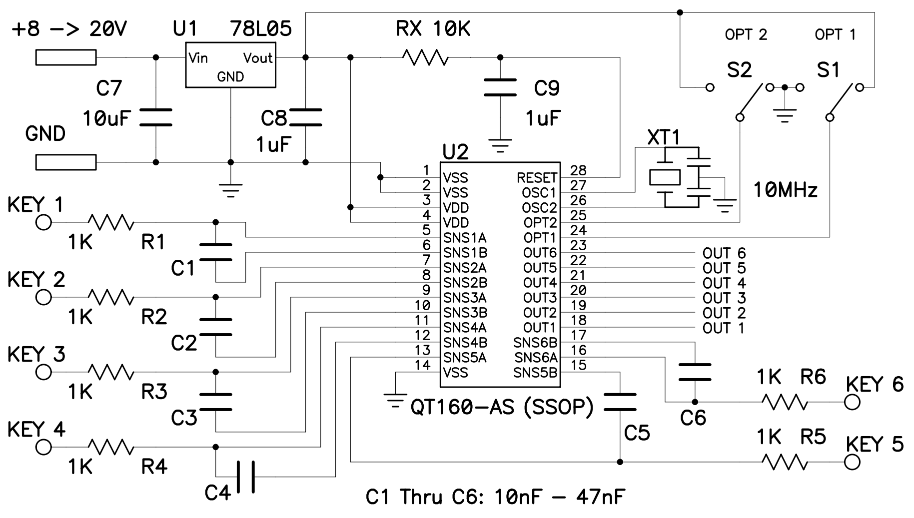
The PCB traces, wiring, and any components associated with or in contact with SNS1A and SNS1B will become touch sensitive and should be treated with caution to limit the touch area to the desired location. Multiple touch electrodes can be used, for example to create a control button on both sides of an object, however it is impossible for the sensor to distinguish between the two touch areas.

1.3 KEY DESIGN

1.3.1 Key Geometry and Size

There is no restriction on the shape of the key electrode; in most cases common sense and a little experimentation can result in a good electrode design. The devices will operate equally well with long, thin keys as with round or square ones; even random shapes are acceptable. The electrode can also be a 3-dimensional surface or object. Sensitivity is related to the amount of surface metallization, touch contact area, overlying panel material and thickness, and ground coupling quality of the sensor circuit.

Figure 1-1 Recommended Basic Circuit (SSOP Package)

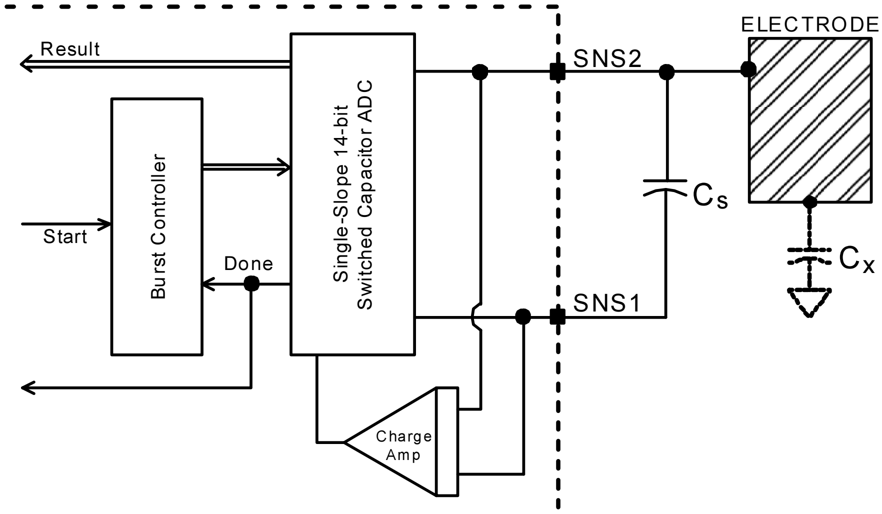


If a relatively large touch area is desired, and if tests show that the electrode has more capacitance than the part can tolerate, the electrode can be made into a sparse mesh (Figure 1-3) having lower Cx than a solid plane.

1.3.2 Backlighting Keys

Touch pads can be back-illuminated quite readily using electrodes with a hole in the middle (Figure 1-4). The holes can be as large as 4 cm in diameter provided that the ring of metal is at least twice as wide as the thickness of the overlying panel, and the panel is greater than 1/8 as thick as the diameter of the hole. Thin panels do not work well with this method they

Figure 1-2 Internal Switching & Timing



do not propagate fields laterally very well, and will have poor sensitivity in the middle. Experimentation is required.

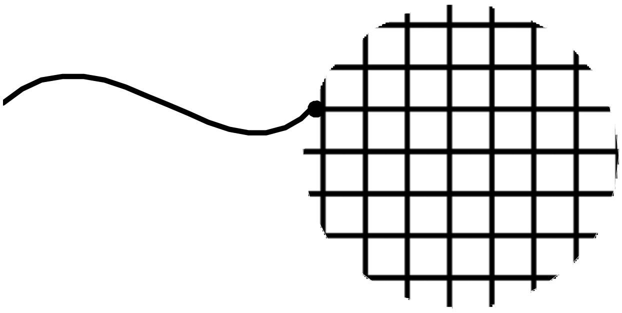
Since the channels acquire their signals in time-sequence, any of the 6 electrodes can be placed in direct proximity to each other if desired without cross-interference.

