
EQCO30T5.2 3G/HD-SDI Video Cable Driver

Features

- Compatible with all SMPTE3G SDI Data Rates:
 - SMPTE259M SDI, 143 to 360 Mbps
 - SMPTE344M, 540 Mbps
 - SMPTE292M HD-SDI, 1.485 Gbps
 - SMPTE372M Dual-Link HD-SDI, 2.97 Gbps
 - SMPTE424M Dual-Speed 3G-SDI, 2.97 Gbps
- Pin Compatible with Gennum and National Semiconductor Parts
- Loss of Signal Detect at Input, Optional 3 dB Input Trace/Receive Equalization
- Also Operates with 8B/10B Coding
- Single 3.3V Supply.
- Low Power Consumption (150 mW, 3.3V supply)
- Output Driver Enable
- LF-Uplink Receiver Included, Receiving 5 Mbps in Full-Duplex Communication for Cable Lengths in 0-450m Range
- Up to 900 mA can be Received for Powering Camera Devices
- Selectable Slew Rate for SD and HD/3G
- 16-Pin, 0.65 mm Pin Pitch, 4 mm QFN Package
- -40°C to +85°C Industrial Temperature Range
- Pb-Free and RoHS Compliant

Applications

- High Definition, High Frame Rate Pro-Video HD-SDI Frame Store
- Surveillance, Industrial/Inspection, Medical Video Inputs
- HDcctv Applications

Introduction

The EQCO30T5 is a video cable driver for 3G/HD/SDI video, with speeds up to 4.0 Gbps. It is designed to be a direct replacement for competing cable drivers. In addition to downlink functionality from camera to frame grabber, it can also receive a 5 Mbps uplink signal from the frame grabber to the camera. Additionally, power can be provided over the same cable using the same chip and a few external components. The device operates with 8B/10B coded signals and with SMPTE signals up to 2.97 Gbps.

Note: The EQCO30T5 cable driver can be used in combination with the EQCO30R5 video equalizer. This device is capable of transmitting the uplink signal whilst other key parameters remain compliant to SMPTE specifications. Please refer to the Microchip web site (www.microchip.com) for the EQCO30R5 data sheet.

EQCO30T5.2

Typical Link Performance

Table 1, Table 2 and Table 3 give an overview of link performance (EQCO30T5 and EQCO30R5 combined) at room temperature without using the uplink and without providing power over the same coax. When providing power or using the uplink communication to the camera, a small length penalty may arise (in cable length, typically 10%) due to added parasitics and noise. The uplink operates to at least 400m at the 5 Mbps bit rate.

TABLE 1: BELDEN TYPICAL LINK PERFORMANCE

	Name	Belden 7731A	Belden 1694A	Belden 1505A	Belden 1505F	Belden 1855A
	Type	Long Distance	Industry Standard	Compromise Coax	Flexible	Thinnest Cable
Diameter	(mm)	10.3	6.99	5.94	6.15	4.03
270 Mbps	(m)	718	469	384	302	270
1.485 Gbps	(m)	332	223	187	136	132
2.97 Gbps	(m)	219	149	128	89	91

TABLE 2: GEPCO TYPICAL LINK PERFORMANCE

	Name	Gepco VHD1100	Gepco VSD2001	Gepco VPM2000	Gepco VHD2000M	Gepco VDM230
	Type	Long Distance	Industry Standard	Compromise Coax	Flexible	Thinnest Cable
Diameter	(mm)	10.3	6.91	6.15	6.15	4.16
270 Mbps	(m)	772	502	387	305	273
1.485 Gbps	(m)	372	241	187	138	133
2.97 Gbps	(m)	252	163	128	91	92

TABLE 3: CANARE TYPICAL LINK PERFORMANCE

	Name	Canare L-7CFB	Canare L-5CFB	Canare L-4CFB	Canare L-3CFB	Canare L-2.5CFB
	Type	Long Distance	Industry Standard	Compromise Coax	Thin Cable	Thinnest Cable
Diameter	(mm)	10.3	6.99	5.94	6.15	4.03
270 Mbps	(m)	615	434	344	287	223
1.485 Gbps	(m)	281	201	161	135	109
2.97 Gbps	(m)	182	132	107	90	73

Table of Contents

1.0	Device Overview	4
2.0	Application Information.....	8
3.0	Electrical Characteristics	11
4.0	Packaging.....	13

TO OUR VALUED CUSTOMERS

It is our intention to provide our valued customers with the best documentation possible to ensure successful use of your Microchip products. To this end, we will continue to improve our publications to better suit your needs. Our publications will be refined and enhanced as new volumes and updates are introduced.

If you have any questions or comments regarding this publication, please contact the Marketing Communications Department via E-mail at docerrors@microchip.com or fax the **Reader Response Form** in the back of this data sheet to (480) 792-4150. We welcome your feedback.

Most Current Data Sheet

To obtain the most up-to-date version of this data sheet, please register at our Worldwide Web site at:

<http://www.microchip.com>

You can determine the version of a data sheet by examining its literature number found on the bottom outside corner of any page. The last character of the literature number is the version number, (e.g., DS30000000A is version A of document DS30000000).

Errata

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.

To determine if an errata sheet exists for a particular device, please check with one of the following:

- Microchip's Worldwide Web site; <http://www.microchip.com>
- Your local Microchip sales office (see last page)

When contacting a sales office, please specify which device, revision of silicon and data sheet (include literature number) you are using.

Customer Notification System

Register on our web site at www.microchip.com to receive the most current information on all of our products.

EQCO30T5.2

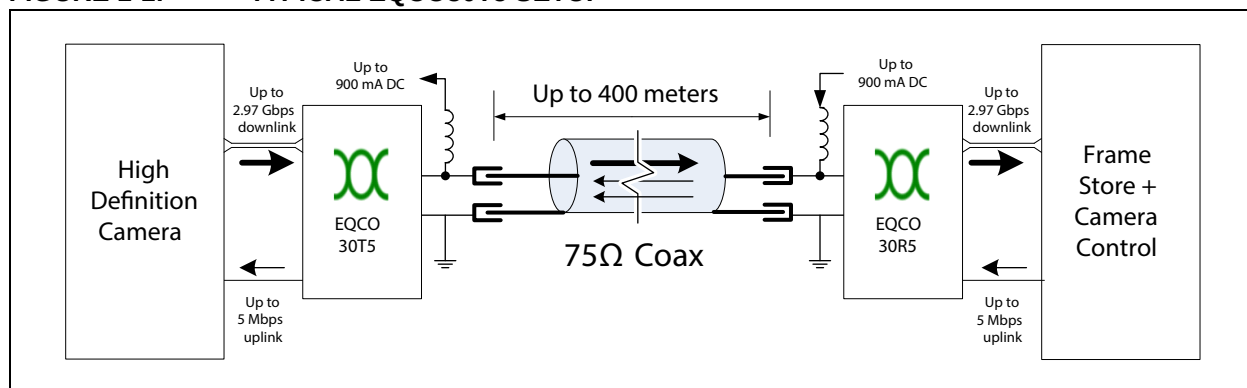
1.0 DEVICE OVERVIEW

The EQCO30T5 is a dual slew rate cable driver designed to drive digital signals over coaxial cable. The EQCO30T5 chip is optimized for driving SMPTE HD-SDI signals, but works equally well with 8B/10B coded signals.

