The Current Test Company

QT-1410

Advanced Transient (IDDT) / Dynamic Supply Current Monitor

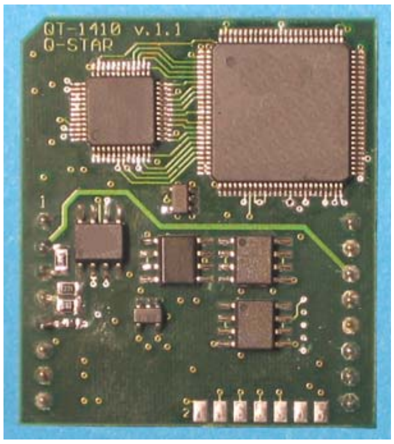
FEATURES

- VDUT Range: -5 to +50V
- Negligible or no voltage drop
- Measurement range: 5mA up to 100A or more
- IDDT best resolution: 5µA$_{RMS}$
- Measurement bandwidth: up to 10MHz
- Data sampling rate: typ. 50MHz
- High measurement repetition rate: up to 3MHz
- Loading Capacitance: up to 100µF
- Optional data storage capability
- On-board data processing capabilities

APPLICATIONS

- Transient Supply Current Measurement
- Dynamic (supply) Current Measurements
- IDDT Peak Measurements
- QDDT Charge Measurements
- Energy Measurement
- Pulse Width Measurement
- IDD(Q) Measurement
- IDD Complete Waveform Capture
- DUT Voltage Measurement
- Current signature analysis
- Off-line data analysis (FFT, …)

DESCRIPTION



The QT-1410 is a fast and sensitive digital transient supply current (IDDT) monitor designed for loadboard applications. Depending on application constraints, the QT-1410 is configured to be used either as a serial or as a parallel measurement device. The serial application allows high-speed high-resolution measurements and is suited for measurement ranges up to 500mA, reduced capacitive loading and DUT supply voltages in the -5 to 7V range. The parallel application targets measurement ranges above 500mA and DUT supply voltages up to 50V. A QT-1410 configured for parallel application either exploits the parasitic resistance of the supply interconnect or makes use of an AC coupling.

The QT-1410's unique design ensures transparency to both the ATE and DUT, under all conditions. When inserted in the DUT supply path (serial application), the QT-1410 causes only a negligible voltage drop. When used as a parallel device the module itself causes no voltage drop and does not affect the DUT' supply level or its operation.

The QT-1410 is designed to accurately quantify and compare transient (supply) currents of up to 100A (500mA for the serial configuration), thereby providing a high repeatability. The module can be configured for different measurement ranges. The serial application offers the best resolution for transient currents with peak values in the 0 to 500mA range, whereas for switching currents with peak values above 500mA the parallel application is suited.

A QT-1410 configured for serial application has a typical 5MHz bandwidth, supports a measurement repetition rate of 3 MHz, offers a best resolution of 5µA, and is capable of driving high capacitive loads.

The target application of the QT-1410 is to make peak and/or charge measurements of the transient current. The monitor can be configured to capture, store and process a whole transient waveform, it can also be used to measure the IDD(Q) current drawn by the DUT, to measure the actual DC value of the DUT' supply voltage, measure pulse width, measure switching energy and other parameters. The on-board memory enables storing a partial or complete transient waveform that can be read for advanced off-line data analysis such as FFT, neural network analysis, … These advanced data analysis techniques are reported to bring additional test coverage. The QT-1410 provides its measured values in a digital way – as a serial digital data bit stream. The QT-1410 functionality

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includes automated offset correction to assure accurate peak readings. For doing so the module has an on-board accurate calibration load, enabling the proper measurement of system and setup related offset.

The QT-1410 has a simple to control serial interface. The module also provides an analogue output voltage on its VIDD pin corresponding to the IDD current.

As the actual IDD can have positive as well as negative values, due to parasitics, the VIDD analog output is positively biased, to provide an always positive output voltage. The bias point is set at 2.00V for IDD=0 and no output load. If the 2.00V positive shift is not desired, an AC coupled connection can be used. Since the IDD signal can have high frequency components (the IDDT portion of the signal), the VIDD output is 50 Ω terminated. If a 'no load' termination is used (e.g. traditional oscilloscope probe), the VIDD load should be preferably ≥ 1MΩ and ≤ 20pF not to affect the output value.