A good example of backlighting can be found in the E160 eval board for the QT160.

1.3.3 Kirchoff's Current Law

Like all capacitance sensors, these parts rely on Kirchoff's Current Law (Figure 1-5) to detect the change in capacitance of the electrode. This law as applied to capacitive sensing requires that the sensor's field current must complete a loop, returning back to its source in order for capacitance to be sensed. Although most designers relate to Kirchoff's law with regard to hardwired circuits, it applies equally to capacitive field flows. By implication it requires that the signal ground and the target object must both be coupled together in some manner for a capacitive sensor to operate properly. Note that there is no need to provide actual hardwired ground connections; capacitive coupling to ground (Cx1) is always sufficient, even if the coupling might seem very tenuous. For example, powering the sensor via an isolated transformer will provide ample ground coupling, since there is capacitance between the windings and/or the transformer core, and from the power wiring itself directly to 'local earth'. Even when battery powered, just the physical size of the PCB and the object into which the electronics is embedded will generally be enough to couple a few picofarads back to local earth.

Figure 1-3 Mesh Key Geometry



Electrodes connected to the IC themselves act as coupling plates back to local ground, since when one channel is sensing the other channels are clamped to circuit ground.

1.3.4 Virtual Capacitive Grounds

When detecting human contact (e.g. a fingertip), grounding of the person is never required. The human body naturally has several hundred picofarads of 'free space' capacitance to the local environment (Cx3 in Figure 1-5), which is more than two orders of magnitude greater than that required to create a return path to the IC via earth. The PCB however can be physically quite small, so there may be little 'free space' coupling (Cx1 in Figure 1-5) between it and the environment to complete the return path. If the circuit ground cannot be earth grounded by wire, for example via the supply connections, then a 'virtual capacitive ground' may be required to increase return coupling.

A 'virtual capacitive ground' can be created by connecting the IC's own circuit ground to:

(1) A nearby piece of metal or metallized housing;
(2) A floating conductive ground plane;
(3) A nail driven into a wall;
(4) A larger electronic device (to which its output might be connected anyway).

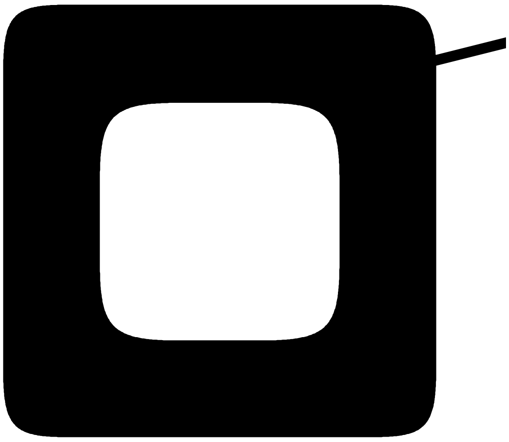


Figure 1-4 Open Electrode for Back-Illumination

Free-floating ground planes such as metal foils should maximize exposed surface area in a flat plane if possible. A square of metal foil will have little effect if it is rolled up or crumpled into a ball. Virtual ground planes are more effective and can be made smaller if they are physically bonded to other surfaces, for example a wall or floor.

1.3.5 Field Shaping

The electrode can be prevented from sensing in undesired directions with the assistance of metal shielding connected to circuit ground (Figure 1-6). For example, on flat surfaces, the field can spread laterally and create a larger touch area than desired. To stop field spreading, it is only necessary to surround the touch electrode on all sides with a ring of metal connected to circuit ground; the ring can be on the same or opposite side from the electrode. The ring will kill field spreading from that point outwards.

If one side of the panel to which the electrode is fixed has moving traffic near it, these objects can cause inadvertent detections. This is called 'walk-by' and is caused by the fact that the fields radiate from either surface of the electrode equally well. Again, shielding in the form of a metal sheet or foil connected to circuit ground will prevent walk-by; putting a small air gap between the grounded shield and the electrode will keep the value of Cx lower and is encouraged. In the case of the QT160/161, sensitivity can be high enough (depending on Cx and Cs) that 'walk-by' signals are a concern; if this is a problem, then some form of rear shielding may be required.