The EQCO30R5 is a video equalizer that matches to the EQCO30T5, since it can transmit the uplink signal. Implementing the uplink requires very few additional components on both sides of the link, and complies with SMPTE specifications. The EQCO30R5 data sheet is available separately from Microchip.

Figure 1-1 shows a typical communication link using the EQCO30T5 and EQCO30R5 chips:

FIGURE 1-1: TYPICAL EQCO30T5 SETUP



The EQCO30T5 includes an uplink receiver for receiving digital data coming from the frame store in full-duplex, giving 5 Mbps of bandwidth for:

- Triggering purposes, Auxiliary outputs
- Firmware upgrades,
- Audio channels
- Etc.

1.1 Pinout and Pin Description

FIGURE 1-2: EQCO30T5.2 PIN DIAGRAM (VIEWED FROM TOP)

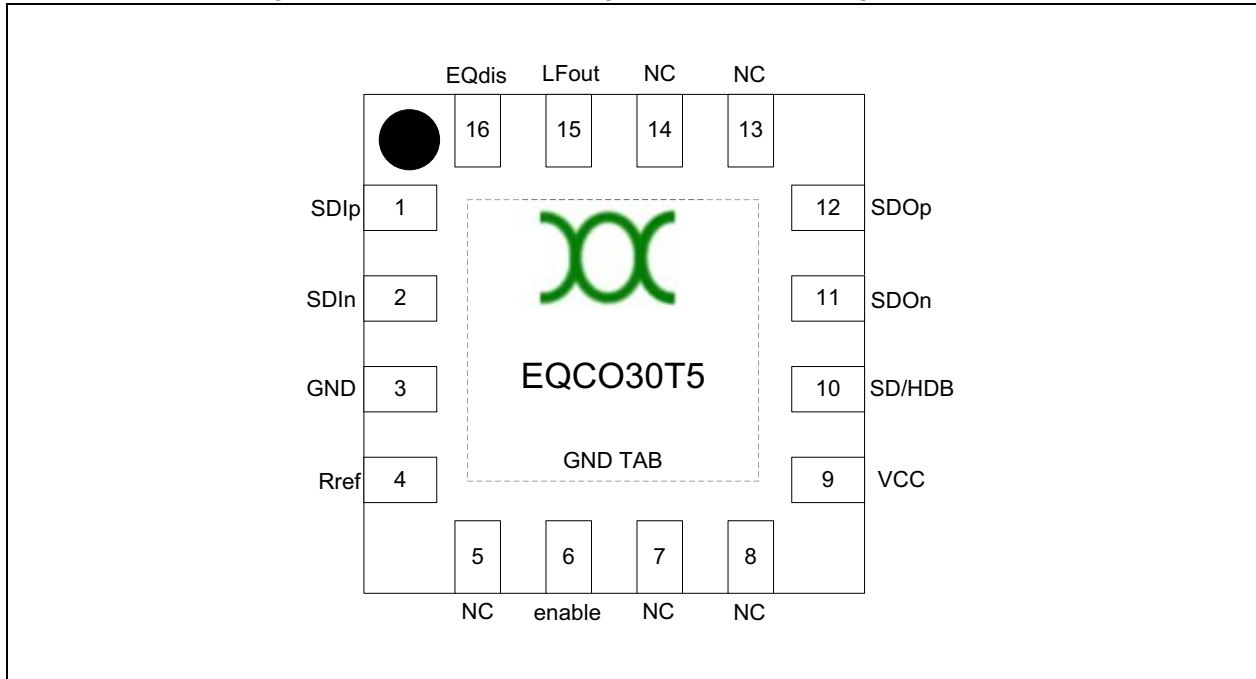


TABLE 1-1: EQCO30T5.2 PIN DESCRIPTIONS

Pin Number	Pin Name	Signal Type	Description
(TAB)	GND	Power	Use as single-point ground.
1, 2	SDIp, SDIn	Differential Input	Serial input positive/negative differential serial input.
3	GND	Power	Ground. Connect to GND TAB.
4	R _{ref}	Analog Input	Input determining output amplitude of cable driver.
9	VCC	Power	+3.3V of power supply.
6	Enable	Input	Enables the output driver pins.
5, 7, 8, 13, 14	NC	Input	Do not connect; leave floating. Used for internal testing.
10	SD/HDB	Input	Select edge rate.
11	SDOn	Driver Output	Serial negative cable driver output with 50Ω on-chip serial output resistance. Complement with 25Ω externally.
12	SDOp	Driver Output	Serial positive cable driver output with 50Ω on-chip serial output resistance. Complement with 25Ω externally.
15	LFout	Output	Digital output signal of the full-duplex uplink.
16	EQdis	Input	Disables input trace equalization.

1.1.1 SDIP/SDIN

SDIp/SDIn together form a differential input pair. Between SDIp and SDIn inputs, there is a termination resistor of 100Ω. The intention is to always use AC coupling. When AC-coupled, the common-mode gets biased to 600 mV.

1.1.2 RREF

A resistor is to be connected between VCC and the R_{ref} pin. A resistor of 750Ω gives an 800 mV launch amplitude in the 75Ω coaxial cables. A larger resistor gives a smaller amplitude.

1.1.3 ENABLE

When enable is floating or pulled high, the output driver is enabled. When enable is low, the output is disabled and power consumption drops significantly.

EQCO30T5.2

1.1.4 SD/HDB

With SD/HDB set to high, the output rise and fall times are set for SD operation. When left floating or pulled low, the rise and fall times are set for 3G/HD operation.

1.1.5 SDO_n, SDO_p

The output driver is not based on a CML output stage. Both outputs operate independently, so there is very little interference between the outputs and their termination condition. There is also no LR-output network needed for achieving good return-loss. A 25Ω resistor should be connected in series with the output to drive a 75Ω coax cable. The output amplitude is achieved behind this 25Ω resistor; refer to the application circuits at the end of the data sheet. The PCB doesn't require layout changes when migrating from competing cable drivers, however, fewer components are needed. One does not need to optimize the return-loss network, since it is omitted.