ELECTRICAL SPECIFICATIONS

V_{CC} = +10.0V, V_{EE} = -10.0V, V_{DUT} = +5.00V, T = +25°C, C_L = 10nF, DUT pin to DUT distance = 3cm

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
Power Supply					
V_{CC}	Positive Supply Voltage	+9.5	+10.0	+13	V
I_{CC}	Positive Supply Current		+120	+150	mA
V_{EE}	Negative Supply Voltage	-13	-10.0	-9.5	V
I_{EE}	Negative Supply Current		-15	-20	mA
Measurement Characteristics - 10mA range, serial configuration					
I_{DDT}	Transient current detection range (1) (4)	-10		+10	mA
Q_{DDT}	Transient charge detection range (1)	-50		+50	µC
I_{DDQ}	Quiescent current detection range	-10		+10	mA
V_{DUT}	DUT Supply Voltage (5)	-5		+7	V
V_{IDD}	I/V Conversion Ratio (2)	99.5	100	100.5	mV/mA
ΔI_{DDT}	Current Resolution @ full range		5		μA_{RMS}
ΔQ_{DDT}	Charge Resolution @ full range		0.1		pC_{RMS}
ΔI_{DDQ}	Quiescent Current Resolution @ full range		1.5		μA_{RMS}
Measurement Characteristics - 50mA range, serial configuration					
I_{DDT}	Transient current detection range (1) (4)	-50		+50	mA
Q_{DDT}	Transient charge detection range (1)	-250		+250	µC
I_{DDQ}	Quiescent current detection range	-50		+50	mA
V_{DUT}	DUT Supply Voltage	-5		+7	V
V_{IDD}	I/V Conversion Ratio (2)	19.9	20	20.1	V/A
ΔI_{DDT}	Current Resolution @ full range		25		μA_{RMS}
ΔQ_{DDT}	Charge Resolution @ full range		0.5		pC_{RMS}
ΔI_{DDQ}	Quiescent Current Resolution @ full range		7.5		μA_{RMS}
Measurement Characteristics – 500mA range, serial configuration					
I_{DDT}	Transient current detection range (1) (4)	-500		+500	mA
Q_{DDT}	Transient charge detection range (1)	-2.5		+2.5	mC
I_{DDQ}	Quiescent current detection range	-500		+500	mA
V_{DUT}	DUT Supply Voltage	-5		7	V
V_{IDD}	I/V Conversion Ratio (2)	1.99	2	2.01	V/A
ΔI_{DDT}	Current Resolution @ full range		250		μA_{RMS}
ΔQ_{DDT}	Charge Resolution @ full range		5		pC_{RMS}
ΔI_{DDQ}	Quiescent Current Resolution @ full range		75		μA_{RMS}

Analogue I/O					
V_{IDD}	Output swing @ Z=50 Ω	-0.5		+0.5	V
	Output swing @ no load	-1		+1	V
	DC bias @ Z=50 Ω		1.00		V
	DC bias @ no load		2.00		V
BW	Analogue input bandwidth -3dB		5	10	MHz
$t_{R/F}$	Rising and falling time 10% to 90%		100		ns
A_{VIDD}	Analog amplification (VIDD output / VDD transient @ DUT pin)	19.9	20	20.1	
R_{IN}	Internal resistance between VDUT and DUT sense pins (3)	0.1	1	10	Ω
I_B	Input bias current of VDUT and DUT sense pins		+/-1		µA
ΔV_{DUT}	Supply voltage drop @ full range (6)		50		mV
I_O	Output current @ Z=50 Ω			+/-10	mA
	Output current @ Z=0 Ω			+/-20	mA
Digital I/O					
V_{IH}	Digital Input High Voltage	2.0		5.5	V
V_{IL}	Digital Input Low Voltage	-0.5		0.8	V
V_{OH}	Digital Output High Voltage @ -0.4mA	2.4		3.6	V
V_{OL}	Digital Output Low Voltage @ 4mA			0.4	V
I_O	Output sink/source capibility	-12		+12	mA
C_{IN}	Input capacitance			8	pF

NOTES:

(1) The typical QT-1410 measurement ranges for serial application are ±10mA/50µC, ±50mA/250µC and ±500mA/2.5mC. Other ranges can be customised on demand.
(2) Valid for DC, actual AC value depends on C_L, the transient duration and the parasitics.
(3) R_{IN} is only applicable for the as a serial measurement application, i.e. when the QT-1410 is inserted in the DUT' supply path. In the parallel application, the QT-1410 is either AC coupled or exploits the DUT' supply interconnect parasitic resistance.
(4) Valid for serial application. For the parallel application, theoretically the upper range is not limited.
(5) The QT-1410 can be used either for positive or negative V_{DUT} voltages. The V_{DUT} polarity is fixed upon assembly. Applying a negative voltage to a module tuned for positive V_{DUT} and vice versa, will result in damage of the module.
(6) Valid for serial application. No voltage drop occurs in parallel application.

