EQCO400T8 - UTP Cable Equalizer

1.1 Features

- Multi-Rate Adaptive Equalization for UTP cable up to 500 Mbps
- Supports general 8B/10B coded signalling over UTP
- Supports Fire-Wire 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[2]
- Carrier Detect and Mute functionality with direct Light Emitting Diode driving capability
- Single 3.3V supply
- Low Power
  - 42mA (140mW) active
  - 4.25mA (14mW) mute
- 16-pin, 0.65mm pin pitch, 4mm QFN package
- Pb-free and RoHS compliant

1.2 Typical Equalization Performance

Device	Bit Rate (8B/10B coding)	1394 Data rate	Range[1] 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

Table 1: Typical Equalization Performance

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

2 Functional Description

2.1 Overview

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 100Mbps and 500Mbps.

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 Figure 1. The EQCO400T8 connects seamlessly to any IEEE 1394b-2002 compliant physical layer controller (PHY).

Figure 1 illustrates a typical long-haul connection:

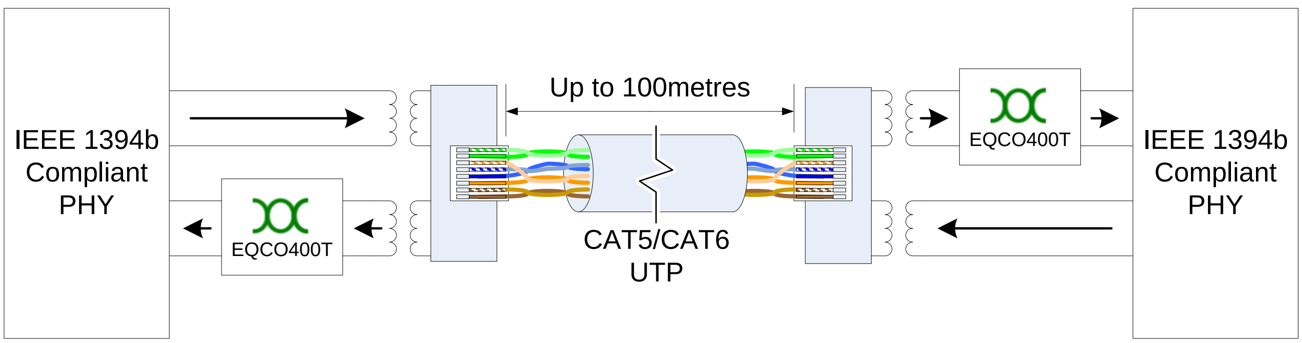

Figure 1: Long-haul IEEE 1394b-2002, IEEE 1394-2008 connection

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 shows the typical performance with CAT5e and CAT6 cables under nominal conditions.