1.1.6 LFOUT

LFout provides the 5 Mbps received uplink signal (LVTTTL voltage levels). It can easily drive a PCB trace of 20 pF at this speed. For longer distance communication from this pin to the next chip, using a buffer is recommended. The output impedance is about 300Ω.

1.1.7 EQ_{dis}

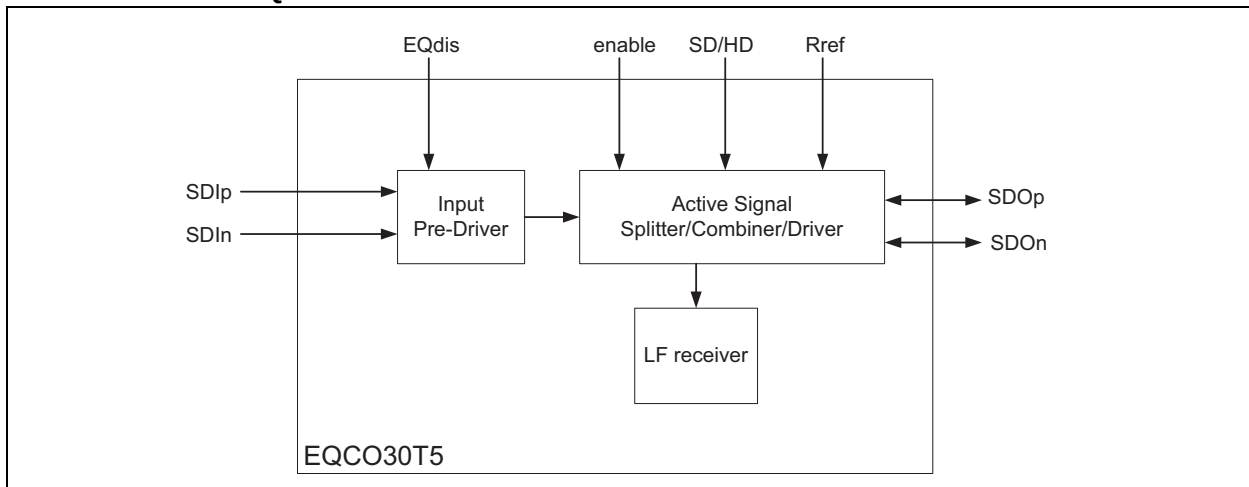
When EQ_{dis} is left floating or pulled low, the input trace equalization is turned on and invokes a typical 3 dB gain at 1.5 GHz.

This value is optimized for compensating the high-frequency losses of approximately 20 cm of 5-mil stripline in FR4. When pulled high, this equalization is turned off.

1.2 Circuit Operation

Figure 1-3 is a block diagram of the EQCO30T5, showing electrical connections. The input pre-driver brings the input signal to a digital signal, with or without the use of input trace equalization. The active splitter/combiner/driver launches the digital signal in the cable, with an amplitude determined by the external resistor connected to R_{ref} and with an edge rate for SD or 3G/HD-SDI depending on the SD/HDB signal. It also splits the incoming signal towards the LF receiver to provide the 5 Mbps LF_{out} signal.

FIGURE 1-3: EQCO30T5 BLOCK DIAGRAM SHOWING ELECTRICAL CONNECTIONS



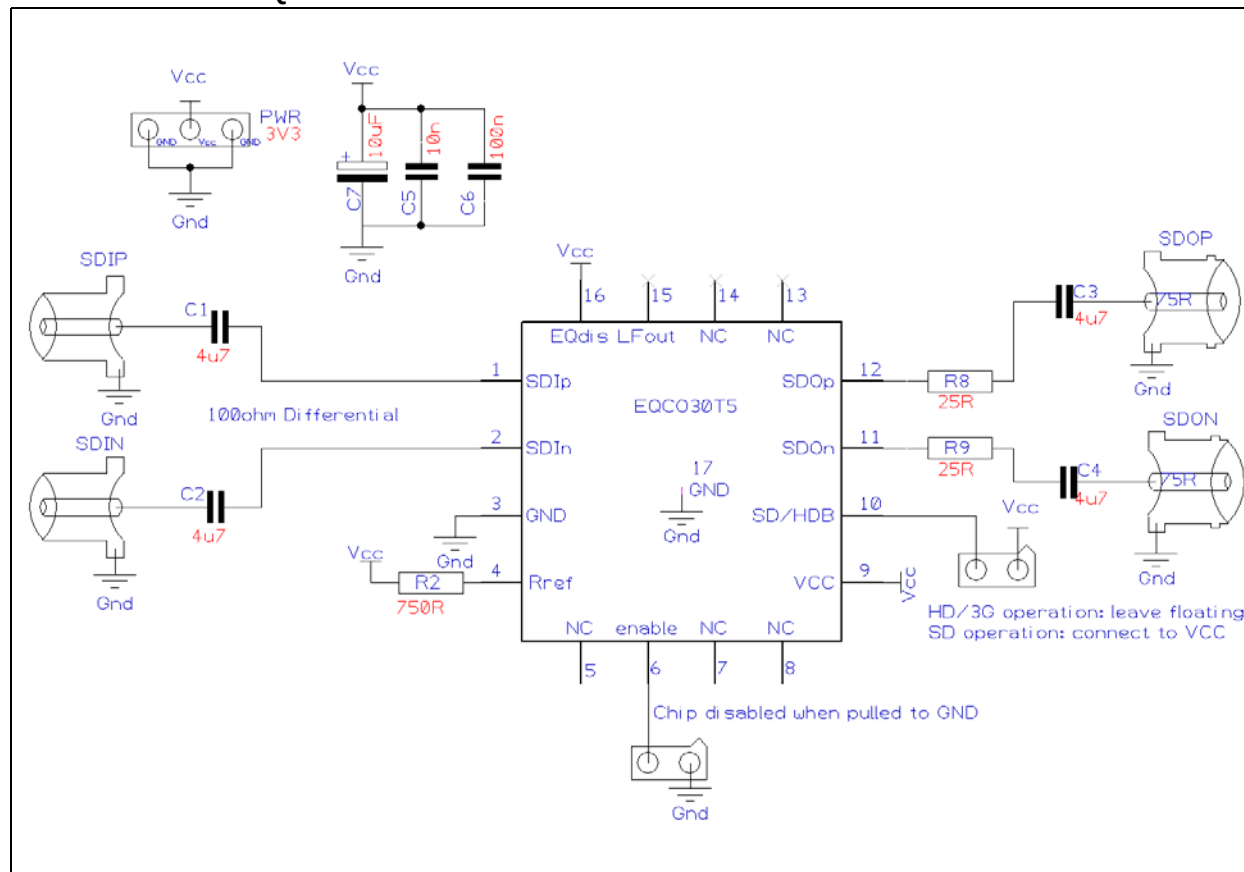
EQCO30T5.2

2.0 APPLICATION INFORMATION

2.1 Typical Application Circuit as SMPTE Cable Driver

Figure 2-1 illustrates a typical schematic implementation of the EQCO30T5 used as a cable driver for SMPTE video signals.