ABSOLUTE MAXIMUM RATINGS

PARAMETER	WITH RESPECT TO	MIN	MAX	UNITS
V_{CC}	GND	-0.5	+13.5	V
V_{EE}	GND	+0.5	-13.5	V
V_{DUT}	GND	-10	+10	V
Digital Inputs	GND	-0.5	+5.5	V
Digital Output	GND	-0.5	+5.5	V
Digital Output	GND	-24	+24	mA
I_{DDT}	GND		3 x FS (2) (3)	A
Operating Temperature Range		0	+70	°C
Storage Temperature		-40	+80	°C
Lead Temperature (10sec) (1)			+220	°C

(1) Manual soldering is recommended using SnPb solder.
(2) Valid for serial application. Unlimited for parallel application.
(3) FS = Full Scale.

NOTE: Stresses above those listed under Absolute Maximum Ratings may cause permanent damage to the device. This is a stress rating only; functional operation of the device at these or other conditions above those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum ratings for extended periods may affect device reliability.

TIMING SPECIFICATIONS

SYMBOL	PARAMETER	MIN	TYP	MAX	UNITS
t_1	Total measurement time	365			ns
t_2	Measurement setup time	45	50	55	ns
t_3	Measurement window	0.020		(1)	µs
t_4	Data processing setup time		300		ns
t_5	Internal sampling frequency			50	MHz

(1) For IDDT peak and pulse width measurements, the measurement window is unlimited. For charge measurements, the charge accumulator saturates when its maximum capacity is reached and imposes as such a practical limit on the measurement window.

OPERATING MODES

The QT-1410 has two main operating modes, namely bypass mode and measurement mode. During bypass mode the monitor accepts data communications to and from the monitor. In measurement mode the actual measurement takes place. The main QT-1410 measurement modes support the use of the module as a peak detector (i.e. for measuring the maximum IDDT value), as a charge collector or as a pulse width detection device. For its charge measurement the module measures the total charge transferred to the DUT in a user specified time window (t_3, see figure 1), by integrating the transient current during the specified period. When operating in bypass mode, data can be exchanged with the monitor (figures 2 and 3). The communication operations allow to select and/or to configure the desired measurement approach, to set the desired pass/fail level(s) in function of the active firmware and read out the measurement results. A simple 3-wire serial protocol (using the MD, CLK and DOUT module pins) is used for communication with the monitor hereby limiting the number of ATE resources needed to operate the monitor.

Figure 1 shows a typical QT-1410 measurement cycle. The measurement operation can be divided in an initial measurement setup period (t_2, region (a), typically 50 ns) and the measurement window (t_3, user controlled: 20ns minimum). A data processing setup period (t_4, region (b), typically 300 ns) precedes the measurement result window (region (c)), causing the measurement result to lag the actual measurement. Within the measurement result window (shown as region (c)), the pass/fail flag can be dynamically monitored to identify the exact (taking the data processing setup time into consideration) moment when the set reference is exceeded. Alternatively the pass/fail flag can be strobed at the end of the measurement cycle. As soon as one of the measured values exceeds the reference value set, the pass/fail flag is frozen. During a measurement period one or more (depending on the user defined measurement window) samples of the analog IDD waveform are taken and converted by the on-board A/D converter.

In function of the actual monitor functionality and configuration, measurement results such as maximum peak value, total charge, IDD value or DUT supply voltage can be read out. The measurement results are typically read out in the bypass period following a measurement cycle. Note that no monitor communications are possible during the measurement phase.

The module can also be used to measure the absolute peak or charge values in an analog way by observing the analogue output VIDD.

