EQCO400T8 UTP Cable Equalizer

Features

- Multi-Rate Adaptive Equalization for UTP Cables up to 500 Mbps
- Supports General 8B/10B Coded Signaling over UTP
- Supports FireWire IEEE 1394b at S400, S200 and S100 Data Rates
- Seamless Connection with any IEEE1394b Compliant PHY
- Internal Termination Resistors for Low External Discrete Count
- Fully Compatible with Power over Ethernet(1)
- Carrier Detect and Mute Functionality with Direct Light Emitting Diode Driving Capability
- Single 3.3V Supply
- Low-Power Operation
  - 42 mA (140 mW) Active
  - 4.25 mA (14 mW) Mute
- 16-pin, 0.65 mm Pin Pitch, 4 mm QFN Package
- Pb-free and RoHS Compliant

General Description

The EQCO400T8 is a multi-rate adaptive cable equalizer designed to restore signals received over Cat 5 or Cat 6 Unshielded Twisted Pair (UTP) cable. For correct operation, the signals must be NRZ (Non-Return-to-Zero) encoded, DC-balanced with a maximum run length of 10 bits and have a speed (edge rate) of between 100 Mbps and 500 Mbps.

Typical Equalization Performance

Device	Bit Rate (8B/10B Coding)	1394 Data Rate	Range(2) using	
			Cat 5e	Cat 6
EQCO400T8	125 Mbps	S100	0m-85m	0m-85m
	250 Mbps	S200	0m-75m	0m-85m
	500 Mbps	S400	0m-50m	0m-75m

Note 1: IEEE 802.3-2008, clause 33 - "Power over Ethernet" (formerly known as IEEE 802.3af)

2: Measured on UTP pairs 1, 2, 3 and 6 as per IEEE 1394-2008 using recommended Coilcraft magnetics as per Table 2-1.

Table of Contents

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An errata sheet, describing minor operational differences from the data sheet and recommended workarounds, may exist for current devices. As device/documentation issues become known to us, we will publish an errata sheet. The errata will specify the revision of silicon and revision of document to which it applies.

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1.0 DEVICE OVERVIEW

The EQCO400T8 is ideally suited for long-haul IEEE 1394b-2002 connections over Category 5 or Category 6 Ethernet cable at the S400 data rate. It can also be used at S200 and S100 data rates over even longer cables, as illustrated in the typical long-haul connection in Figure 1-1. The EQCO400T8 connects seamlessly to any IEEE 1394b-2002 compliant physical layer controller (PHY).

The achievable connection reach with the EQCO400T8 depends on the input jitter tolerance of the IEEE 1394 PHY and the quality of the connectors and cables used. Figure 1-1 shows the typical performance with CAT5e and CAT6 cables under nominal conditions.

FIGURE 1-1: LONG-HAUL IEEE 1394B-2002, IEEE 1394-2008 CONNECTION

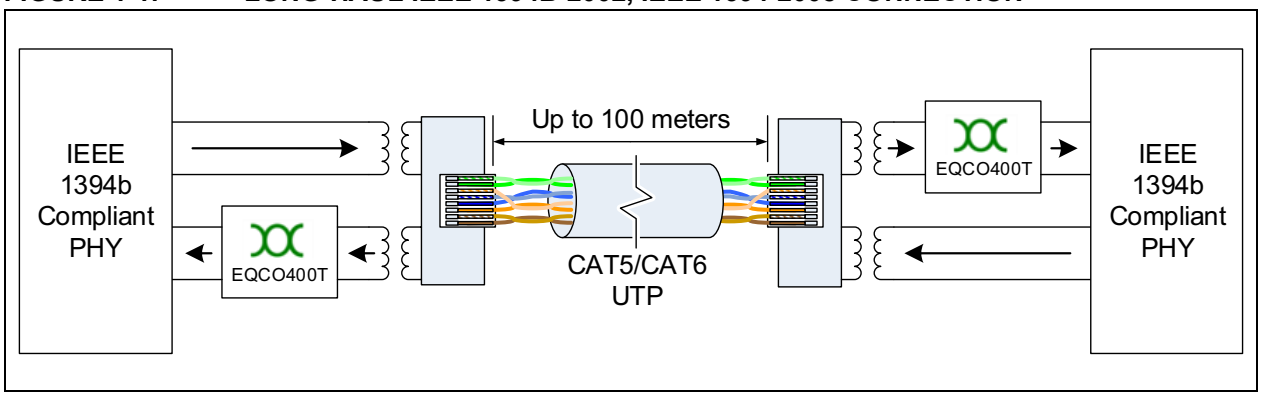


FIGURE 1-2: EQCO400T8 PIN DIAGRAM (VIEWED FROM TOP)