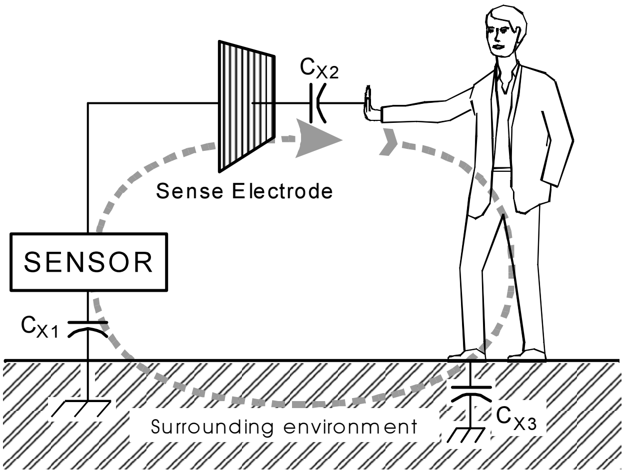
1.3.6 SENSITIVITY

Sensitivity can be altered to suit various applications and situations on a channel-by-channel basis. The easiest and most direct way to impact sensitivity is to alter the value of Cs. More Cs yields higher sensitivity.

1.3.6.1 Alternative Ways to Increase Sensitivity

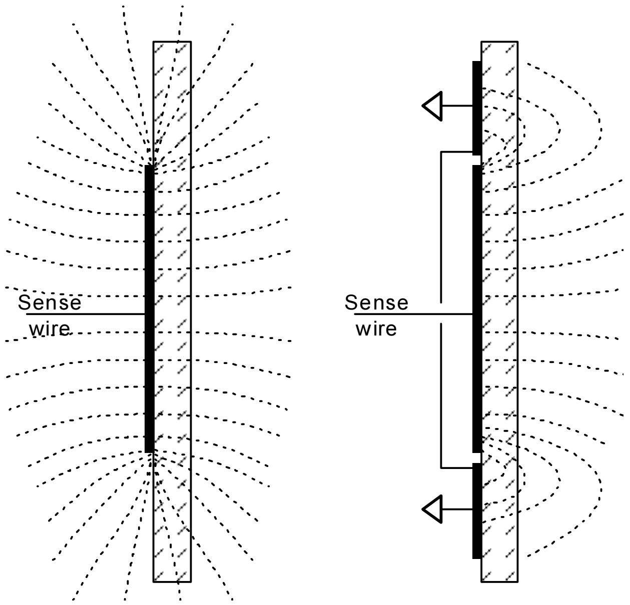
Sensitivity can also be increased by using bigger electrodes, reducing panel thickness, or altering panel composition.

Figure 1-5 Kirchoff's Current Law



Increasing electrode size can have diminishing returns, as high values of Cx counteract sensor gain. Also, increasing the electrode's surface area will not substantially increase touch sensitivity if its diameter is already much larger in surface area than the object being detected. The panel or other intervening material can be made thinner, but again there are diminishing rewards for doing so. Panel material can also be changed to one having a higher dielectric constant, which will help propagate the field through to the front. Locally adding some conductive material to the panel (conductive materials essentially have an infinite dielectric constant) will also help; for example, adding carbon or metal fibers to a plastic panel will greatly increase frontal field strength, even if the fiber density is too low to make the plastic bulk-conductive.

Figure 1-6 Shielding Against Fringe Fields



1.3.6.2 Decreasing Sensitivity

In some cases the QT160 may be too sensitive. In this case gain can be lowered further by a number of strategies:
a) making the electrode smaller, b) making the electrode into a sparse mesh using a high space-to-conductor ratio (Figure 1-3), or c) by decreasing the Cs capacitors.

2 - QT160/QT161 SPECIFICS

2.1 SIGNAL PROCESSING

The QT160 processes all signals using 16 bit math, using a number of algorithms pioneered by Quantum. The algorithms are specifically designed to provide for high survivability in the face of adverse environmental changes.

2.1.1 DRIFT COMPENSATION ALGORITHM

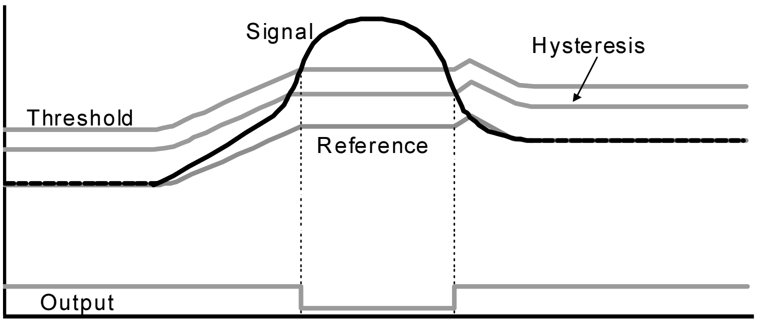
Signal drift can occur because of changes in Cx, Cs, and Vdd over time. If a low grade Cs capacitor is chosen, the signal can drift greatly with temperature. If keys are subject to extremes of temperature and humidity, the signal can also shift. It is crucial that drift be compensated, else false detections, non-detections, and sensitivity shifts will follow.

Drift compensation (Figure 2-1) is a method that makes the reference level track the raw signal at a slow rate, only while no detection is in effect. The rate of reference adjustment must be performed slowly else legitimate detections can also be ignored. The IC drift compensates each channel independently using a slew-rate limited change to the reference level; the threshold and hysteresis values are slaved to this reference.