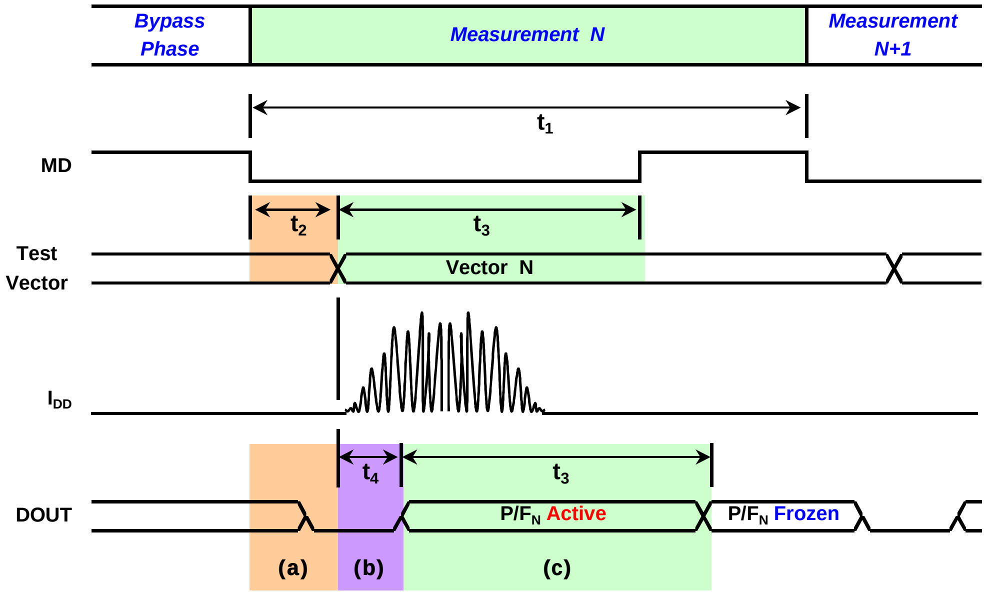


Figure 1. QT-1410 Typical Measurement Cycle

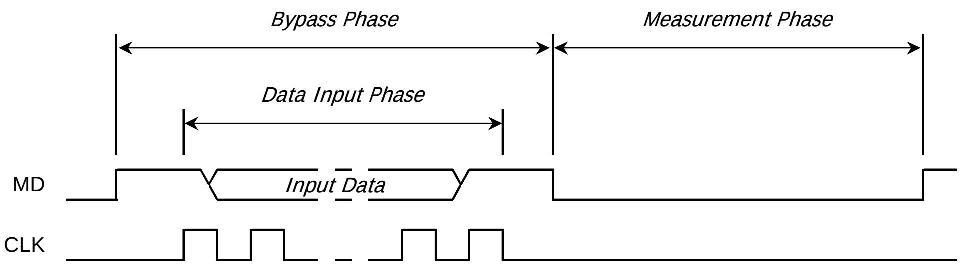


Figure 2. QT-1410 input data stream timing.

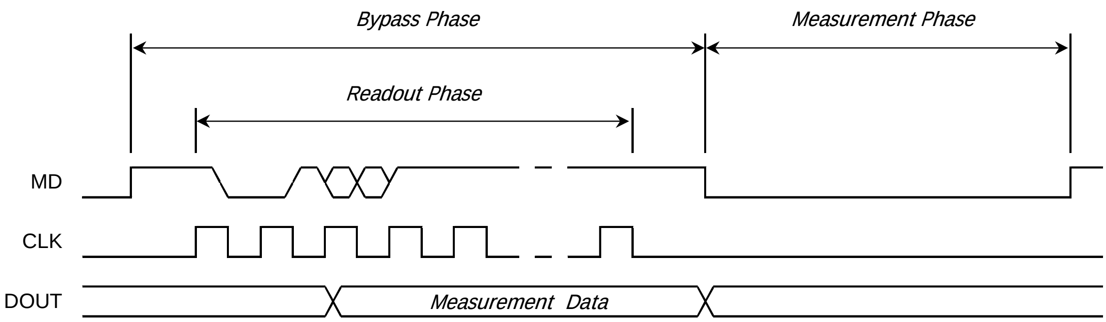


Figure 3. QT-1410 output data stream timing.