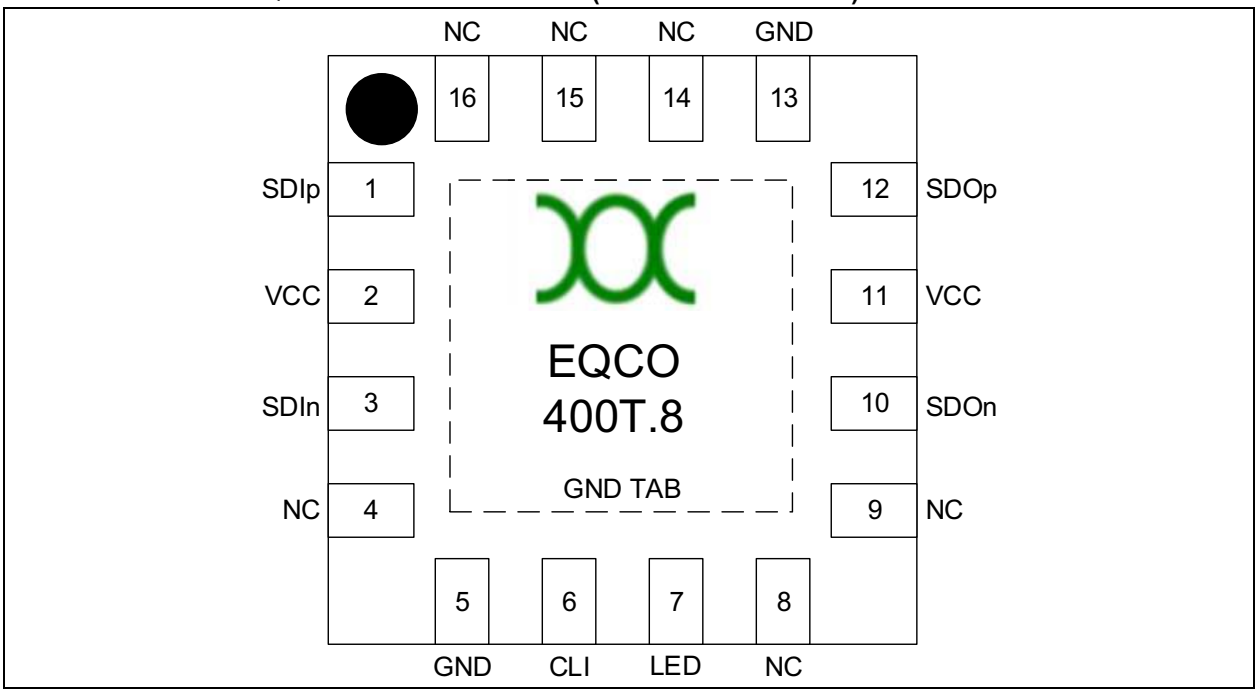
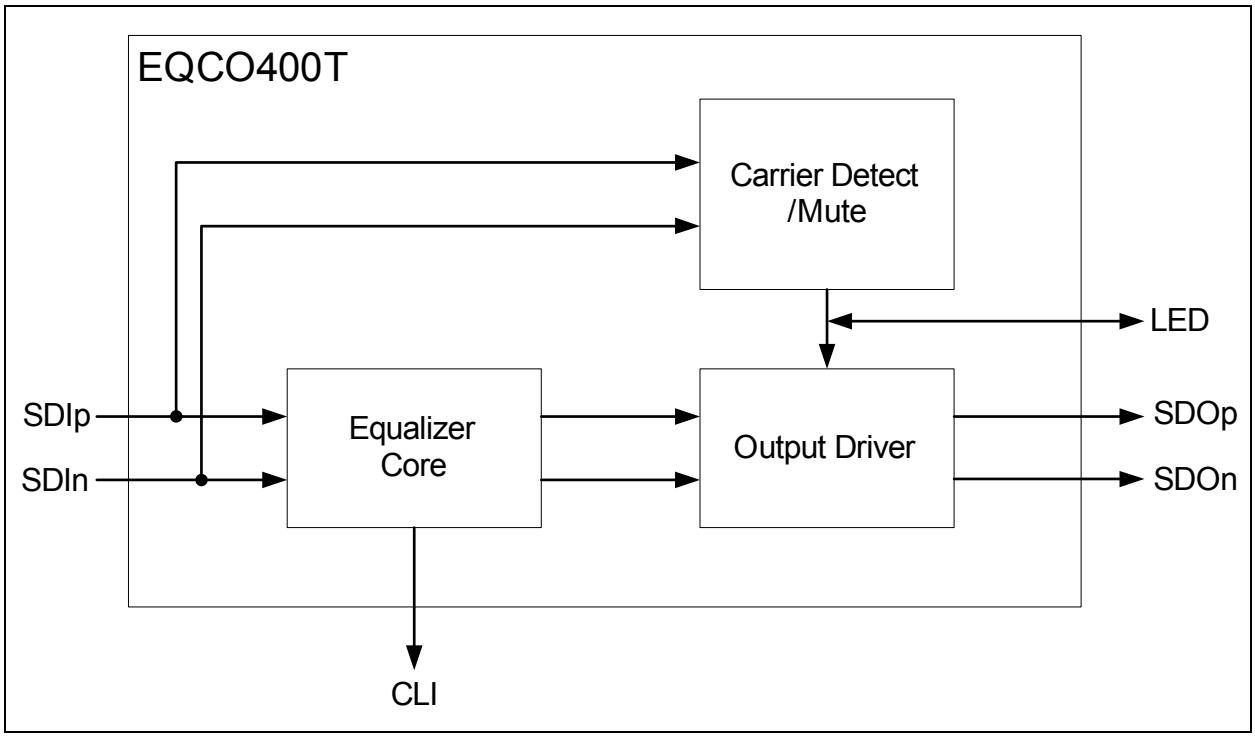


TABLE 1-1: EQCO400T8 PIN DESCRIPTIONS

Pin Number	Pin Name	Signal Type	Description
2, 11	VCC	Power	Connect to +3.3V power supply.
5, 13	GND	Power	Connect to power supply ground.
1, 3	SDIp/SDIn	LVDS Input	Differential serial data input pair.
12, 10	SDOp/SDOn	LVDS Output	Differential serial data output pair.
6	CLI	Analog Output	Cable length indicator: Analog voltage can be used to indicate the length of the cable being equalized; this gives an indication of the amount of equalization being applied. A higher output voltage results from more compensation being used to recover the signal. Leave unconnected when not used.
7	LED	Output	Carrier detect with light emitting diode driver. High means a valid input signal, and SDOp/SDOn are turned on. Low means no RX signal or the signal is too low, and SDOp/SDOn are muted. This pin can source up to 3 mA to directly drive an LED. Leave unconnected when not in use.
4, 8, 9, 14, 15, 16	NC		Leave unconnected.

FIGURE 1-3: EQCO400T8 BLOCK DIAGRAM SHOWING ELECTRICAL CONNECTIONS



1.1 SDIp/SDIn

SDIp/SDIn together form a differential input pair that is connected to the receive signal pair of the cable. It is the differential voltage between these pins that the EQCO400T8 analyzes and adaptively equalizes for signal level and frequency response. The equalizer automatically detects and adapts to signals with different edge rates, e.g. S100, S200 and S400.

Both SDI+ and SDI- inputs are terminated by 50Ω to VCC on-chip. It is advised to isolate the inputs from the UTP via a transformer, as shown in Figure 2-1.

1.2 SDOp/SDOn

SDOp/SDOn together form a differential pair outputting the reconstructed far-end transmit signal. The signals can be connected via capacitive coupling directly to the RX signal pair of a standard IEEE1394b PHY.

The EQCO400T8 uses Current Mode Logic (CML) drivers with source matching for the 110Ω transmission line.