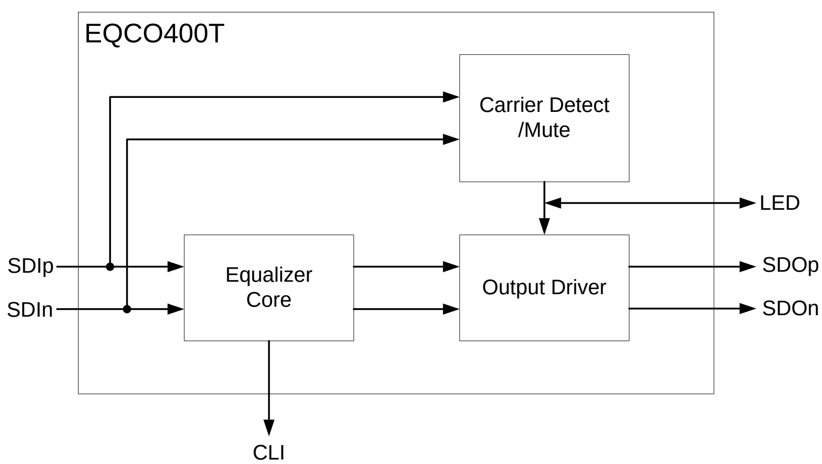

Figure 2: EQCO400T8 block diagram showing electrical connections

2.2 Package and Pinout

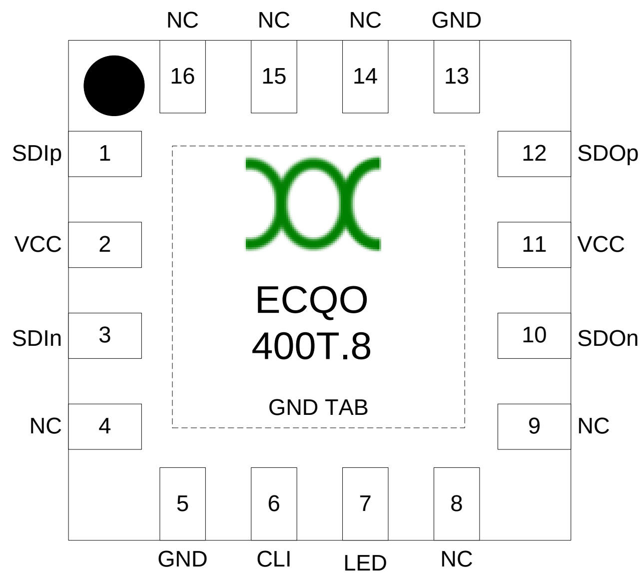

Figure 3: EQCO400T8 Pin Layout (viewed from top)

2.3 Pin Descriptions

Pin #	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 that can be used to indicate the length of the cable being equalized; 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 → valid input signal; SDOp/SDOn are turned on LOW → no rx signal/signal too low; SDOp/SDOn are muted Can source up to 3mA to directly drive a LED Leave unconnected when not used
4, 8, 9, 14, 15, 16	NC		Leave unconnected

Table 2: Device Pin List

2.3.1 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 analyses 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 8.

2.3.2 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.

2.3.3 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 4 illustrates the voltage at CLI for a typical CAT6 cable.

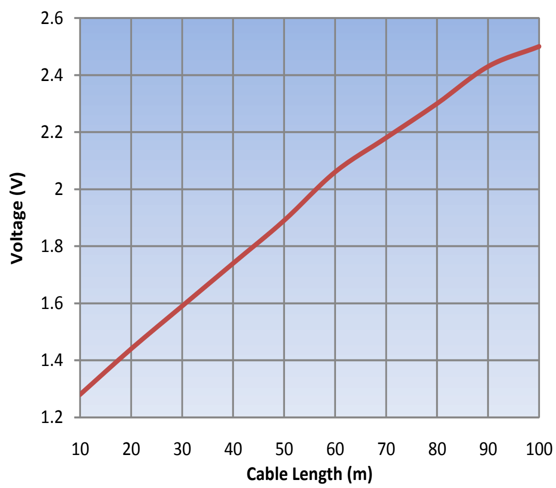

Figure 4: CLI voltage as a function of cable length (Systimax CAT6 cable)

2.3.4 LED

LED is an output that indicates the detection of 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 < 40mV) 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 3mA enabling it to be used to directly drive a Light Emitting Diode. The Light Emitting Diode will thus be ON when a signal is detected, and OFF otherwise. It is advised to use a high efficiency Light Emitting Diode. As the output from this pin is current limited no series resistor is required.