TYPICAL APPLICATIONS

The QT-1410 is a transient off-chip I_{DDT} measurement device, which is designed to measure and test transient supply currents (I_{DDT}) of digital as well as mixed signal ICs and to monitor dynamic currents of analog ICs. The QT-1410 can either be used as a serial measurement device (to be inserted in the DUT' supply path between the power supply and the DUT and causing a potential but neglect able voltage drop) or as a parallel measurement device (to be placed in parallel with the DUT, not affecting the DUT' supply level nor its operation). The QT-1410 consists of 2 active units, a measurement unit (MU) and a processing and control unit (PU). The measurement unit converts the measured current peak in a corresponding voltage. The processing unit combines a fast A/D converter with on-board data processing capabilities. The QT-1410 can measure both positive and negative currents. A current is regarded is positive when the current is flowing from the V_{DUT} terminal to the DUT terminal (pin 3) and vice versa.

When using the serial application, the module has to be inserted between the ATE Digital Power Supply (DPS) and the Device Under Test (DUT), as illustrated in figure 4. Note that for negative V_{DUT} voltages, the DUTF pin (pin 4) must be left floating. For serial application, the transient current/charge measurement is based on measuring the voltage drop, caused by the I_{DDT}/Q_{DDT} flowing through a sense resistor inside QT-1410. The typical values of the sense resistor are 100mΩ to 10Ω (configuration and measurement range dependent). The serial approach is sensitive and fast at low C_L, however like a traditional ammeter, it can slightly decrease the supply current due to the voltage drop caused by the sense resistor. Therefore the QT-1410 design makes a trade off between a good sensitivity and an acceptable DUT supply voltage drop. The maximum voltage drop induced by the module is 50mV at full range, and the internal resistance is low enough not to affect DUT operation. The QT-1410 can be customised for a higher internal gain and reduced voltage drop.

In contrast, the parallel method does not require splitting the supply and inserting the module into the supply path as it is placed in parallel with the DUT' supply connection (connection between ATE DPS and DUT), as illustrated in figures 5 and 6. The module then either uses the parasitic resistance of the DUT supply connection as sensing element (figure 5) or makes use of an AC coupling (figure 6). Note that for negative V_{DUT} voltages, the DUTF pin (pin 4) must be left floating. An AC coupled configuration enables I_{DDT} testing of high voltage circuits such as automotive ICs. This unique approach requires only 1 sense line and requires no modification of the DUT set-up. The DC coupled parallel application requires only 2 sense lines and one force line (none when V_{DUT} is negative) to place the module in parallel to the DUT' supply path. It is recommended to connect the VDUT and DUT sense lines in parallel with C_L terminal and use the star configuration for this connection unless a DUT supply plane is used. The resolution of the parallel method is worse and the settling of such a system takes somewhat more time than the serial approach, but the advantage is that the operation of the DUT is not affected at all, even when operating at high frequencies and drawing very high current spikes during functional test. Therefore the parallel method is convenient to measure high I_{DDT} currents (peak values above 500mA).