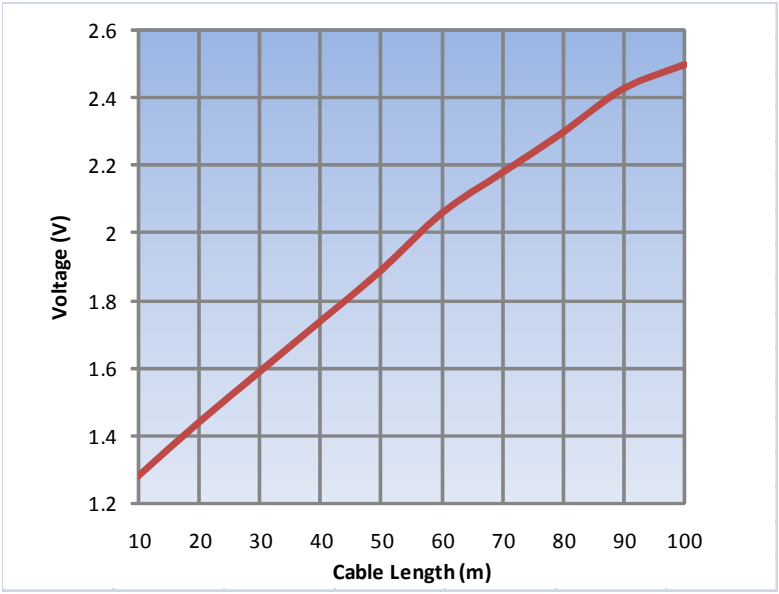
1.3 CLI

The EQCO400T, being a fully analog equalizer, has a continuous transfer function with respect to the equalization applied. CLI (Cable Length Indicator) is an analog output. The voltage on the pin is proportional to the amount of equalization being applied.

CLI can be used qualitatively to indicate the length of the cable being equalized; the higher the voltage, the longer the cable. However the CLI pin voltage depends on a number of factors, including connector quality, device temperature and to a certain degree on chip-to-chip variations, and as such cannot be used for accurate cable length measurement.

Figure 1-4 illustrates the voltage at CLI for a typical CAT6 cable.

FIGURE 1-4: CLI VOLTAGE AS A FUNCTION OF CABLE LENGTH (SYSTIMAX CAT6 CABLE)



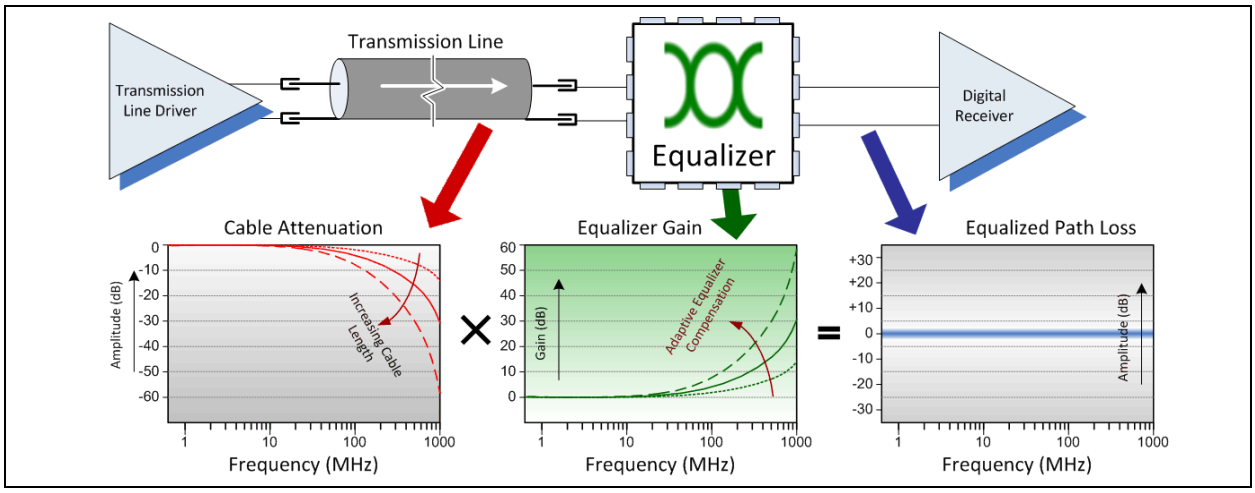
1.4 LED

LED is an output that detects and indicates sufficient differential signal power at SDIp/SDIn for a link to be established.

If the received signal at the serial inputs is either not present or too small for proper reconstruction of the output (i.e. a signal with amplitude < 40 mV) the voltage on LED is driven low; if sufficient signal power is detected, the voltage at LED will be driven high. When high, the pin can source up to 3 mA, enabling it to be used to directly drive an LED. The LED will thus be on when a signal is detected, and off otherwise. It is advised to use a high-efficiency LED. The output from this pin is current limited, and no series resistor is required.

1.5 Equalizer Operation

FIGURE 1-5: PRINCIPLE OF EQUALIZER OPERATION



The EQCO400T8 is an equalizer with unique characteristics:

- Auto-adaptive

The equalizer controls a multiple-pole analog filter which compensates for attenuation of the cable, as illustrated in Figure 1-5. The filter frequency response needed to restore the signal is automatically determined by the device using a time-continuous feedback loop that measures the frequency components in the signal. Upon the detection of a valid signal, the control loop converges within a few microseconds.

- Variable gain

The EQCO400T8 has variable gain to work independently of the transmit amplitude of the line driver.

The equalizer can be used with any IEEE1394b compliant transmitter. The standard(1) requires a differential transmit amplitude in the range of 475 mV to 800 mV.

- Multi-speed

The EQCO400T8 works at data rates from 100 Mbps to 500 Mbps. In particular, it supports the S400, S200 and S100 data rates specified in the IEEE Standard 1394b-2002.

- Carrier detect/auto-mute to save power

The EQCO400T8 will automatically mute its output driver when no incoming signal is present. The EQCO400T8 estimates the remote transmit amplitude by measuring the low-frequency components of the signal. When the low-frequency amplitude is approximately 190 mV or higher, the output stage is turned on. Auto-mute reduces the power consumption from 140 mW to less than 14 mW.

Example equalizer performance measurements can be found in **Appendix B: Typical Operating Characteristics**.