FIGURE 2-1: EQCO30T5.2 TYPICAL APPLICATION CIRCUIT AS SMPTE CABLE DRIVER



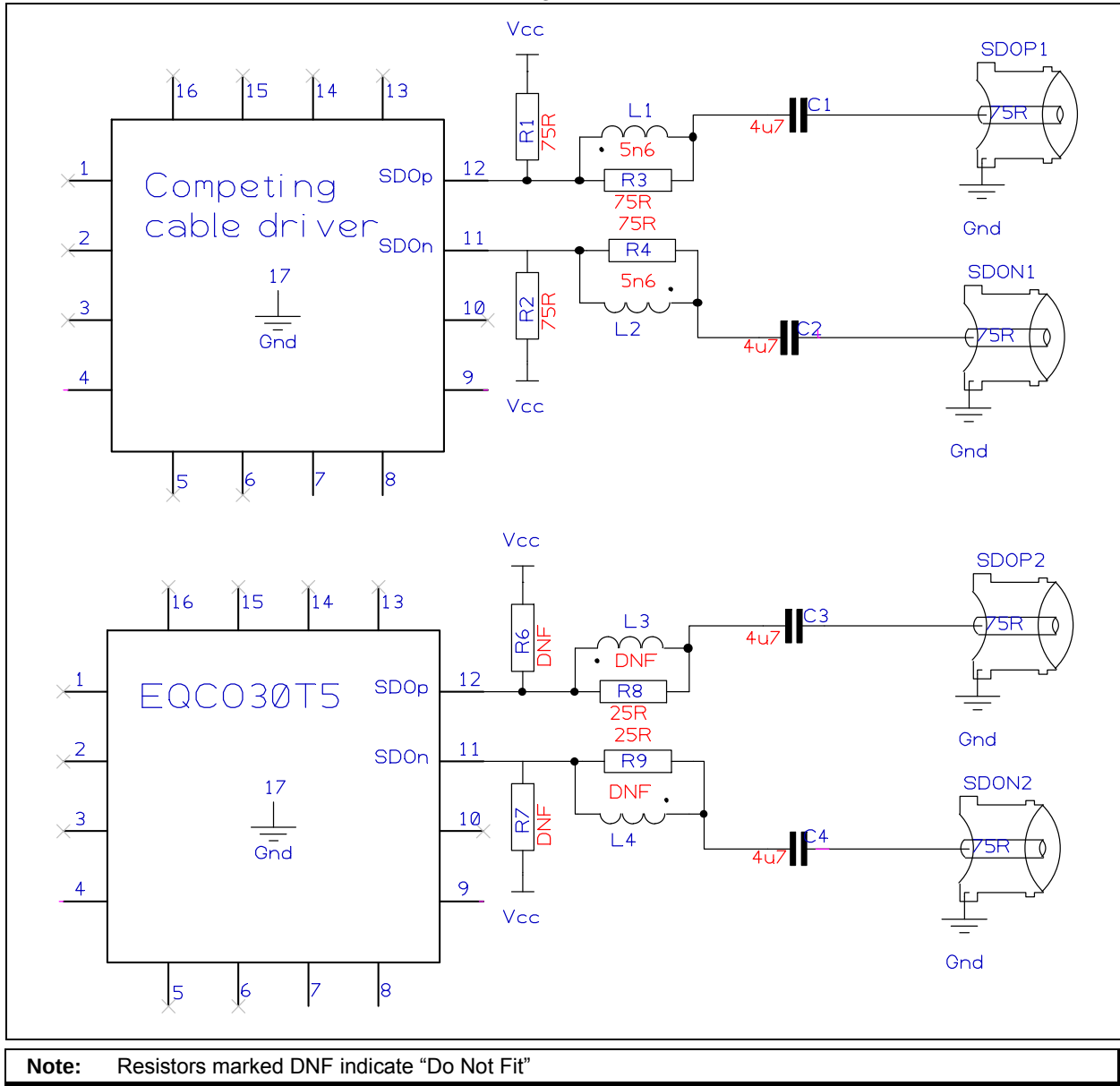
Resistors R8 and R9 are to be placed close to pins 12 and 11, respectively. From there onwards, the traces up to the coax connectors should be laid-out as 75Ω traces (including the C3 and C4 capacitors as AC-couplers).

2.1.1 RETURN-LOSS NETWORK

Competing cable drivers need external RL return-loss networks. The EQCO30T5 does not need these type of external networks. Figure 2-2 compares the output network of the EQCO30T5 with the network of competing cable drivers.

The EQCO30T5 is pin-compatible with other cable drivers, but with a different component population. No termination resistor to VCC is required (do not fit = DNF). The inductor of the return loss network must not be populated and the 75Ω resistor of this network should be replaced with a 25Ω resistor to achieve correct operation.