2.4 Equalizer Operation

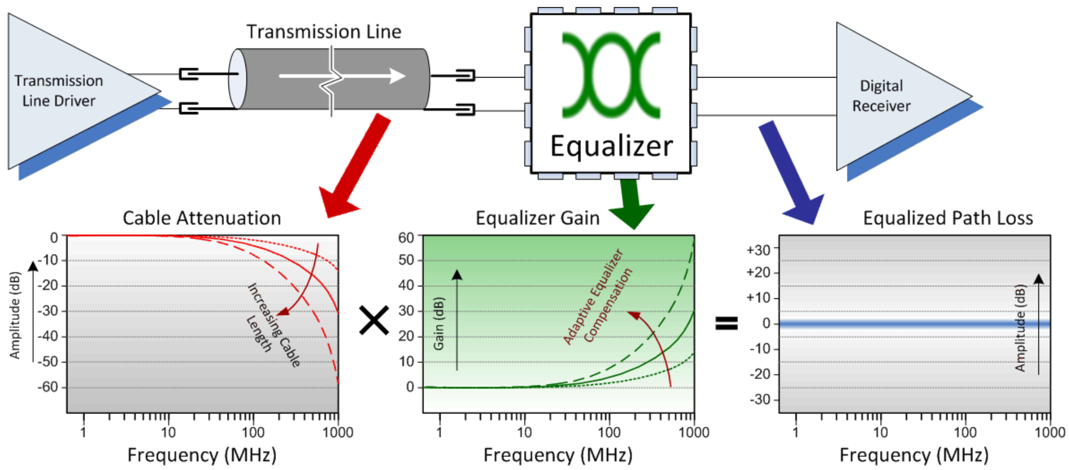

Figure 5: Principle of Equalizer Operation

The EQCO400T8 is an equalizer with unique characteristics [3]:

- Auto-adaptive

  The equalizer controls a multiple pole analog filter which compensates for attenuation of the cable, as illustrated in Figure 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 475mV to 800mV.

- Multi-speed

  The EQCO400T8 works at data rates from 100Mbps to 500Mbps. 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 190mV (approx) or higher the output stage is turned on. Auto-mute reduces the power consumption from 140mW to less than 14mW.

Example equalizer performance measurements can be found in Appendix 1.

3 Electrical Specifications

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.

Parameter	Conditions	Min	Typ	Max	Units
Storage Temperature		-65		+150	°C
Ambient Temperature	Power Applied	-55		+125	°C
Operating Temperature	Normal Operation (VCC=3.3V±5%)	-40		+85	°C
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
Output current into Outputs	Outputs Low			90	mA
Electro Static Discharge (ESD) HBM	JEDEC EIA/JESD-A114A	>3.3			kV
Electro Static Discharge (ESD) contact	IEC 61000-4-2	>8			kV
Latch-Up Current		>200			mA(DC)

Table 3: Absolute Maximum Ratings

3.2 Current Consumption

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

Table 4: Maximum Current Consumption @ 3.3V

3.3 Electrical Characteristics

Parameter	Description	Min	Typ	Max	Unit
VCC		3.135	3.3	3.465	V
	Signalling rate (NRZ, 8B/10B encoded)	100	500	600	Mbps
SDIp/SDIn inputs					
Differential input voltage swing	$\lvert V_{SDIp} - V_{SDIn} \rvert$ measured at cable input	475[2]		800	mV
$LVDSI_{min}$	Minimum differential input for fully reconstructed output		40		mV
	Common-mode input voltage		3.3[3]		V
Input R	Single ended; to VCC		50		Ω
SDOp/SDOn Outputs					
LVDSo	Differential output voltage swing $\lvert V_{SDOp} - V_{SDOn} \rvert$ (50Ω load to VCC on each output) LED is HIGH		440		mV
	Common-mode output voltage		VCC - LVDSo/2		V
SDO_{off}	Output voltage with disabled driver Single ended; LED is LOW		VCC		V
Output R	Single ended; to VCC		55		Ω
Rise/Fall time	20% to 80%	100	190	260	ps
LED					
V_{oh}	Diff. input voltage at cable input > 250mV	1.5	VCC		V
V_{ol}	Diff. input voltage at cable input < 40mV		GND	0.8	V
CLI					
V_{oh}	Output voltage at minimum cable length		1.2		V
V_{ol}	Output voltage at maximum cable length		2.6		V

Table 5: Electrical Characteristics (Over the Operating Range)

[2] Per IEEE1394-2008 specification. Not a hard requirement but recommended for maximum cable reach as per Figure 1
[3] SDI Inputs are terminated to 3V3 internally. It is recommended to AC couple these signals to avoid high DC currents from flowing

4 Package Drawing

The EQCO400T8 is packaged in a 16 pin Micro Lead frame Package (MLP) also known as Quad Flat No Lead (QFN) package. The package outline conforms to JEDEC MO-220.

Dimensions in Figure 6 and Figure 7 are in millimeters.