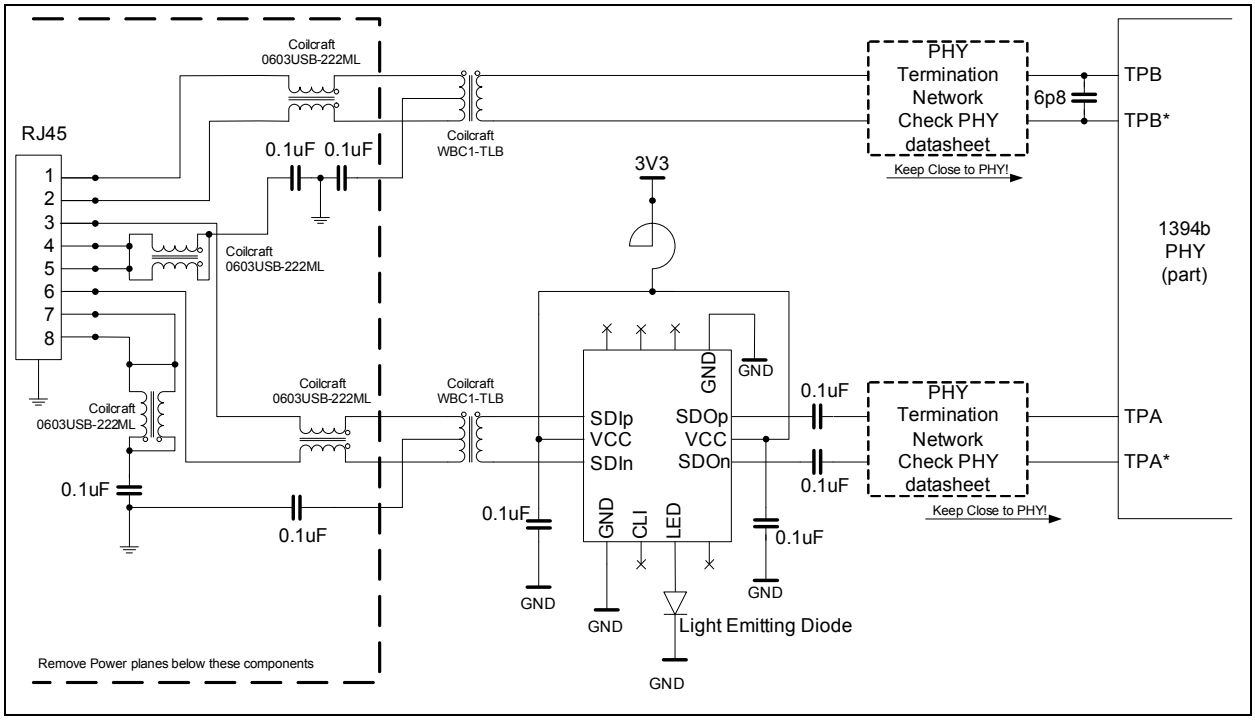
Note 1: IEEE 1394-2008, Standard for High-Performance Serial Bus

NOTES:

2.0 APPLICATION INFORMATION

Figure 2-1 illustrates a typical schematic implementation. In this diagram, data is transmitted on pins 1 and 2, and received on pins 3 and 6 of the RJ45.

FIGURE 2-1: EQCO400T-8 TYPICAL APPLICATION CIRCUIT



To improve isolation from noise on the board power plane, it is recommended to power the equalizer through a ferrite bead. A 0.1 µF decoupling capacitor should be placed as close as possible to each VCC pin. Ground vias should be placed as close as possible to the device GND pins to minimize inductance. To reduce electromagnetic emissions, it may be advised to place a 6.8 pF capacitor in between TPB and TPB* (transmit LVDS) of the PHY to reduce the rise/fall time of the transmitted signals. If fitted, the capacitor should be placed as close as possible to the pins of the PHY.

2.1 Guidelines for PCB Layout

Because signals are strongly attenuated by a long cable, special attention must be paid on the PCB layout between the RJ45 connector and the EQCO400T. The EQCO400T8 should be as close as is practical to the RJ45 connector. Traces between the RJ45, the transformer and the EQCO400T8 should be either single-ended 50Ω traces or, preferably, differential traces with a differential impedance of 100Ω. To avoid noise pickup, these traces should be placed as far away as possible from other traces carrying digital signals or fast switching signals. All differential traces should be matched in length to minimize time of arrival skew.

For best EMC performance, identical common-mode chokes should be used on the unused pairs to those used on the signal pairs as shown in Figure 2-1. This ensures the impedance seen by all conductors in the UTP cable is the same.

A reference design is available on request.

2.2 Recommended Magnetics

The following magnetics are recommended for use with EQCO400T:

TABLE 2-1: RECOMMENDED MAGNETICS

Component	Part Number
Transformers (1:1 with center tap) Two per channel	Coilcraft WBC1-1TLB
Common-mode chokes Four per channel	Coilcraft 1206USB-113MLB

Note: Operation with magnetics other than the recommended components cannot be guaranteed.

2.3 Connector Pins and Cable Connection

The EQCO400T8 does not support auto-crossover. If required, this must be implemented externally to the device.

To be the same as 100BaseT Ethernet, IEEE Standard 1394-2008 recommends that data is transmitted on RJ45 pins 1 and 2, and received on pins 3 and 6. If both sides of the long-haul UTP connection are configured in this way, a crossover cable or patch cord must be used.

If one side of the UTP connection transmits data on RJ45 pins 1 and 2 and receives data on pins 3 and 6, and the other side transmits data on RJ45 pins 3 and 6 and receives data on pins 1 and 2, a straight-through cable must be used.

If maximum reach is the highest priority and if a closed system is created, it is recommended to use pins 1 and 2 for transmit (receive) and pins 7 and 8 for receive (transmit). This reduces near-end crosstalk (NEXT) significantly, which will give a bonus on the maximum cable span; especially for CAT5e.

2.4 Supplying Power over the UTP Cable

The EQCO400T8 is fully compatible with the Power Over Ethernet standard, allowing standard POE chip sets to be used at the ends of the cable to transmit power to a remote device. The unused pairs (RJ45 pins 4,5 and 7,8) are most easily used for the transmission of power. The signal pairs can also be used as specified in the standard, but in this case, careful choice of magnetic components is required to conform to both the DC requirements of POE and the AC requirements of IEEE-1394.

A POE reference design is available on request.