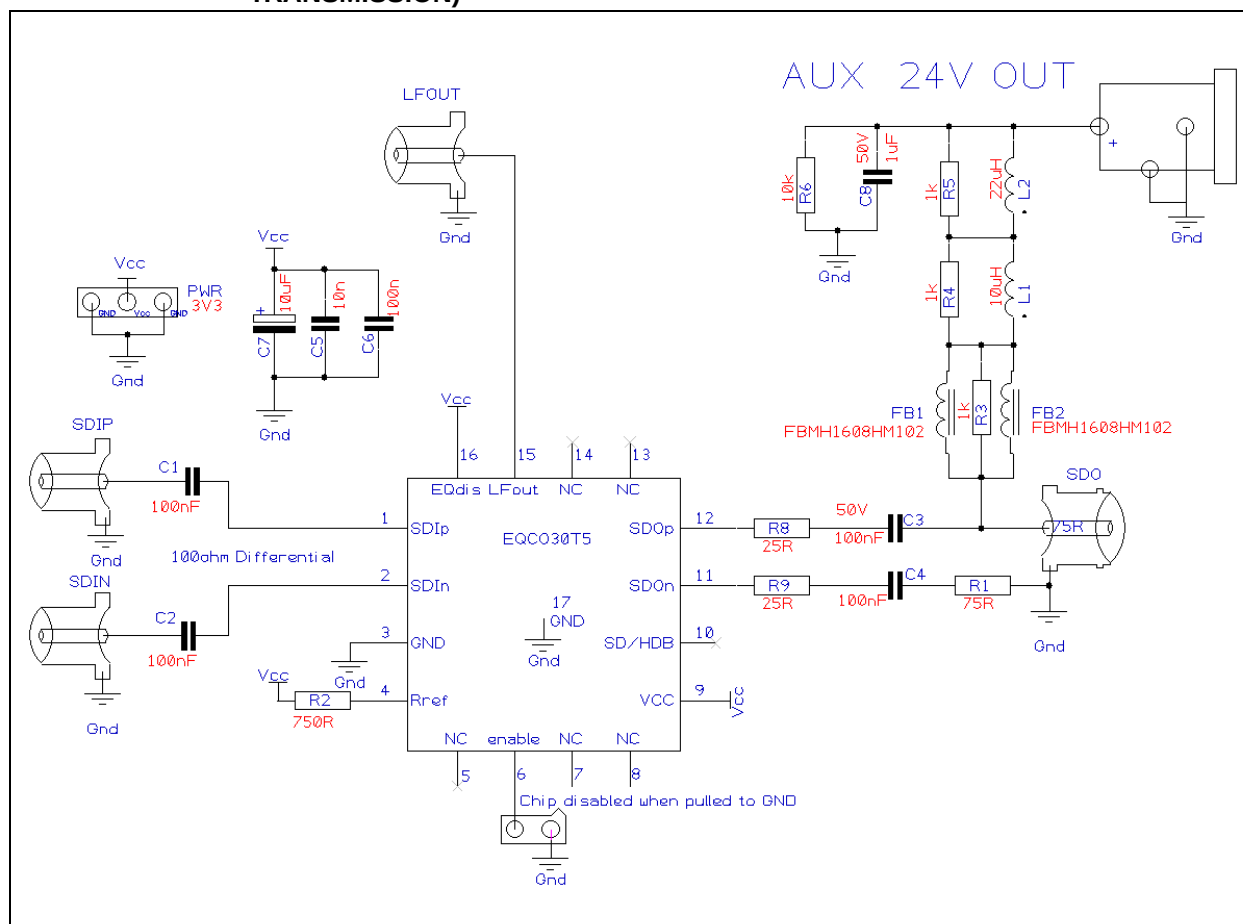
FIGURE 2-2: COMPARISON BETWEEN EQCO30T5 AND COMPETING SOLUTIONS



EQCO30T5.2

2.2 EQCO30T5 in Bidirectional Link (Including Power Supply)

FIGURE 2-3: EQCO30T5 IN BIDIRECTIONAL LINK (INCLUDING POWER SUPPLY TRANSMISSION)



Resistors R8 and R9 are to be placed close to pins 12 and 11, respectively. From there onwards, the traces up to the coax connector SDIP1 should be laid out as 75Ω traces (including the C3 and C4 capacitors as AC couplers). Resistor R1 has to be placed very close to this coax connector with a very short, low-impedance connection between one of the shielding pins of the connector and the resistor. To achieve the return-loss illustrated in the appendix, the power and ground planes below components FB1, FB2, R3, R4, L1, R5, L2 should be removed (applying cut-outs).

2.2.1 COMPONENT RECOMMENDATION

When using the components below, a maximum current of 900 mA can be communicated to power-up the camera side. Different types of inductors may be suitable in order to allow a higher current level, however, the RF quality of the inductor should be checked.

Ferrite Beads Fb1, Fb2 = FBMH1608HM102 from Taiyo Yuden

Inductor L1= 1812PS_103 from Coilcraft

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	Conditions	Min.	Typ.	Max.	Units
Storage Temperature	—	-65	—	+150	°C
Ambient Temperature	Power applied	-55	—	+125	°C
Operating Temperature	Normal operation (VCC = 1.2V ±5%)	-40	—	+85	°C
Supply Voltage to Ground	—	-0.8	—	+3.6	V
DC Input Voltage	—	-0.8	—	+3.6	V
DC Voltage to Outputs	—	-0.8	—	+3.6	V
Current into Outputs	Outputs low	—	—	90	mA

TABLE 3-2: ELECTRICAL CHARACTERISTICS (OVER THE OPERATING VCC AND -40 TO +85°C RANGE)

Parameter	Description	Min.	Typ.	Max.	Unit
Power Supply					
VCC	Supply voltage	3.15	3.3	3.45	V
I _S	Supply current, both transmitting and receiving	—	45	—	mA
Operational Bit Rate					
BR _{output}	Bit rate cable driver output	0.05	—	4	Gbps
BR _{uplink}	Bit rate uplink receiver	0.5	—	5	Mbps
SDIp/SDIn Input					
ΔVi	Input amplitude V _{SDIp,n}	2x100	—	2x900	mV
V _{CMIN}	Input common-mode voltage	—	600	—	mV
R _{input}	Differential input termination	—	2x50	—	Ω

EQCO30T5.2

TABLE 3-2: ELECTRICAL CHARACTERISTICS (OVER THE OPERATING VCC AND -40 TO +85°C RANGE) (CONTINUED)

SDOp connection to Coax					
Z_{coax}	Coax cable characteristic impedance	—	75	—	Ω
$R_{\text{SDOp}}, R_{\text{SDOn}}$	Input impedance between SDOp and VCC/GND. To get to 75, add external 25 Ω series resistor.	45	50	55	Ω
R_{loss}	Return-Loss as seen on SDOp pin having 25 Ω series resistor. Frequency range = 5 MHz-1.5 GHz	—	—	-15	dB
R_{loss}	Return-Loss as seen on SDOp pin having 25 Ω series resistor. Frequency range = 1.5 GHz-3.0 GHz	—	—	-10	dB
ΔV_{TX}	Transmit amplitude with $R_{\text{ref}} = 750\Omega$	720	800	880	mV
$t_{\text{rise_tx_SD}}$	Rise/Fall time 20% to 80% of ΔV_{TX} (SD/HDB = High)	400	—	800	ps
$t_{\text{rise_tx}}$	Rise/Fall time 20% to 80% of ΔV_{TX} (SD/HDB = Low)	—	—	65	ps
LFO Output (LVTTTL-like)					
$t_{\text{rise_ILFO}}$	Rise/Fall time 20% to 80% of V_{CC} for 20 pF load	—	15	—	ns

TABLE 3-3: JITTER NUMBERS⁽¹⁾

Parameter	Conditions	Min.	Typ.	Max.	Units
Additive peak to peak jitter on SDOp and SDOn	Downlink signal = 3.0 Gbps	—	10	—	ps
Peak to peak jitter on LFO	0-450m ⁽²⁾ , @ low-speed signal = 5 Mbps, 8B/10B, and @ downlink signal = 270 Mbps, 8B/10B	—	50	—	ns

1: Jitter numbers (over operating VCC range at -40°C to +85°C and full ΔV_{TX} range with pathological patterns)