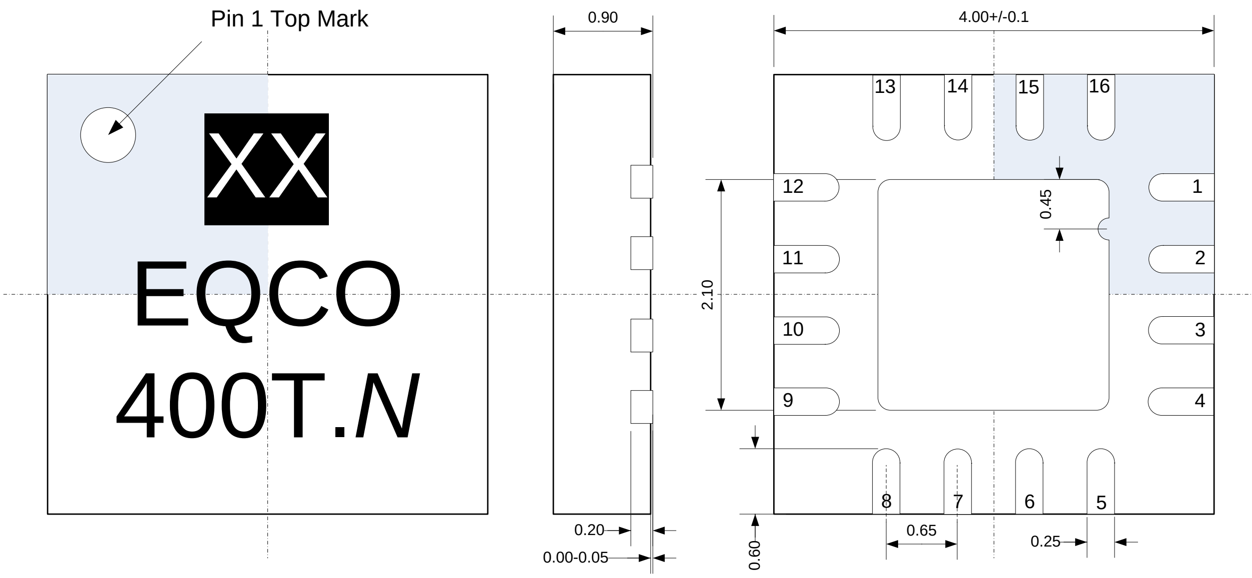

Figure 6: Package Drawing viewed from Top - Side - Bottom[4]

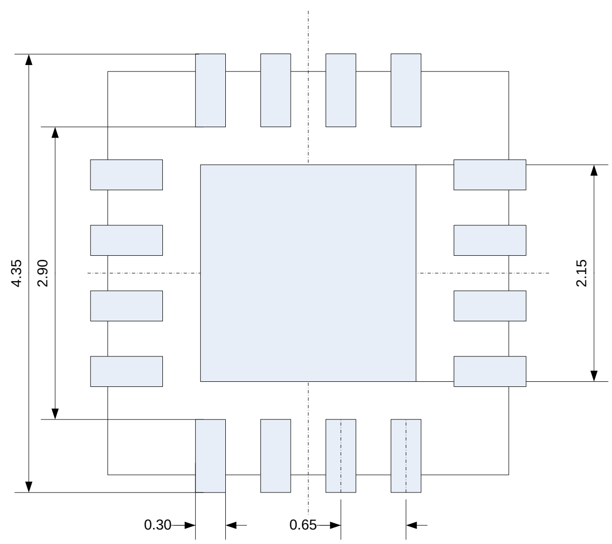

Figure 7: Recommended PCB Footprint

[4] The "*N*" on the package refers to the variant mark, being "5" for EQCO400T-5, "7" for EQCO400T-7 or "8" for EQCO400T-8

5 Application Information

5.1 Typical Application Circuit

Figure 8 illustrates a typical schematic implementation. In this diagram data is transmitted on pins 1,2 and received on pins 3,6 of the RJ45.