3.0 ELECTRICAL CHARACTERISTICS

3.1 Absolute Maximum Ratings

Stresses beyond those listed under this section may cause permanent damage to the device. These are stress ratings only and are not tested. Functional operation of the device at these or any other conditions beyond those indicated in the operational sections are not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

TABLE 3-1: ABSOLUTE MAXIMUM RATINGS

Parameter	Min.	Typ.	Max.	Units	Conditions
Storage Temperature	-65	—	+150	°C	
Ambient Temperature	-55	—	+125	°C	Power Applied
Operating Temperature	-40	—	+85	°C	Normal Operation (VCC = 3.3V ±5%)
Supply Voltage to Ground	-0.5	—	+4.0	V	
DC Input Voltage	-0.5	—	+4.0	V	
DC Voltage to Outputs	-0.5	—	+4.0	V	
Current into Outputs	—	—	90	mA	Outputs Low

TABLE 3-2: MAXIMUM CURRENT CONSUMPTION AT 3.3V

Description	Max	Unit
No input signal, LED is low, output driver is disabled	4.25	mA
Valid input, LED is high, output driver is enabled	42.5	mA

TABLE 3-3: ELECTRICAL CHARACTERISTICS (OVER THE OPERATING VCC AND -40°C TO +85°C RANGE)

Parameter	Min.	Typ.	Max.	Unit	Description
Power Supply					
VCC	3.135	3.3	3.465	V	
	100	500	600	Mbps	Signaling rate (NRZ, 8b/10b encoded)
SDIp/SDIn Input					
Differential Input Voltage Swing	475	—	800	mV	V_{SDIp}-V_{SDIn} measured at cable input
$LVDSI_{min}$	—	40	—	mV	Minimum differential input for fully reconstructed output
	—	3.3	—	V	Common-mode input voltage
R_{input}	—	50	—	Ω	Single-ended; to VCC

TABLE 3-3: ELECTRICAL CHARACTERISTICS (OVER THE OPERATING VCC AND -40°C TO +85°C RANGE)

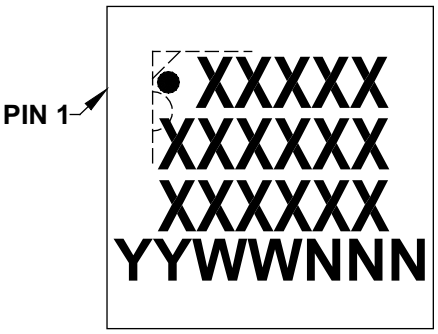
SDOp Connection to Coax					
LVDSo	—	440	—	mV	Differential output voltage swing V_{SDOp}-V_{SDOn} (50Ω load to VCC on each output) LED is high.
	—	VCC–LVDSo/2	—	V	Common-mode output voltage
SDO_{off}	—	VCC	—	V	Output voltage with disabled driver. Single-ended; LED is low.
R_{output}	—	55	—	Ω	Single-ended; to VCC
Rise/Fall Time	100	190	260	ps	20% to 80%
LED					
V_{oh}	1.5	VCC	—	V	Differential input voltage at cable input > 250 mV
V_{ol}	—	GND	0.8	V	Differential input voltage at cable input < 40 mV
CLI					
V_{oh}	—	1.2	—	V	Output voltage at maximum cable length
V_{ol}	—	2.6	—	V	Output voltage at maximum cable length

4.0 PACKAGING INFORMATION

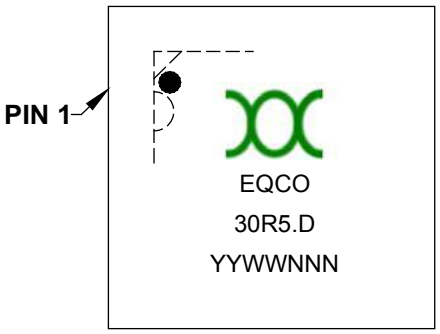
4.1 Package Marking Information

16-Lead Plastic Quad Flat, No Lead Package – 4x4x0.9 mm Body [QFN]

16-Lead QFN (4x4x0.9 mm)