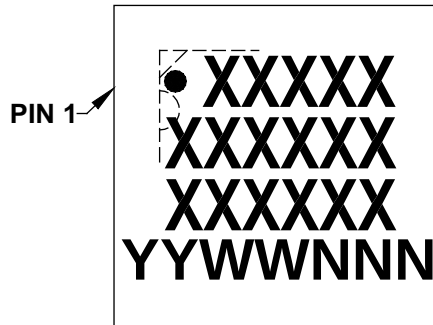
2: Measured with Belden 1694A coaxial cable

4.0 PACKAGING INFORMATION

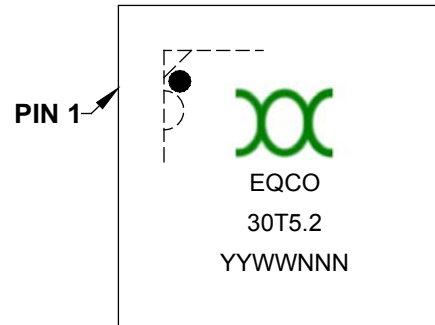
4.1 Package Marking Information

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

16-Lead QFN (4x4x0.9 mm)



Example



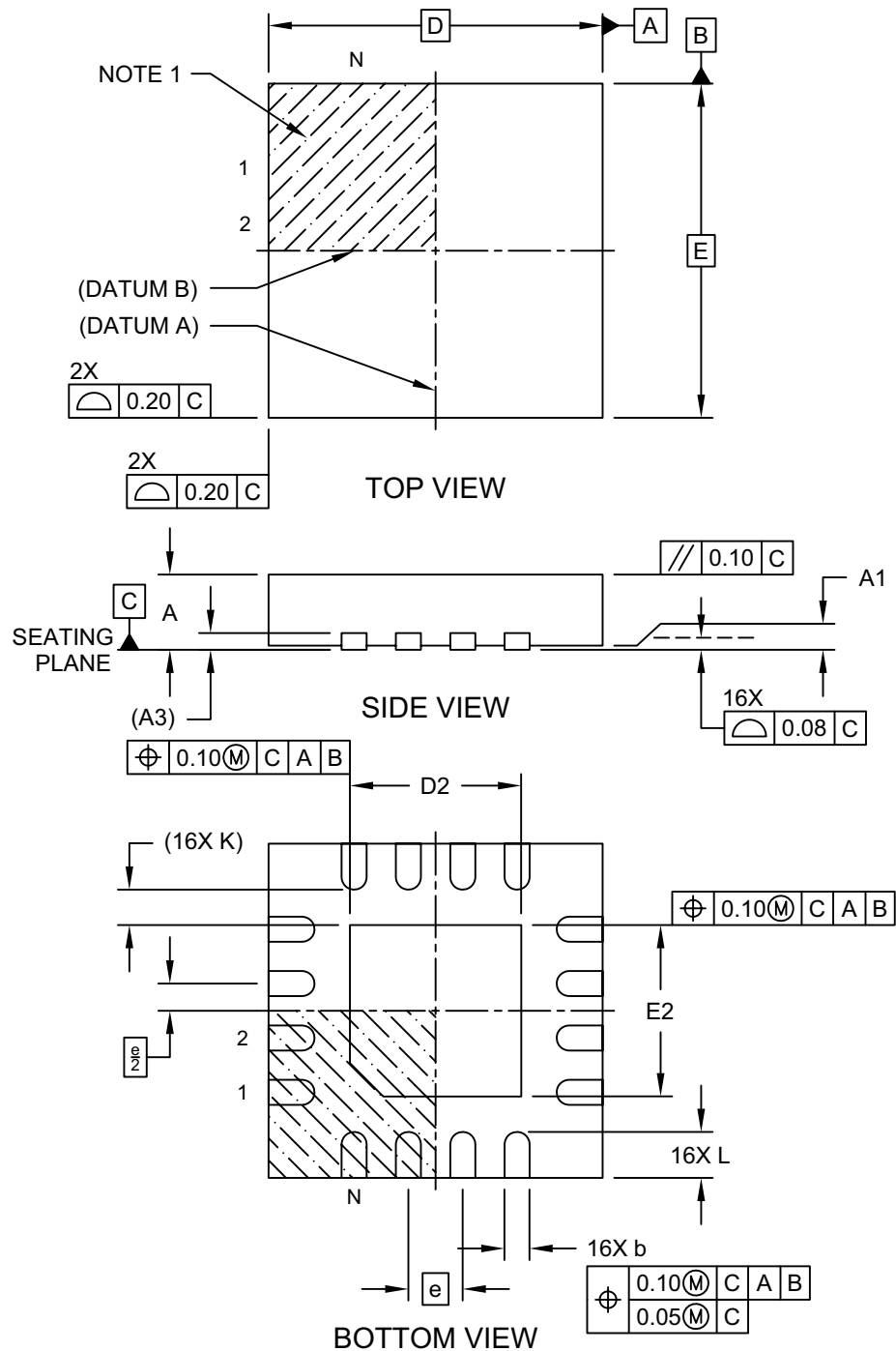
Legend:	XX...X	Customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week '01')
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package is Pb-free. The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

EQCO30T5.2

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

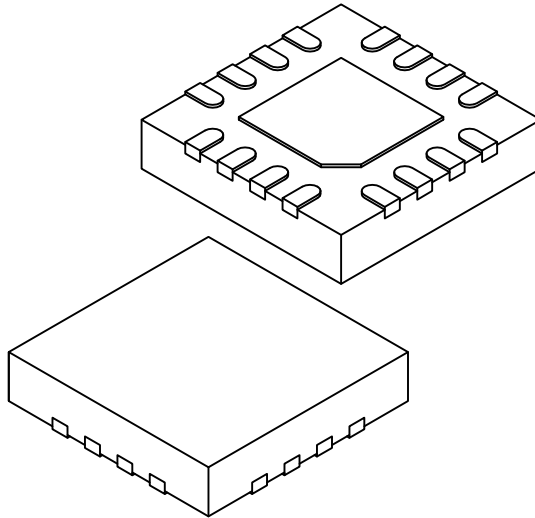
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-259B Sheet 1 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>



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:

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

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

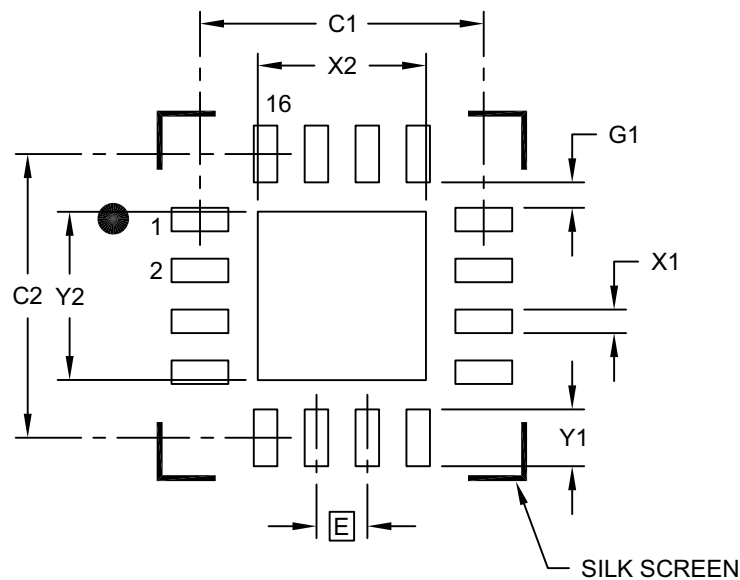
REF: Reference Dimension, usually without tolerance, for information purposes only.