Once an object is sensed, the drift compensation mechanism ceases since the signal is legitimately high, and therefore should not cause the reference level to change.

The signal drift compensation is 'asymmetric'; the reference level drift-compensates in one direction faster than it does in the other. Specifically, it compensates faster for decreasing signals than for increasing signals. Increasing signals should not be compensated for quickly, since an approaching finger

Figure 2-1 Drift Compensation



could be compensated for partially or entirely before even approaching the sense electrode. However, an obstruction over the sense pad, for which the sensor has already made full allowance for, could suddenly be removed leaving the sensor with an artificially elevated reference level and thus become insensitive to touch. In this latter case, the sensor will compensate for the object's removal very quickly, usually in only a few seconds.

With large values of Cs and small values of Cx, drift compensation will appear to operate more slowly than with the converse.

2.1.2 Threshold Calculation

The internal threshold level is fixed at 6 counts for all channels. These IC's employ a fixed hysteresis of 2 counts below the threshold (33%).

2.1.3 Max On-Duration

If an object or material contacts a sense pad the signal may rise enough to trigger an output, preventing further normal operation. To prevent this ‘stuck key’ condition, the sensor includes a timer on each channel to monitors detections. If a detection exceeds the timer setting, the timer causes the sensor to perform a full recalibration (when not set to infinite). This is known as the Max On-Duration feature.

After the Max On-Duration interval, the sensor channel will once again function normally, even if partially or fully obstructed, to the best of its ability given electrode conditions. There are three timeout durations available via strap option: 10s, 60s, and infinite (disabled) (Table 2-1).

Max On-Duration works independently per channel; a timeout on one channel has no effect on another channel except when the AKS feature is impacted on an adjacent key. Note also that the timings in Table 2-1 are dependent on the oscillator frequency: Doubling the recommended frequency will halve the timeouts.

Infinite timeout is useful in applications where a prolonged detection can occur and where the output must reflect the detection no matter how long. In infinite timeout mode, the designer should take care to be sure that drift in Cs, Cx, and Vdd do not cause the device to ‘stick on’ inadvertently even when the target object is removed from the sense field.

The delay timings for max on-duration will increase if the total duration of all bursts is greater than 33ms, i.e. an average of 5.5ms per channel.

2.1.4 Detection Integrator

It is desirable to suppress detections generated by electrical noise or from quick brushes with an object. To accomplish this, the IC's incorporate a detect integration counter that increments with each detection until a limit is reached, after which the output is activated. If no detection is sensed prior to the final count, the counter is reset immediately to zero. In the QT160/161, the required count is 3.

The Detection Integrator can also be viewed as a 'consensus' filter, that requires three detections in three successive bursts to create an output.

2.1.5 Forced Sensor Recalibration

Pin 28 is a Reset pin, active-low, which in cases where power is clean can be simply tied to Vdd. On power-up, the device will automatically recalibrate all 6 channels of sensing.

Pin 28 can also be controlled by logic or a microcontroller to force the chip to recalibrate, by toggling it low for 5µs then raising it high again.

The option pins are read by the IC once each acquisition cycle and can be changed during operation.

2.1.6 Response Time

Response time is fixed at 99ms at a 10MHz clock. Response time can be altered by changing the clock frequency. Doubling the recommended clock frequency to 20MHz will halve the response time to 49ms.

Response time will become slower if the total duration of all bursts is greater than 33ms, i.e. an average of 5.5ms per channel.

2.2 OUTPUT FEATURES

The ICs are designed for maximum flexibility and can accommodate most popular sensing requirements. These are selectable using strap options on pins OPT1 and OPT2. All options are shown in Table 2-1.

2.2.1 DC Mode Output

The outputs of these ICs can respond in a DC mode, where they are active upon detection. The output will remain active for the duration of the detection, or until the Max On-Duration expires (if not infinite), whichever occurs first. If a max on-duration timeout occurs first, the sensor performs a full recalibration and the output becomes inactive until the next detection.

2.2.2 Toggle Mode Output

This makes the sensor respond in an on/off mode like a flip flop. It is most useful for controlling power loads, for example in kitchen appliances, power tools, light switches, etc.

Max On-Duration in Toggle mode is fixed at 10 seconds. When a timeout occurs, the sensor recalibrates but leaves the output state unchanged.

2.2.3 Output Drive

The outputs are active-high and can source 1mA and sink 5mA of non-inductive current. If inductive loads are used, such as small relays, the inductances should be diode clamped to prevent damage. When set to operate in a proximity mode (at high gain) Out currents should be limited to 1mA to prevent gain shifting side effects from occurring, which happens when the load current creates voltage drops on the die and bonding wires; these small shifts can materially influence the signal level to cause detection instability as described below.

Care should be taken when the IC and the loads are both powered from the same supply, and the supply is minimally regulated. The QT160/161 derives its internal references from the power supply, and sensitivity shifts can occur with changes in Vdd, as happens when loads are switched on. This can induce detection ‘cycling’, whereby an object is detected, the load is turned on, the supply sags, the detection is no longer sensed, the load is turned off, the supply rises and the object is reacquired, *ad infinitum.* To prevent this occurrence, the Out pins should only be lightly loaded if the device is operated from an unregulated supply, e.g. batteries. Detection ‘stiction’, the opposite effect, can occur if a load is *shed* when an Out pin is active.