Example

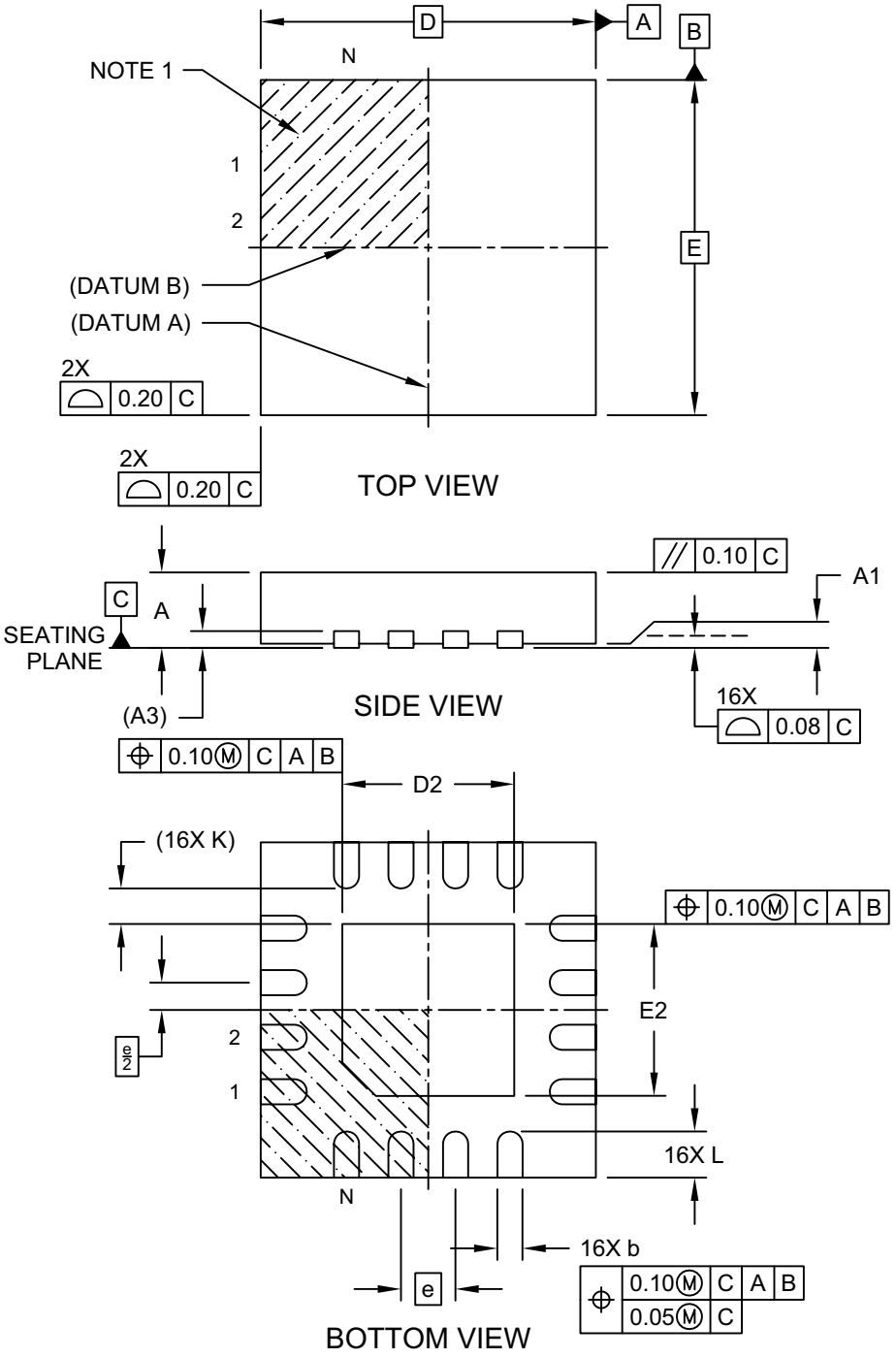


Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The Pb-free JEDEC designator ((e3)) can be found on the outer packaging for this package.

Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

16-Lead Plastic Quad Flat, No Lead Package (8E) - 4x4x0.9 mm Body [QFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



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16-Lead Plastic Quad Flat, No Lead Package (8E) - 4x4x0.9 mm Body [QFN]

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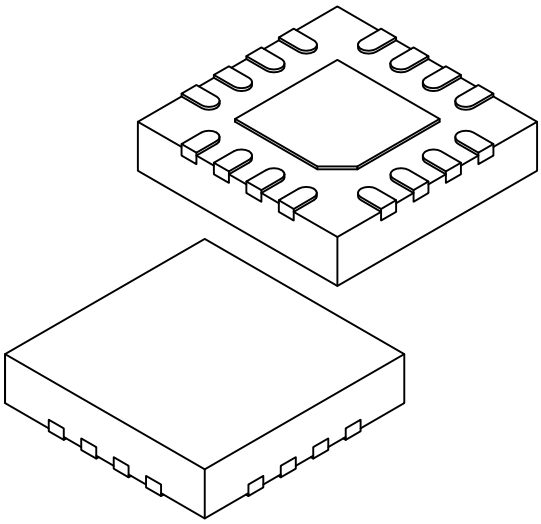


Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Pins	N		16	
Pitch	e		0.65 BSC	
Overall Height	A	0.80	0.87	0.95
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.20 REF	
Overall Width	E		4.00 BSC	
Exposed Pad Width	E2	1.95	2.05	2.15
Overall Length	D		4.00 BSC	
Exposed Pad Length	D2	1.95	2.05	2.15
Terminal Width	b	0.25	0.30	0.35
Terminal Length	L	0.45	0.55	0.65
Terminal-to-Exposed-Pad	K		0.425 REF	

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.
2. Package is saw singulated
3. Dimensioning and tolerancing per ASME Y14.5M

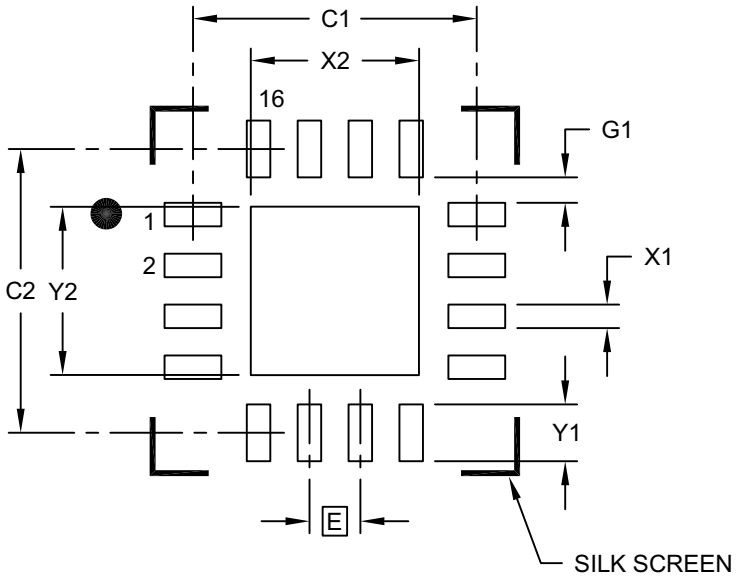
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

   REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-259B Sheet 2 of 2

16-Lead Plastic Quad Flat, No Lead Package (8E) - 4x4x0.9 mm Body [QFN]

Note: For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E		0.65 BSC	
Optional Center Pad Width	X2			2.15
Optional Center Pad Length	Y2			2.15
Contact Pad Spacing	C1		3.625	
Contact Pad Spacing	C2		3.625	
Contact Pad Width (X16)	X1			0.30
Contact Pad Length (X16)	Y1			0.725
Contact Pad to Center Pad (X16)	G1	0.20		

Notes:

1. Dimensioning and tolerancing per ASME Y14.5M

BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-2259A

APPENDIX A: REVISION HISTORY

Revision B (February 2016)

- Updated **Section 4.1 "Package Marking Information"**.
- Removed electrostatic discharge ratings from Table 3-1.
- Minor typographical changes.

Revision A (July 2015)

- This is the initial release of the document in the Microchip format. This replaces EqcoLogic document version 2.4.

TABLE A-1: REVISION HISTORY

Version	Date	Author	Comments
2.4	2/27/14	M. Kuijk	Removed data about previous version, added patent information.
2.3	5/3/09	S.E. Ellwood	Added information on EQCO400T-8.
2.2	12/8/08	S.E. Ellwood	Correction to Table 2-1.
2.1	11/2/08	S.E. Ellwood	Added Table 2-1 Recommended Magnetics, changed postal address.
2.0	7/22/08	S.E. Ellwood	Released.
1.1	2/2/06	K. Van Den Brande	New document.

APPENDIX B: TYPICAL OPERATING CHARACTERISTICS

Figures B-1 to B-14 have been made under the following conditions:

Receive signal on pair 3, 6; S400; 630 mV Transmit amplitude.