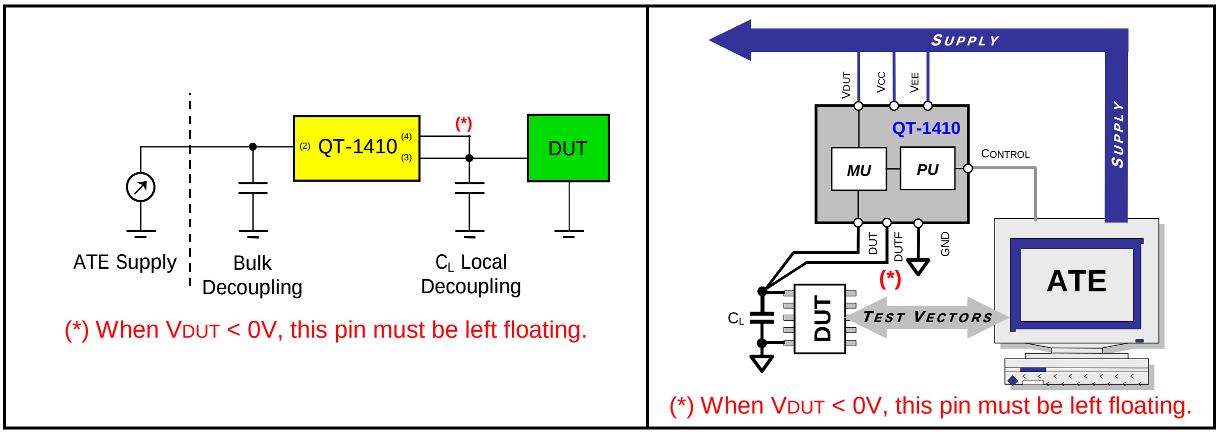


Figure 4. QT-1410 Serial Application

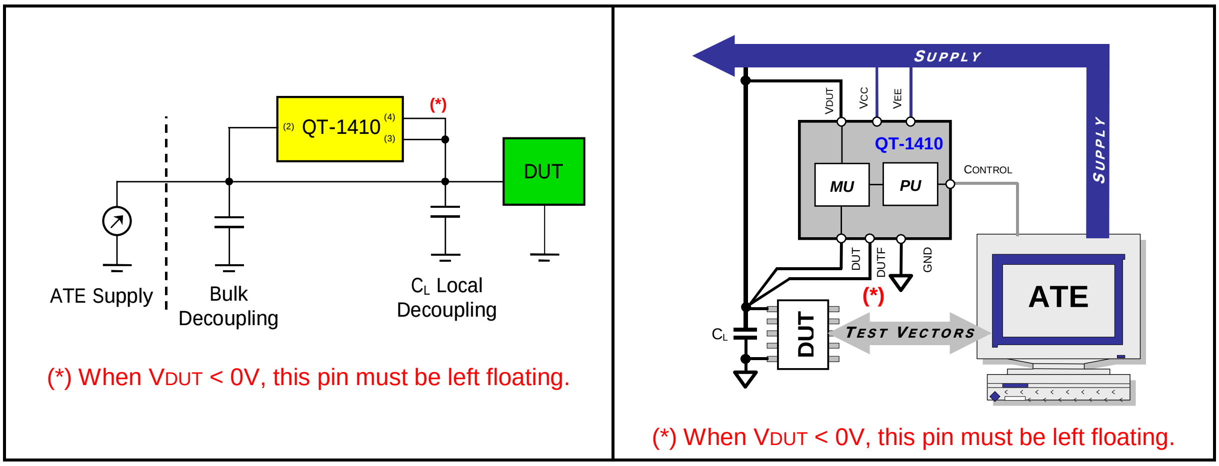


Figure 5. QT-1410 Parallel Application DC coupled

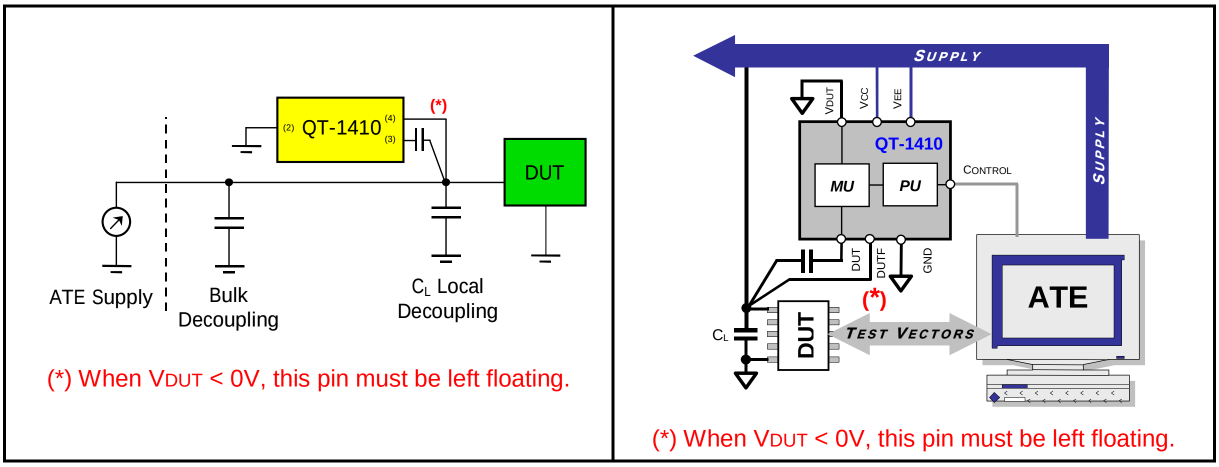
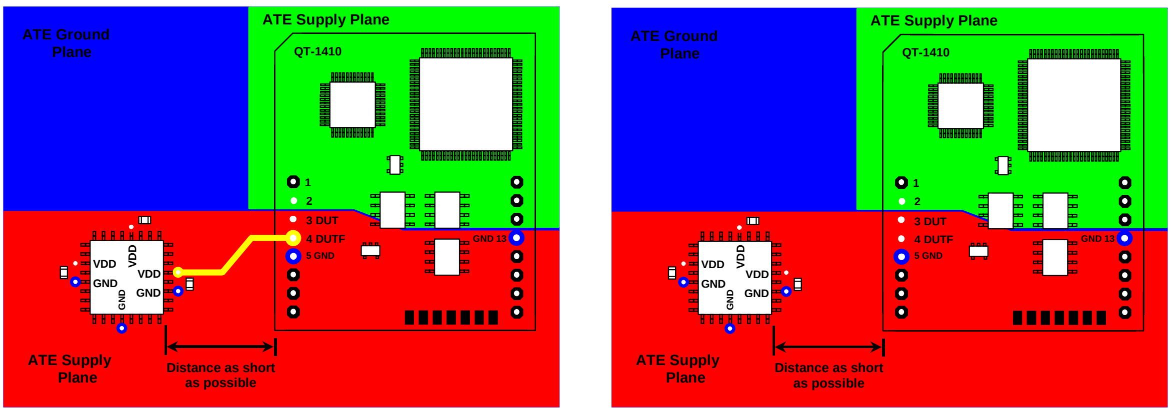