The outputs of the IC can directly drive LEDs with series resistors. The LEDs should be connected with anodes to the outputs and cathodes towards Vss, so that it lights when the sensor is active.

2.3 AKS™ - Adjacent Key suppression

The QT160 (not QT161) features adjacent key suppression for use in applications where keys are tightly spaced. If keys are very close and a large finger touches one key, the keys on either side might also activate. AKS stops detections on adjacent keys by comparing relative signal levels among them and choosing the key with the largest signal strength.

Key number 1 will cause a suppression of keys 6 and 2. Key number 2 will cause a suppression of keys 1 and 3. Key 3 will cause a suppression of keys 2 and 4 and so on.

When a touch is detected on a key, but just before the corresponding OUT pin is activated, a check is made for a detection on the adjacent keys. If OUT is active on one or both of the adjacent keys, *or if a signal of greater strength is found on them*, the key is suppressed. This means that it is not possible to activate both keys 3 and 4 for example; if 4 is already on when 3 is touched, key 3 will be suppressed. Likewise, if keys 3 and 4 are both touched, but 3 has a weaker signal than 4 at the moment the decision is made, then only key 4 will detect and 3 will be suppressed. Once the detected key is released, the other key is free to detect.

Drift compensation also ceases for the key or keys which have been suppressed, so long the signal on it is greater than its threshold level.

This feature is also very effective on water films which bridge over adjacent keys. When touching one key a water film will ‘transport’ the touch to the adjacent keys covered by the same film. These side keys will receive less signal strength than the key actually being touched, and so they will be suppressed even if the signal they are detecting is large enough to otherwise cause an output.

3 - CIRCUIT GUIDELINES

3.1 SAMPLE CAPACITOR

Charge sampler caps Cs can be virtually any plastic film or low to medium-K ceramic capacitor. The acceptable Cs range is from 10nF to 47nF depending on the sensitivity required; larger values of Cs demand higher stability to ensure reliable sensing. Acceptable capacitor types include polyester film, PPS film, or NP0 / C0G ceramic.

Table 2-1 Strap Options

	OPT1	OPT2	Max On-Duration
DC Out	Gnd	Vdd	10s
DC Out	Vdd	Gnd	60s
Toggle	Vdd	Vdd	10s
DC Out	Gnd	Gnd	infinite

3.2 OPTION STRAPPING

The option pins OPT1 and OPT2 should never be left floating. If they are floated, the device can draw excess power and the options will not be properly read.

See Table 2-1 for options. Note that the timings shown are depend inversely on the oscillator frequency: Doubling the recommended frequency will halve the timeouts.

3.3 POWER SUPPLY, PCB LAYOUT

The power supply can range from 4.5 to 5.5 volts. If this fluctuates slowly with temperature, the QT160/161 will track and compensate for these changes automatically with only minor changes in sensitivity.

If the power supply is shared with another electronic system, care should be taken to assure that the supply is free of digital spikes, sags, and surges which can adversely affect the IC. The QT160/161 will track slow changes in Vdd, but it can be seriously affected by rapid voltage steps.

The supply is best locally regulated using a conventional 78L05 type regulator, or almost any 3-terminal LDO device from 3V to 5V.

For proper operation a 0.1µF or greater bypass capacitor should be used between Vdd and Vss; the bypass cap should be placed very close to the device’s power pins.

3.4 OSCILLATOR

The oscillator should be a 10MHz resonator with ceramic capacitors to ground on each side. 3-pin resonators with built-in capacitors designed for the purpose are inexpensive and commonly found. Manufacturers include AVX, Murata, Panasonic, etc.

Alternatively an external clock source can be used in lieu of a resonator. The OSC_I pin should be connected to the external clock, and OSC_O should be left unconnected.

These ICs are fully synchronous, clocked devices that operate all sections from the OSC_I clock. If the frequency of OSC_I is changed, all timings will also change in direct proportion, from the charge and transfer times to the detection response times and the max on-duration timings.

3.5 UNUSED CHANNELS

Unused signal channels should not be left open. They should have a small value non-critical dummy Cs capacitor connected to their SNS pins to allow the internal circuit to continue to function properly. A nominal value of 1nF (1,000pF) X7R will suffice.

Unused channels should not have sense traces or electrodes connected to them.

3.6 ESD PROTECTION

In cases where the electrode is placed behind a dielectric panel, the IC will be protected from direct static discharge. However even with a panel, transients can still flow into the electrodes via induction, or in extreme cases via dielectric breakdown. Porous materials may allow a spark to tunnel right through the material. Testing is required to reveal any problems. The device does have diode protection on its SNS pins which absorb and protect the device from most induced discharges, up to 20mA; the usefulness of the internal clamping will depending on the dielectric properties, panel thickness, and rise time of the ESD transients.