Crosstalk source on pair 1, 2; S400; 630 mV Transmit amplitude.

B.1 Auto-Adaptive

FIGURE B-1: 2M CAT6 CABLE BEFORE EQUALIZER

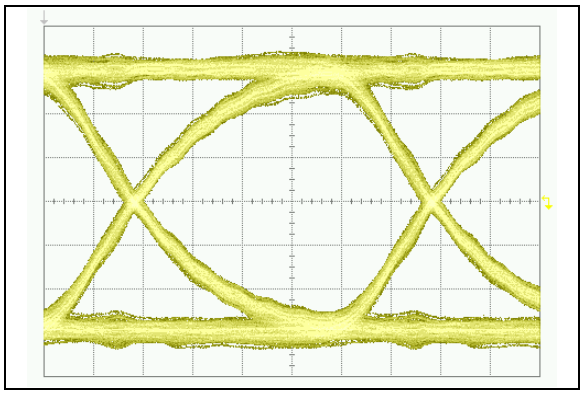


FIGURE B-2: 30M CAT6 CABLE BEFORE EQUALIZER

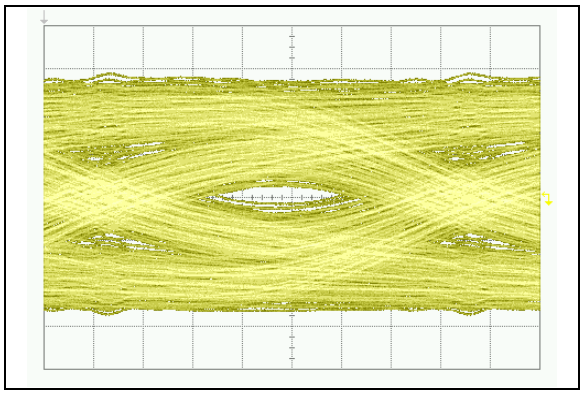


FIGURE B-3: 60M CAT6 CABLE BEFORE EQUALIZER

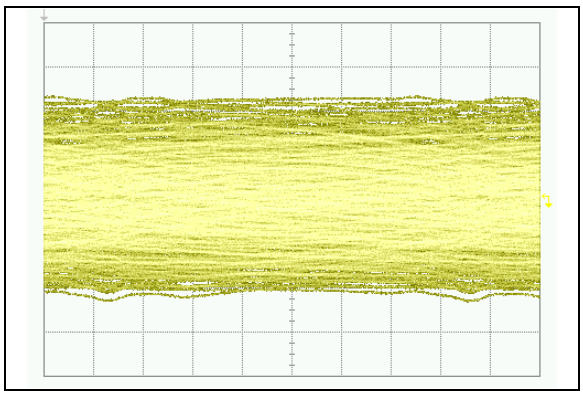


FIGURE B-4: 2M CAT6 CABLE AFTER EQUALIZER

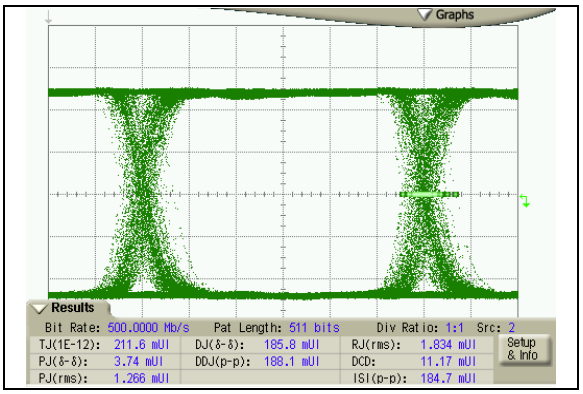


FIGURE B-5: 30M CAT6 CABLE AFTER EQUALIZER

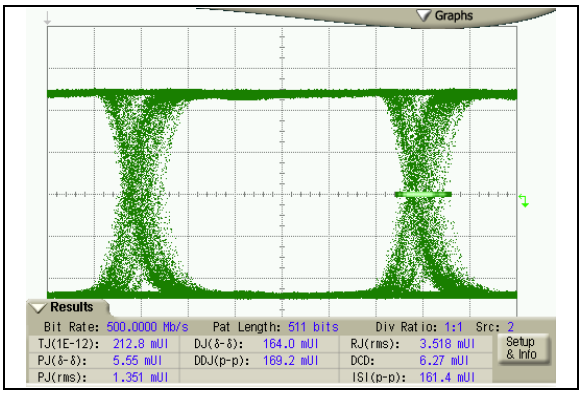


FIGURE B-6: 60M CAT6 CABLE AFTER EQUALIZER

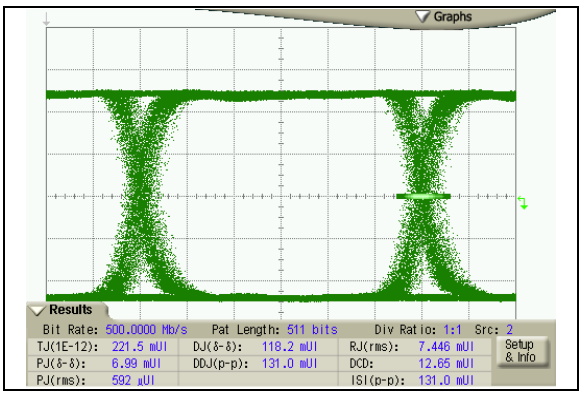


FIGURE B-7: 90M CAT6 CABLE BEFORE EQUALIZER

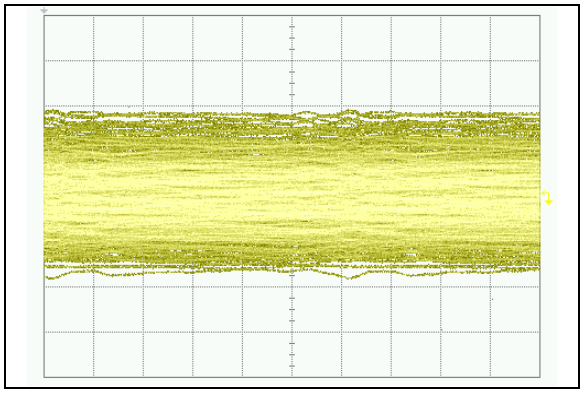
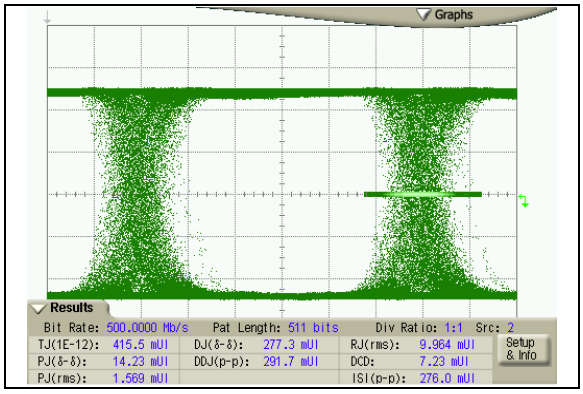


FIGURE B-10: 90M CAT6 CABLE AFTER EQUALIZER



B.2 CAT5e

The crosstalk generated in a CAT5e system is much higher than in a CAT6 system. This reduces the maximum cable length over which a link can be maintained.