Microchip Technology Drawing C04-259B Sheet 2 of 2

EQCO30T5.2

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 C (February 2016)

- Removed electrostatic discharge ratings from [Table 3-1](#).
- Minor typographical changes.

Revision B (February 2015)

- Updated the typical application circuit diagrams in [Figures 2-1](#) and [2-3](#).

Revision A (September 2014)

This is the initial release of the document in the Microchip format. This replaces EqcoLogic document version 2v0.

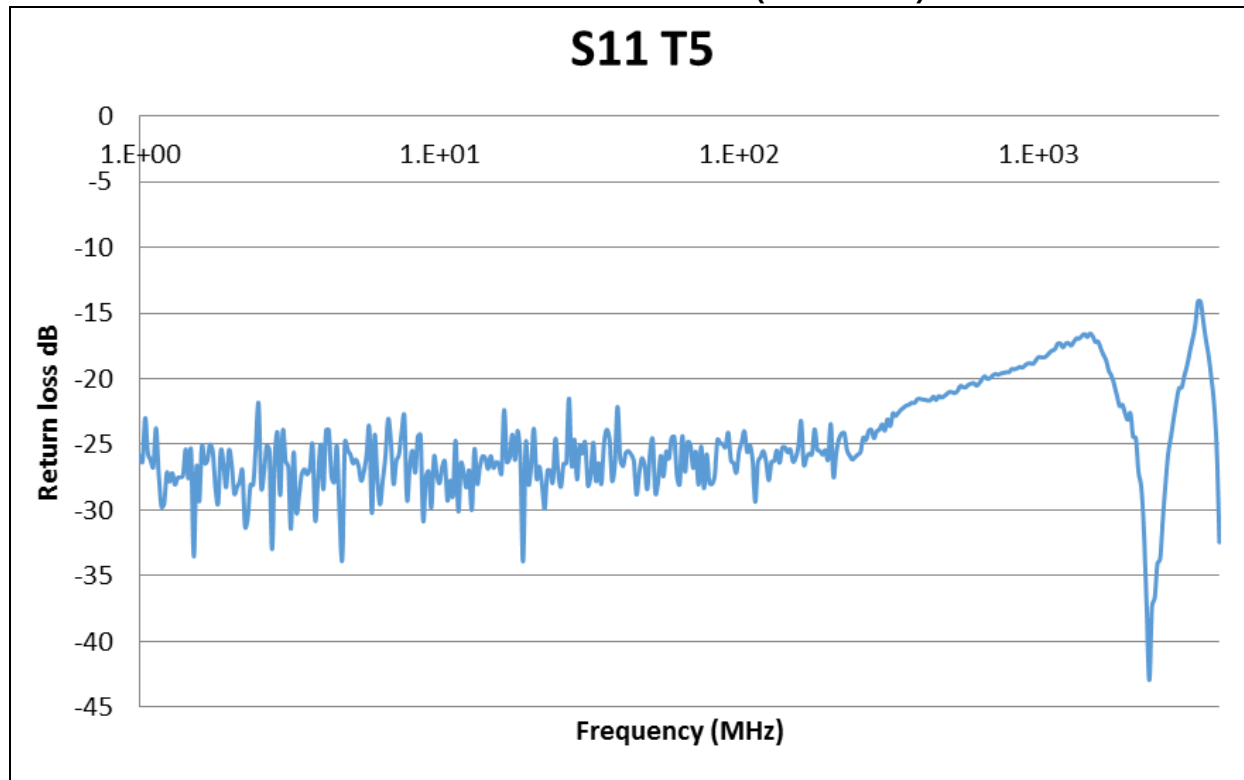
TABLE A-1: VERSION HISTORY

Version	Date	Author	Comments
2v0	1/27/14	A. Peeters	Revision
1v0	3/13/12	A. Peeters	Final document
0v2	1/17/12	M. Kuijk	Added Return-Loss measurement
0v1	1/6/12	B. Devuyst	New document

APPENDIX B: TYPICAL RETURN-LOSS MEASUREMENT

All measurements at VCC = 3.3V, Temp = +25°C, data pattern = prbs15 (including 20 μ s of each polarity of pathological pattern), measured with Belden 1694A cable.

FIGURE B-1: TYPICAL RETURN-LOSS MEASUREMENT (DB VS MHZ)



THE MICROCHIP WEB SITE

Microchip provides online support via our web site at www.microchip.com. This web site is used as a means to make files and information easily available to customers. Accessible by using your favorite Internet browser, the web site contains the following information:

- **Product Support** – Data sheets and errata, application notes and sample programs, design resources, user's guides and hardware support documents, latest software releases and archived software
- **General Technical Support** – Frequently Asked Questions (FAQs), technical support requests, online discussion groups, Microchip consultant program member listing
- **Business of Microchip** – Product selector and ordering guides, latest Microchip press releases, listing of seminars and events, listings of Microchip sales offices, distributors and factory representatives

CUSTOMER CHANGE NOTIFICATION SERVICE

Microchip's customer notification service helps keep customers current on Microchip products. Subscribers will receive e-mail notification whenever there are changes, updates, revisions or errata related to a specified product family or development tool of interest.

To register, access the Microchip web site at www.microchip.com. Under "Support", click on "Customer Change Notification" and follow the registration instructions.

CUSTOMER SUPPORT

Users of Microchip products can receive assistance through several channels:

- Distributor or Representative
- Local Sales Office
- Field Application Engineer (FAE)
- Technical Support

Customers should contact their distributor, representative or field application engineer (FAE) for support. Local sales offices are also available to help customers. A listing of sales offices and locations is included in the back of this document.

Technical support is available through the web site at: <http://microchip.com/support>

EQCO30T5.2

PRODUCT IDENTIFICATION SYSTEM

To order parts, including industrial, or obtain information, for e.g., on pricing or delivery, refer to the factory or the listed sales office.