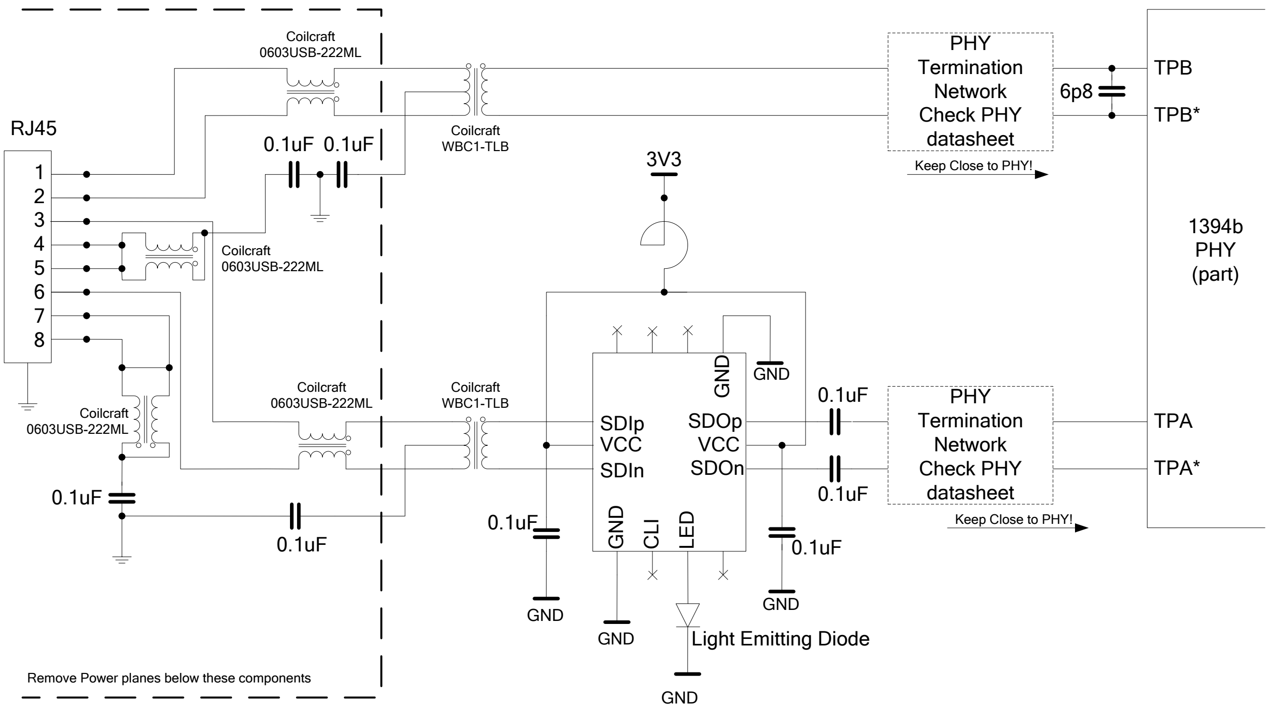

Figure 8: Example Schematic Implementation

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 6.8pF 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.[5]

[5] The toning process in Fire Wire applications cannot handle near end cross-talk very well: it can turn-on the receiver unwantedly, especially at low temperatures, troubling the toning process. With the use of pairs 12 and 36 like in Fig. 8, temperatures below -10C are prone to this difficulty, due to the crosstalk between the adjacent pins 2 and 3 of the UTP connector. When low temperature Fire Wire operation is needed, it is advised to use pairs 12 and 78 instead. For other UTP applications that do not use toning, this is not an issue.

5.2 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 8. This ensures the impedance seen by all conductors in the UTP cable is the same.

A reference design is available on request.

5.3 Recommended Magnetics

EqcoLogic recommends the following magnetics for use with their EQCO400T:

Component	Part Number
Transformers (1:1 with centre tap) 2 per channel	Coilcraft WBC1-1TLB
Common Mode Chokes 4 per channel	Coilcraft 1206USB-113MLB

Table 6: Recommended Magnetics

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

5.4 Connector pins and cable connection

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

To be the same as 100BaseT Ethernet, IEEE Standard 1394-2008[1] 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.

5.5 Supplying Power over the UTP Cable

The EQCO400T8 is fully compatible with the Power Over Ethernet standard[2] allowing standard POE chipsets 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.

6 Document Control

6.1 Version History

Version	Date	Author	Comments
2.4	27 Febr 2014	M. Kuijk	Removed data about previous versions, added patent information.
2.3	03 May 2009	S.E. Ellwood	Added information on EQCO400T-8
2.2	08 Dec 2008	S.E. Ellwood	Correction to Table 6
2.1	02 Nov 2008	S.E. Ellwood	Added Table 6: Recommended Magnetics, changed postal address
2.0	22 Jul 2008	S.E. Ellwood	Released
1.1	02 Feb 2006	K. Van Den Brande	New document

6.2 Document References

[1] IEEE 1394-2008, Standard for High Performance Serial Bus
[2] IEEE 802.3-2008, clause 33 – "Power over Ethernet" (formerly known as IEEE 802.3af)
[3] Patents: US7564899B2, US7633354B2, EP1932305B1 & US7894515B2.