FIGURE B-8: 70M CAT5E

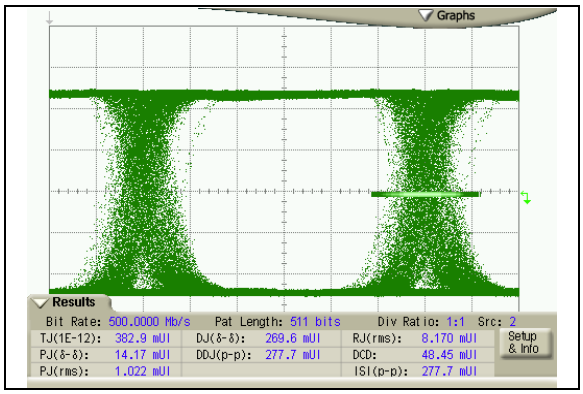
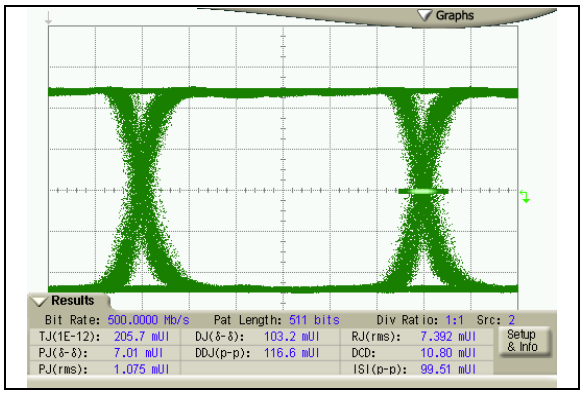


FIGURE B-11: 70M CAT5E - RX ONLY



B.3 Variable Gain

FIGURE B-9: 300 MV TRANSMIT AMPLITUDE (80M CAT6 CABLE)

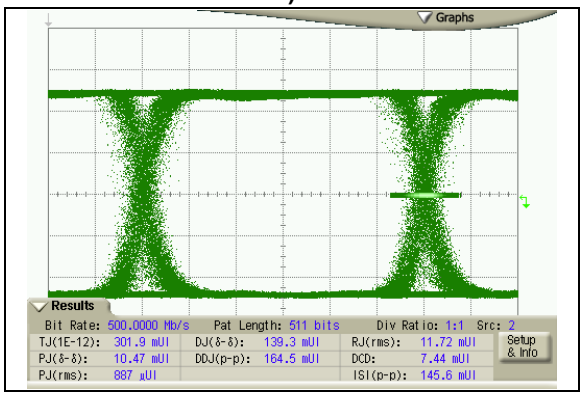
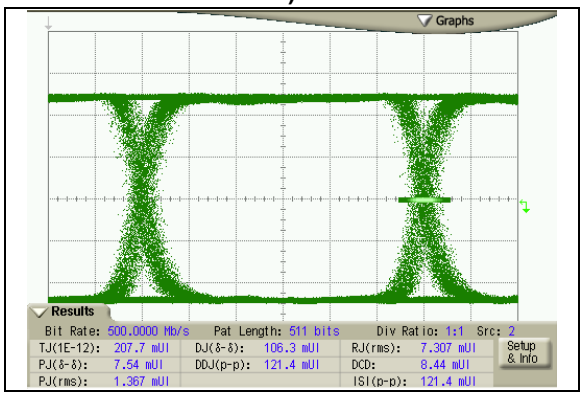


FIGURE B-12: 800 MV TRANSMIT AMPLITUDE (80M CAT6 CABLE)



B.4 Multi-Speed

FIGURE B-13: S200B, 110M CAT6 CABLE

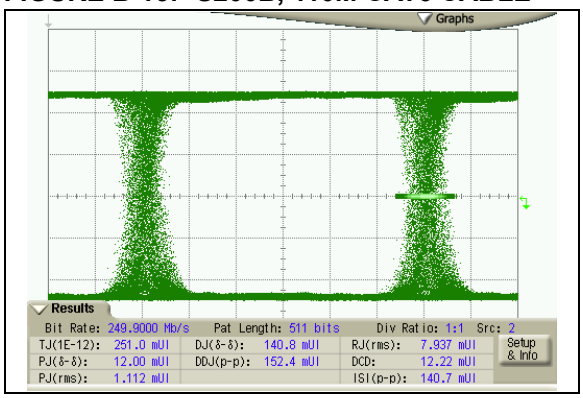
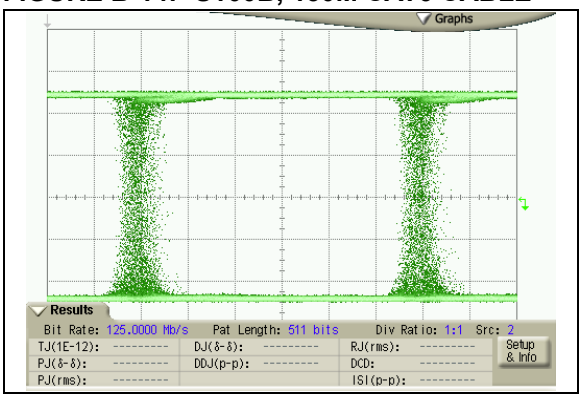


FIGURE B-14: S100B, 130M CAT6 CABLE



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Temperature Range	I = -40°C to +85°C (Industrial temperature)

Examples:

a) EQCO400T8/I = Industrial temperature
16-Lead QFN package

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