<u>PART NO.</u>	<u>I</u>	<u>RM</u>	<u>XXX</u>
Device	Temp. Range	Radio Module	Firmware Revision Number
Device: EQCO30T5.2 Temperature Range: I = -40°C to +85°C (Industrial temperature) Package: TRAY = Tray (Blank) = Tube			
Examples: a) EQCO30T5.2 = Industrial temperature, 16-Lead QFN Tube packaging b) EQCO30T5.2-TRAY = Industrial temperature, 16-Lead QFN Tray packaging			

Note the following details of the code protection feature on Microchip devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
- There are dishonest and possibly illegal methods used to breach the code protection feature. All of these methods, to our knowledge, require using the Microchip products in a manner outside the operating specifications contained in Microchip's Data Sheets. Most likely, the person doing so is engaged in theft of intellectual property.
- Microchip is willing to work with the customer who is concerned about the integrity of their code.
- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of their code. Code protection does not mean that we are guaranteeing the product as "unbreakable."

Code protection is constantly evolving. We at Microchip are committed to continuously improving the code protection features of our products. Attempts to break Microchip's code protection feature may be a violation of the Digital Millennium Copyright Act. If such acts allow unauthorized access to your software or other copyrighted work, you may have a right to sue for relief under that Act.

Information contained in this publication regarding device applications and the like is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION, INCLUDING BUT NOT LIMITED TO ITS CONDITION, QUALITY, PERFORMANCE, MERCHANTABILITY OR FITNESS FOR PURPOSE. Microchip disclaims all liability arising from this information and its use. Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

Microchip received ISO/TS-16949:2009 certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona; Gresham, Oregon and design centers in California and India. The Company's quality system processes and procedures are for its PIC® MCUs and dsPIC® DSCs, KEELoQ® code hopping devices, Serial EEPROMs, microperipherals, nonvolatile memory and analog products. In addition, Microchip's quality system for the design and manufacture of development systems is ISO 9001:2000 certified.

QUALITY MANAGEMENT SYSTEM
CERTIFIED BY DNV
== ISO/TS 16949 ==

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, dsPIC, FlashFlex, flexPWR, Helder, JukeBlox, KeeLoq, KeeLoq logo, Klear, LANCheck, LINK MD, MediaLB, MOST, MOST logo, MPLAB, OptoLyzer, PIC, PICSTART, PIC32 logo, RightTouch, SpyNIC, SST, SST Logo, SuperFlash and UNI/O are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

ClockWorks, The Embedded Control Solutions Company, ETHERSYNCH, Hyper Speed Control, HyperLight Load, IntelliMOS, mTouch, Precision Edge, and QUIET-WIRE are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, BodyCom, chipKIT, chipKIT logo, CodeGuard, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, EtherGREEN, In-Circuit Serial Programming, ICSP, Inter-Chip Connectivity, JitterBlocker, KlearNet, KlearNet logo, MiWi, motorBench, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PureSilicon, RightTouch logo, REAL ICE, Ripple Blocker, Serial Quad I/O, SQL, SuperSwitcher, SuperSwitcher II, Total Endurance, TSHARC, USBCheck, VariSense, ViewSpan, WiperLock, Wireless DNA, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

Silicon Storage Technology is a registered trademark of Microchip Technology Inc. in other countries.

GestIC is a registered trademarks of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2012-2016, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

ISBN: 978-1-5224-0256-5

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
<http://www.microchip.com/support>
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Cleveland
Independence, OH
Tel: 216-447-0464
Fax: 216-447-0643

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110

Canada - Toronto
Tel: 905-673-0699
Fax: 905-673-6509

ASIA/PACIFIC

Asia Pacific Office
Suites 3707-14, 37th Floor
Tower 6, The Gateway
Harbour City, Kowloon

Hong Kong
Tel: 852-2943-5100
Fax: 852-2401-3431

Australia - Sydney
Tel: 61-2-9868-6733
Fax: 61-2-9868-6755

China - Beijing
Tel: 86-10-8569-7000
Fax: 86-10-8528-2104

China - Chengdu
Tel: 86-28-8665-5511
Fax: 86-28-8665-7889

China - Chongqing
Tel: 86-23-8980-9588
Fax: 86-23-8980-9500

China - Dongguan
Tel: 86-769-8702-9880

China - Hangzhou
Tel: 86-571-8792-8115
Fax: 86-571-8792-8116

China - Hong Kong SAR
Tel: 852-2943-5100
Fax: 852-2401-3431

China - Nanjing
Tel: 86-25-8473-2460
Fax: 86-25-8473-2470

China - Qingdao
Tel: 86-532-8502-7355
Fax: 86-532-8502-7205

China - Shanghai
Tel: 86-21-5407-5533
Fax: 86-21-5407-5066

China - Shenyang
Tel: 86-24-2334-2829
Fax: 86-24-2334-2393

China - Shenzhen
Tel: 86-755-8864-2200
Fax: 86-755-8203-1760

China - Wuhan
Tel: 86-27-5980-5300
Fax: 86-27-5980-5118

China - Xian
Tel: 86-29-8833-7252
Fax: 86-29-8833-7256

ASIA/PACIFIC

China - Xiamen
Tel: 86-592-2388138
Fax: 86-592-2388130

China - Zhuhai
Tel: 86-756-3210040
Fax: 86-756-3210049

India - Bangalore
Tel: 91-80-3090-4444
Fax: 91-80-3090-4123

India - New Delhi
Tel: 91-11-4160-8631
Fax: 91-11-4160-8632

India - Pune
Tel: 91-20-3019-1500

Japan - Osaka
Tel: 81-6-6152-7160
Fax: 81-6-6152-9310

Japan - Tokyo
Tel: 81-3-6880-3770
Fax: 81-3-6880-3771

Korea - Daegu
Tel: 82-53-744-4301
Fax: 82-53-744-4302

Korea - Seoul
Tel: 82-2-554-7200
Fax: 82-2-558-5932 or
82-2-558-5934

Malaysia - Kuala Lumpur
Tel: 60-3-6201-9857
Fax: 60-3-6201-9859

Malaysia - Penang
Tel: 60-4-227-8870
Fax: 60-4-227-4068

Philippines - Manila
Tel: 63-2-634-9065
Fax: 63-2-634-9069

Singapore
Tel: 65-6334-8870
Fax: 65-6334-8850

Taiwan - Hsin Chu
Tel: 886-3-5778-366
Fax: 886-3-5770-955

Taiwan - Kaohsiung
Tel: 886-7-213-7828

Taiwan - Taipei
Tel: 886-2-2508-8600
Fax: 886-2-2508-0102

Thailand - Bangkok
Tel: 66-2-694-1351
Fax: 66-2-694-1350

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4450-2828
Fax: 45-4485-2829

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Dusseldorf
Tel: 49-2129-3766400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Venice
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Poland - Warsaw
Tel: 48-22-3325737

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820