Figure 6. QT-1410 Parallel Application AC coupled

APPLICATIONS HINTS

The requirements/recommendations to guarantee optimum performance of the QT-1410 module are listed below:

- To reduce the interconnection parasitics, it is recommended to place the QT-1410 module as close as possible to the DUT. Preferably the distance between the DUT and the QT-1410's DUT pin should be kept below 2cm and the use of a power plane is recommended rather than a wired connection.
- All connections to the QT-1410 should be well designed not to degrade the monitor's accuracy.
- The ATE is expected to deliver a good quality VDUT reference signal (DUT supply voltage reference) for the DUT. VDUT pin 2 and DUT pin 3 are the main supply pins with lowest parasitics. These pins should be connected as close as possible to the DUT to maximise the monitor performance, see figure 7. Preferably these pins are connected using a plane.
- When VDUT is positive, it is recommended to use a Kelvin connection to connect the DUTF pin (pin 4), in other words, the DUTF pin must be connected as close as possible to the DUT decoupling capacitance (figure 7a). If not possible, the QT-1410 DUT pin and DUTF pin must be shorted (figure 7b). When VDUT is negative, the DUTF pin must be left floating.
- Global decoupling capacitors should be placed at the VDUT side of the monitor.
- Although the QT-1410 has on-board decoupling, it is recommended to decouple VCC, VEE and VDUT also externally by ceramic multilayer capacitors 100nF close to the supply and ground pins.
- For optimal performance of the QT-1410 monitor, the GND pin and the GNDPWR pin must be connected to the same ground level as the DUT supply being monitored. Preferably these pins are connected using a ground plane.
- The auxiliary DUT supply reference input (pin 14) is present for pin compatibility with older monitors only. This pin should be left floating in new applications.



(a) (b)

Figure 7. PCB layout (a) using a Kelvin connection, (b) shorting pins DUT & DUTF.

PACKAGE & PIN DESCRIPTION

The QT-1410 interface board has a 16 pins footprint. The pin description and package dimensions are given below.

Pin #	Name	Type	Function
1	MD	I	Mode control ("H" = Bypass, "L" = Measurement) – Serial Data input
2	VDUT [11]	I	Main DUT supply sense input pin for serial application, VDUT input sense pin for DC coupled parallel application, GND sense input pin for the AC coupled parallel application.
3	DUT [1]	I/O	DUT supply pin for serial application,
4	DUTF [3]	O	Force pin for calibration load
5	GND [9]	S	Monitor ground
6	DOUT[2]	O	Serial digital data output pin - Output flag ("L" = current below threshold; "H" = current above threshold)
7	$\overline{\text{RESET}}$ [4][5]	S	Monitor reset
8	RSP [10]	S	Reserved system pin
9	RSP [10]	S	Reserved system pin
10	NC		Not connected
11	VEE	S	Negative supply voltage (-10V/-20mA)
12	VCC	S	Positive supply voltage (+10V/+100mA)
13	GNDPWR [9]	S	Power supply ground
14	VDUT [6]	I	Auxiliary DUT supply reference input used for pin compatibility with older monitors
15	VIDD [7]	O	RF analogue output of the IDDT Current Measurement Unit (50Ω terminated, 2.00V biased)
16	CLK[8]	I	Clock input

(1) In a serial application, the QT-1410 is inserted in the DUT supply line. As such the DUT pin becomes a DUT supply pin. In a parallel application, the QT-1410 is connected in parallel with the DUT' supply path. The DUT pin is then used to sense the the supply voltage drop cause by IDDT across inherent impedance of supply path.