In extreme cases ESD dissipation can be aided further with added series resistors in line with the electrodes as shown in Figure 1-1. Because the charge time is 1.2 µs, the circuit can tolerate large values of series-R, up to 20k ohms in cases where electrode Cx load is below 10pF. Extra diode protection at the electrodes can also be used, but this often leads to additional RFI problems as the diodes will rectify RF signals into DC which will disturb the measurement.

Directly placing semiconductor transient protection devices or MOV's on the sense leads is not advised; these devices have extremely large amounts of nonlinear parasitic C which will swamp the capacitance of the electrode.

Series-R’s should be low enough to permit at least 6 RC time-constants to occur during the charge and transfer phases, where R is the added series-R and C is the load Cx.

If the device is connected to an external control circuit via a cable or long twisted pair, it is possible for ground-bounce to cause damage to the Out pins and/or interfere with key sensing. Noise current injection into the power supply is best dealt with by shunting the noise aside to chassis ground with capacitors, and limited using resistors or ferrites.

3.7 RFI PROTECTION

PCB layout, grounding, and the structure of the input circuitry have a great bearing on the success of a design that can withstand strong RF interference.

The circuit is remarkably immune to RFI provided that certain design rules be adhered to:

1. Use SMT components to minimize lead lengths.
2. Always use a ground plane under and around the circuit and along the sense lines, that is as unbroken as possible except for relief under and beside the sense lines to reduce total Cx. Relieved rear ground planes should be ‘mended’ by bridging over them at 1cm intervals with 0.5mm ‘rungs’ like a ladder.
3. Ground planes should be connected only to a common point near the Vss pins of the IC.
4. Route sense traces away from other traces or wires that are connected to other circuits.
5. Sense electrodes should be kept away from other circuits and grounds which are not directly connected to the sensor’s own circuit ground; other grounds will appear to float at high frequencies and couple RF currents into the sense lines.
6. Keep the 6 Cs sampling capacitors and all series-R components close to the IC.
7. Use a 0.1µF minimum ceramic bypass cap very close to the QT160/161 supply pins.
8. Use series-R’s in the sense lines, of as large a value as the circuit can tolerate.
9. Bypass input power to chassis ground and again at circuit ground to reduce line-injected noise effects. Ferrites over the power wiring may be required to attenuate line injected noise.

Achieving RF immunity mostly requires diligence and a good working knowledge of grounding, shielding, and layout techniques.

4.1 ABSOLUTE MAXIMUM SPECIFICATIONS

Operating temp.	as designated by suffix
Storage temp.	-55°C to +125°C
V_{DD}	-0.5 to +7.0V
Max continuous pin current, any control or drive pin	±20mA
Short circuit duration to ground, any pin	infinite
Short circuit duration to V_{DD}, any pin	infinite
Voltage forced onto any pin	-0.6V to (Vdd + 0.6) Volts

4.2 RECOMMENDED OPERATING CONDITIONS

V_{DD}	+3.0 to 5.5V
Operating temperature range, 4.5V - 5.5V (QT160-AS, QT161-AS)	-40 - +105C
Operating temperature range, 3.0V - 4.5V (QT160-AS, QT161-AS)	-40 - +85C
Operating temperature range (QT160-D, QT161-D)	0 - +70C
Operating frequency, 4.5V - 5.5V	4 - 20MHz
Operating frequency, 3.0V - 5.5V	4 - 10MHz
Short-term supply ripple+noise	±5mV/s
Long-term supply stability	±100mV
Cs value	1nF to 200nF
Cx value	0 to 100pF

4.3 AC SPECIFICATIONS

Vdd = 5.0, Ta = recommended, Cx = 5pF, Cs = 39nF, Fosc = 10MHz

Parameter	Description	Min	Typ	Max	Units	Notes
T_{RC}	Recalibration time			330	ms	
T_{PC}	Charge duration		1.2		µs	
T_{PT}	Transfer duration		1.6		µs	
T_{BS}	Burst spacing interval		33		ms	
T_{BL}	Burst duration, each channel		3		ms	
N_{BL}	Burst length, each channel		1,000		counts	
T_{BLMR}	Allowable burst duration range	0.1		5.5	ms	Before all timings degrade
T_R	Response time		99		ms	Including detection integrator

4.4 DC SPECIFICATIONS

Vdd = 5.0V, Cs = 39nF, Cx = 5pF, Fosc = 10MHz, Ta = recommended range, unless otherwise noted

Parameter	Description	Min	Typ	Max	Units	Notes
I_{DD}	Supply current		2.5	8	mA	
V_{DDS}	Supply turn-on slope	100			V/s	Req'd for startup, w/o reset circuit
V_{IL}	Low input logic level			0.7	V	OPT1, OPT2
V_{HL}	High input logic level	2			V	OPT1, OPT2
V_{OL}	Low output voltage			0.6	V	OUTn, 4mA sink
V_{OH}	High output voltage	Vdd-0.7			V	OUTn, 1mA source
I_{IL}	Input leakage current			±1	µA	OPT1, OPT2
A_R	Acquisition resolution		10	14	bits	