6.3 Ordering Information

Order Code	Application	Package Type	Operating Range
EQCO400T.5	Long-haul S100,S200,S400	16 Pin, 4mm QFN	0^oC-70^oC
EQCO400T.7	S100, S200 cable extender	16 Pin, 4mm QFN	0^oC-70^oC
EQCO400T8	S100, S200,S400 cable extender	16 Pin, 4mm QFN	0^oC-70^oC

6.4 Disclaimer:

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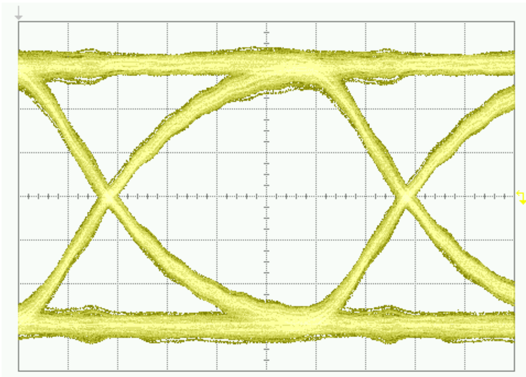
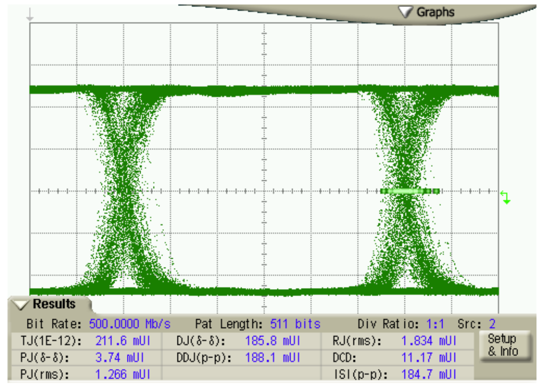
Appendix 1: Typical Operating Characteristics