(2) This pin has dual functionality, it serves either as a serial data output pin when reading data from the module or as a above/below threshold indicator during measurement mode.

(3) When VDUT > 0V, it is recommended to connect this pin as close as possible to the CL and DUT. If not possible, this pin must be connected to the QT-1410 DUT terminal (pin 3).
When VDUT < 0V, this pin must be left floating.

(4) This pin is pulled up internally, no external pull-up resistor is required. The QT-1410 is reset when a low level is present on the RESET pin for more than 50ns. A module reset takes maximum 10ms starting from the rising edge of the reset signal, during this reset period no module communication should occur.

(5) There is no requirement to connect the reset pin for normal operation of the QT-1410. This pin can be left floating.

(6) Only used for compatibility with older monitors. Not to be used (should be left unconnected) in new applications.

(7) The VIDD output has a standard 50Ω impedance. A high impedance probe or standard 50Ω RF matching can be used.

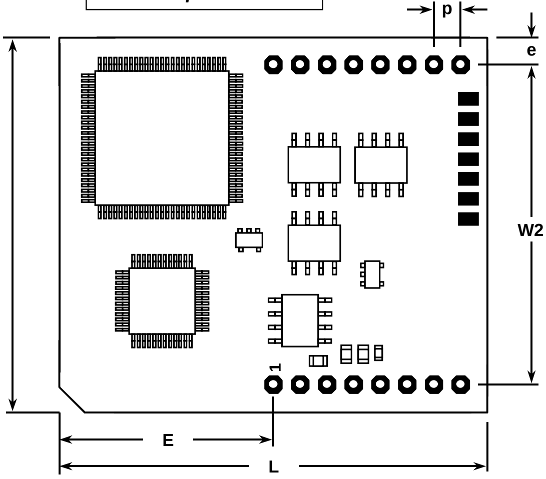
(8) This pin is internally pulled down.

(9) For optimal performance of the QT-1410 monitor, the GND pin and the GNDPWR pin must be connected to the same ground level as the DUT supply being monitored. Preferably these pins are connected using a ground plane.

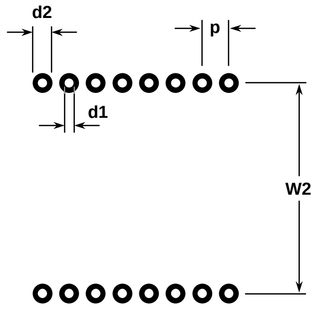
(10) This pin is internally connected and must be left floating for proper operation of the module.

(11) The VDUT pin must be permanently connected to a voltage source or ground and must not be left floating. The QT-1410 can be used either for positive or negative VDUT voltages. The VDUT polarity is fixed upon assembly. Applying a negative voltage to a module tuned for positive VDUT and vice versa, will result in damage of the module.

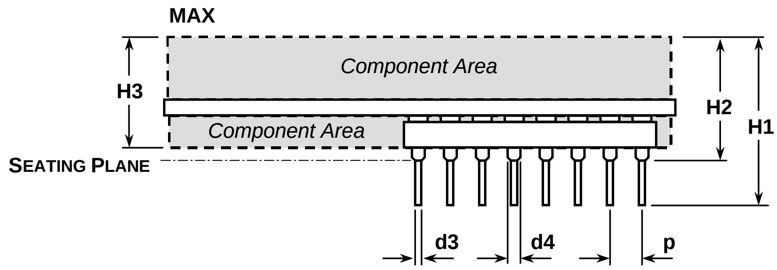
Top View



Land Pattern Recommendation



Side View



Unit	*W1*	*W2*	*L*	*p*	*d1*	*d2*	*d3*	*d4*
inches	1.40	1.20	1.60	0.10	0.035	0.067	0.020	0.039
mm	35.56	30.48	40.64	2.54	0.90	1.70	0.50	1.00

Unit	*H1*	*H2*	*H3*	*E*	*e*
inches	0.591	0.453	0.354	0.80	0.10
mm	15.00	11.50	9.00	20.32	2.54