4.5 SIGNAL PROCESSING

Description	Min	Typ	Max	Units	Notes
Threshold differential		6		counts	
Hysteresis		2		counts	
Consensus filter length (Detection integrator)		3		samples	
Positive drift compensation rate		990		ms/level	
Negative drift compensation rate		231		ms/level	
Post-detection recalibration timer duration		10, 60, infinite		secs	Option pin selected

All curves at Vdd = 5.0V

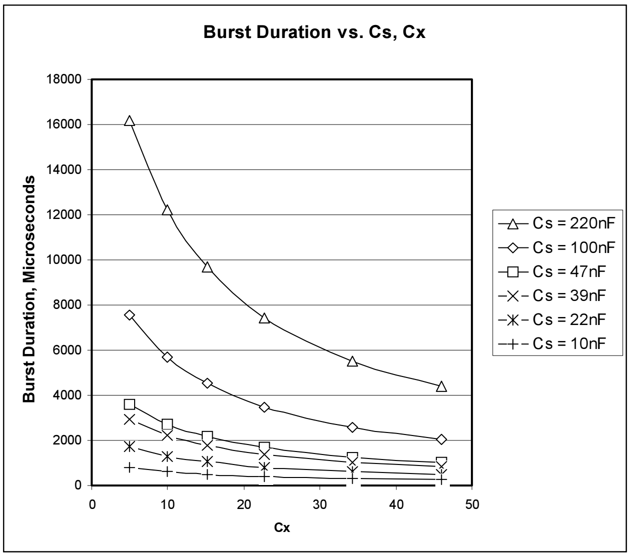


Figure 4-1

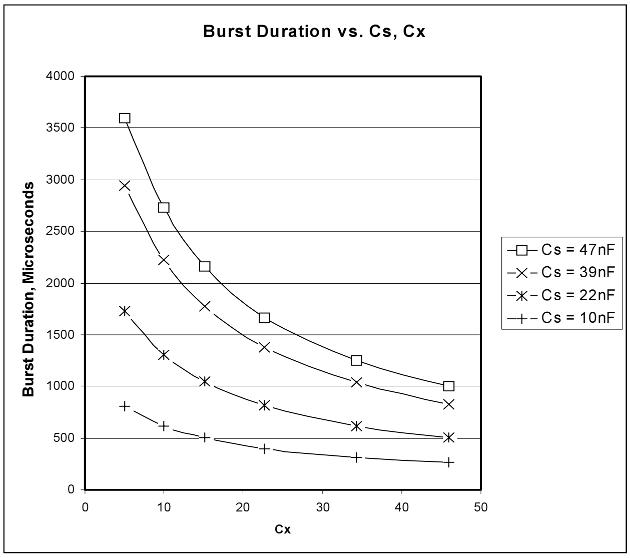


Figure 4-2

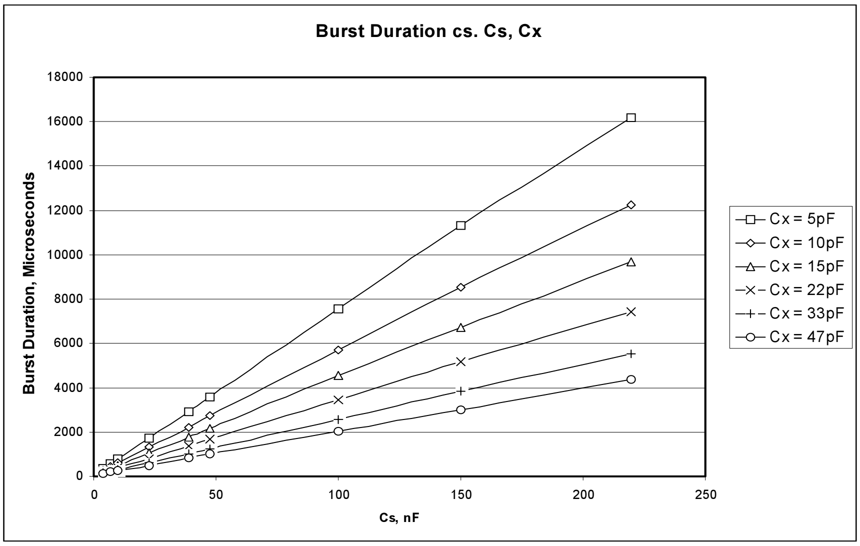
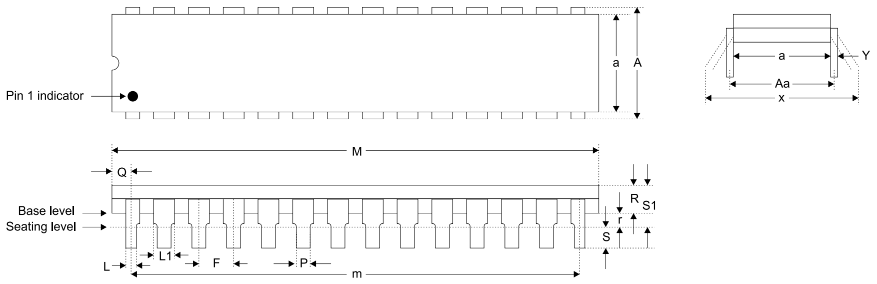