Auto-adaptive

2m CAT6 cable before equalizer

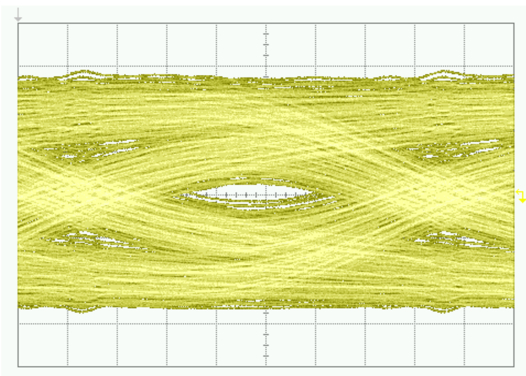


after equalizer

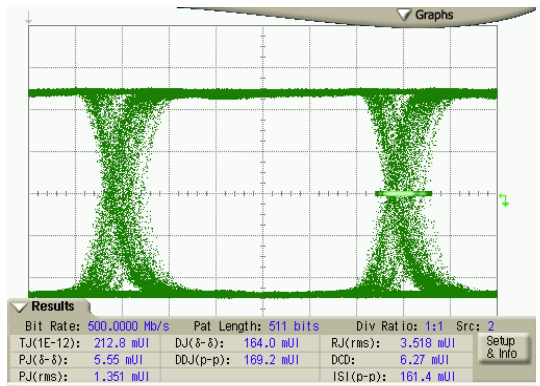


Measured Jitter: ~ 0.2 UI

30m CAT6 cable before equaliser

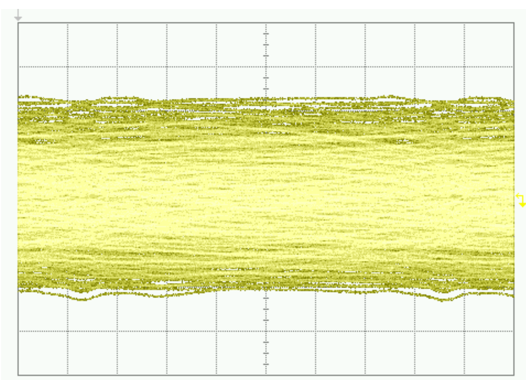


after equaliser

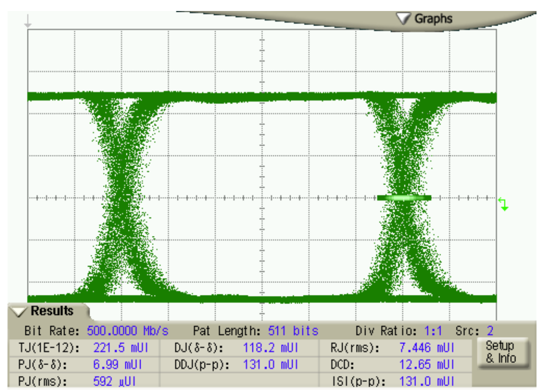


Measured Jitter: ~ 0.2 UI

60m CAT6 cable before equaliser

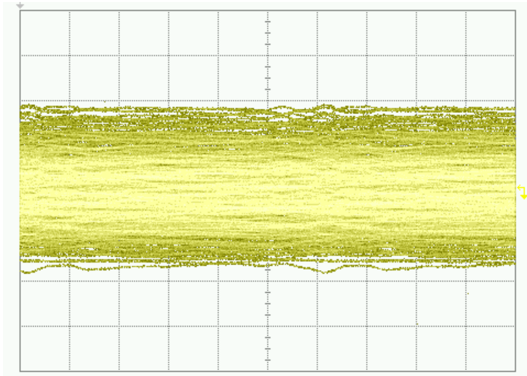


after equaliser

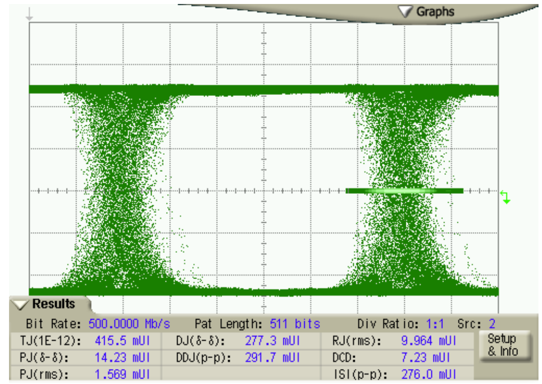


Measured Jitter: ~ 0.2 UI

90m CAT6 cable before equaliser



after equaliser

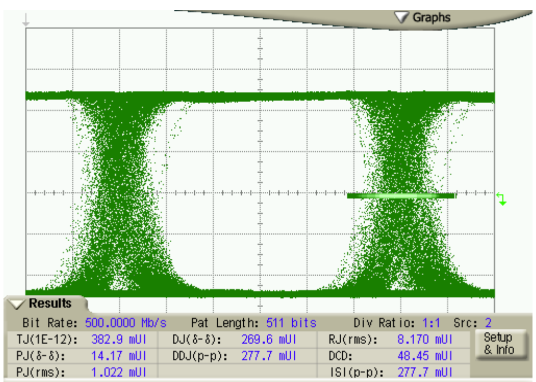


Measured Jitter: ~ 0.4 UI

CAT5e

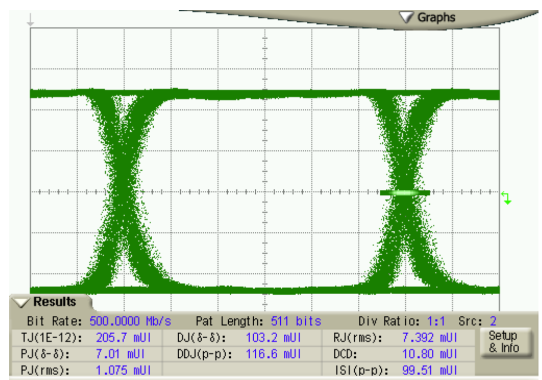
The crosstalk generated in a CAT5e system is much higher than in a CAT6 system. This reduces the maximum cable length over which a link can be maintained.

70m CAT5e



Measured Jitter: ~ 0.4 UI:
Crosstalk source: Tx on pair 1,2 ; S400β ; 630mV Tx ampl

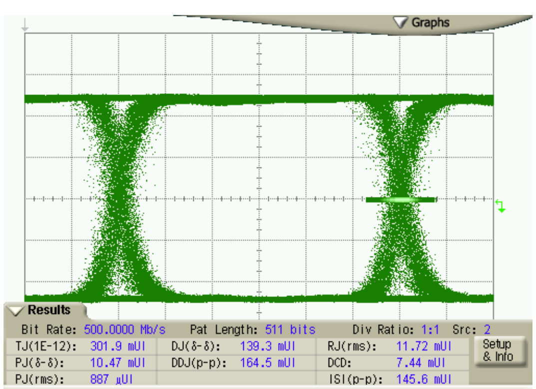
70m CAT5e - RX only



Measured Jitter: ~ 0.2 UI
No crosstalk source

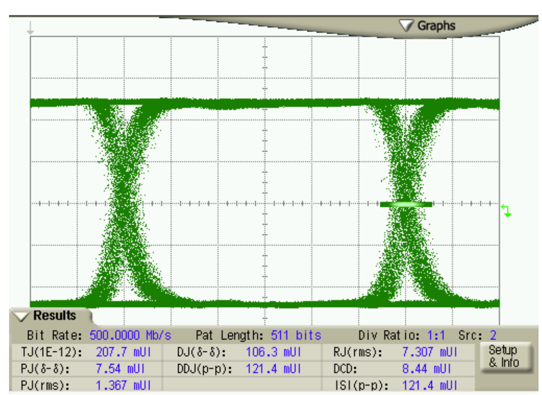
Variable gain

300mV Transmit amplitude (80m CAT6 cable)



Measured Jitter: ~ 0.3 UI
No crosstalk source

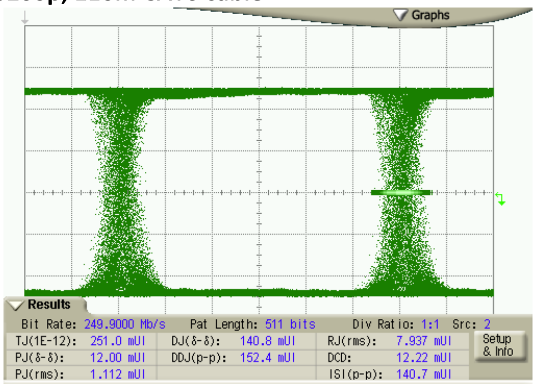
800mV Transmit amplitude (80m CAT6 cable)



Measured Jitter: ~ 0.2 UI
No crosstalk source

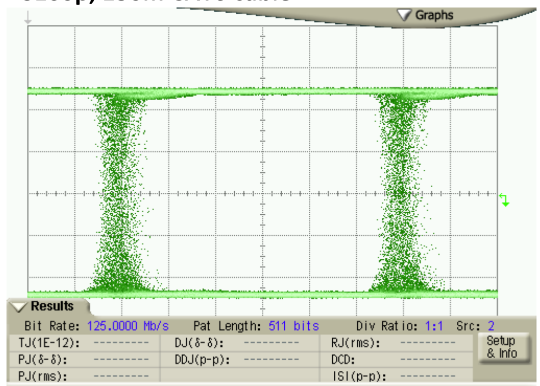
Multi-speed

S200β, 110m CAT6 cable



Measured Jitter: ~ 0.25 UI
Crosstalk source: Tx on pair 1,2 ; S200β ; 630mV Tx ampl

S100β, 130m CAT6 cable



Measured Jitter: < 0.3 UI
Crosstalk source: Tx on pair 1,2 ; S100β ; 630mV Tx ampl

Notes:

Figures shown are for the EQCO400T.5 variant
All measurements at VCC = 3.3V, Temp = +25ºC, data pattern = $2^9 – 1$ PRBS
Unless otherwise stated measurement parameters are as follows:
Receive signal on pair 3,6 ; S400β ; 630mV Transmit amplitude
Crosstalk source on pair 1,2 ; S400β ; 630mV Transmit amplitude