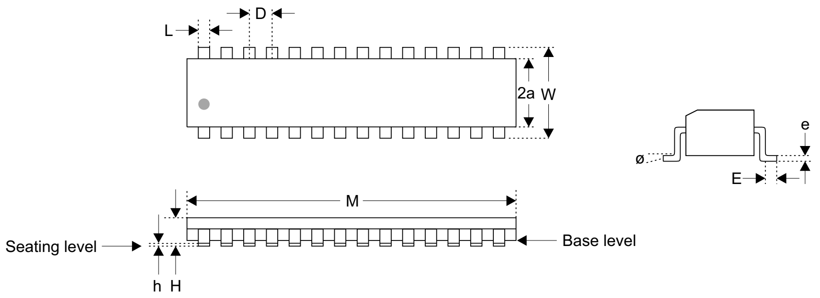
Figure 4-3

5 - PACKAGE OUTLINES



Package type: 28-Pin 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



Package type: 28-pin SSOP

SYMBOL	Millimeters			Inches		
	Min	Max	Notes	Min	Max	Notes
M	10.070	10.33		0.396	0.407	
W	7.650	7.9		0.301	0.311	
2a	5.200	5.38		0.205	0.212	
D	0.650	0.65		0.026	0.026	
L	0.250	0.38		0.010	0.015	
E	0.550	0.95		0.022	0.037	
e	0.130	0.22		0.005	0.009	
Ø	0º	8º		0º	8º	
H	1.730	1.99		0.068	0.078	
h	0.050	0.21		0.002	0.008	

7 - PIN LISTINGS

Table 7-1 Pin Descriptions - QT160-D

Pin	Name	Function
1	Vdd	Positive power
2	Vdd	Positive power
3	Vss	Negative power (Ground)
4	Vss	Negative power (Ground)
5	Vss	Negative power (Ground)
6	SNS1A	Channel 1 pin A to key
7	SNS1B	Channel 1 pin B
8	SNS2A	Channel 2 pin A to key
9	SNS2B	Channel 2 pin B
10	SNS3A	Channel 3 pin A to key
11	SNS3B	Channel 3 pin B
12	SNS4A	Channel 4 pin A to key
13	SNS4B	Channel 4 pin B
14	SNS5A	Channel 5 pin A to key
15	SNS5B	Channel 5 pin B
16	SNS6A	Channel 6 pin A to key
17	SNS6B	Channel 6 pin B
18	OUT1	Detection output 1 (active high)
19	OUT2	Detection output 2 (active high)
20	OUT3	Detection output 3 (active high)
21	OUT4	Detection output 4 (active high)
22	OUT5	Detection output 5 (active high)
23	OUT6	Detection output 6 (active high)
24	OPT1	Option input 1
25	OPT2	Option input 2
26	OSC_O	Oscillator output
27	OSC_I	Oscillator input
28	/RST	Reset / recalibrate (active low)

Table 7-2 Pin Descriptions - QT160-AS

Pin	Name	Function
1	Vss	Negative power (Ground)
2	Vss	Negative power (Ground)
3	Vdd	Positive power
4	Vdd	Positive power
5	SNS1A	Channel 1 pin A to key
6	SNS1B	Channel 1 pin B
7	SNS2A	Channel 2 pin A to key
8	SNS2B	Channel 2 pin B
9	SNS3A	Channel 3 pin A to key
10	SNS3B	Channel 3 pin B
11	SNS4A	Channel 4 pin A to key
12	SNS4B	Channel 4 pin B
13	SNS5A	Channel 5 pin A to key
14	Vss	Negative power (Ground)
15	SNS5B	Channel 5 sense pin B
16	SNS6A	Channel 6 sense pin A to key
17	SNS6B	Channel 6 sense pin B
18	OUT1	Detection output 1 (active high)
19	OUT2	Detection output 2 (active high)
20	OUT3	Detection output 3 (active high)
21	OUT4	Detection output 4 (active high)
22	OUT5	Detection output 5 (active high)
23	OUT6	Detection output 6 (active high)
24	OPT1	Option input 1
25	OPT2	Option input 2
26	OSC_O	Oscillator output
27	OSC_I	Oscillator input
28	/RST	Reset / recalibrate (active low)

8 - ORDERING INFORMATION

PART	TEMP RANGE	PACKAGE	MARKING	LEAD-FREE
QT160-D	0 - 70C	PDIP-28	QT160	NO
QT160-AS	-40 - 105C	SSOP-28	QT160-A	NO
QT160-ASG	-40 - 105C	SSOP-28	QT160-AG	YES
QT161-D	0 - 70C	PDIP-28	QT161	NO
QT161-AS	-40 - 105C	SSOP-28	QT161-A	NO

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