AN2189

Transformerless Applications of Microchip's LAN9252 EtherCAT® Controller

Author: Kansal Mariam Banu Shaick Ibrahim
Microchip Technology Inc.

INTRODUCTION

The Microchip LAN9252 provides a design solution targeted to support next generation EtherCAT® industrial controllers. Applications which are sensitive to cost, utilize short distance PCB connections, or even extreme environmental conditions like temperature may benefit from operation without the use of a transformer. A magnetic-less design could be applied anywhere when two known fixed Ethernet devices need to communicate over a known distance.

This application note provides guidelines for connecting two Microchip Ethernet devices together without a transformer.

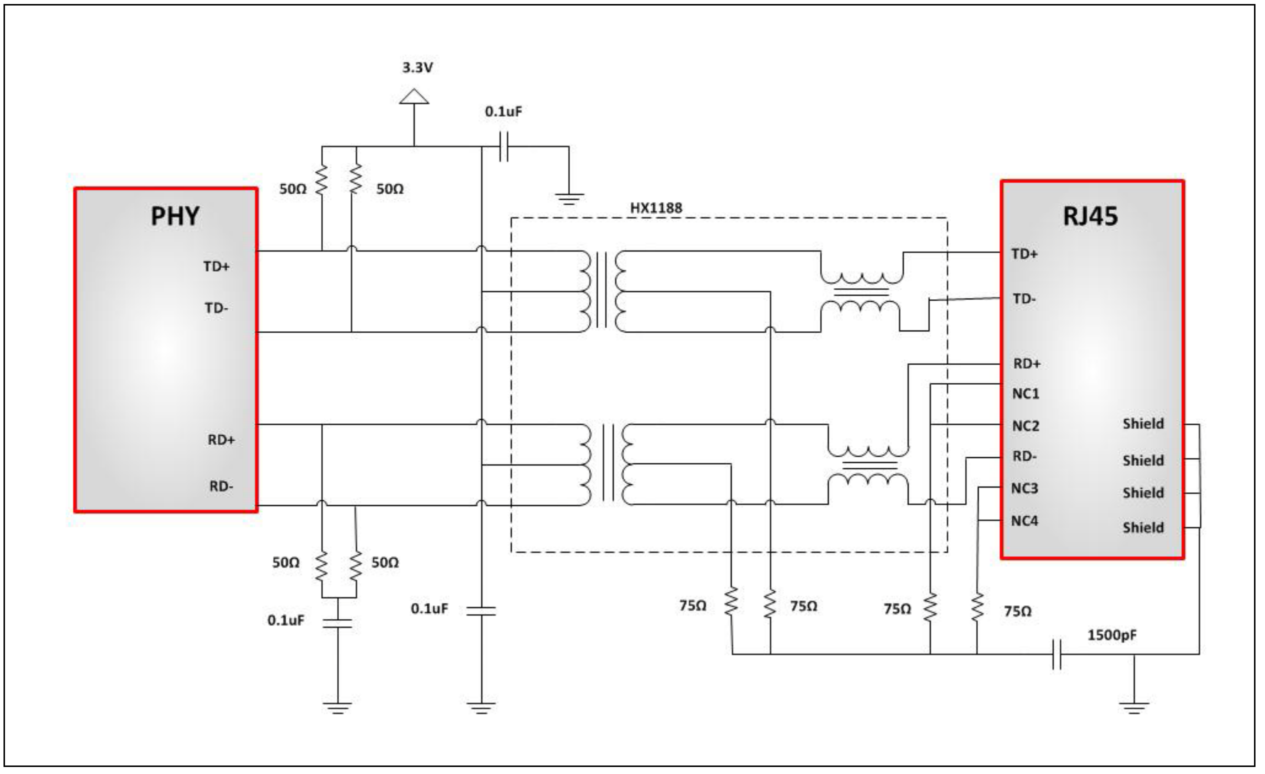
Note: For information on transformerless operation of the LAN9250/LAN935x, refer to the Transformerless Applications of Microchip's LAN9250/LAN935x Ethernet Controller and Switches application note.

TYPICAL TRANSFORMER ISOLATION

To appreciate non-typical transformerless application development constraints, it is first necessary to understand physical network services and signaling, and the functions that transformers provide in typical applications.

A typical network configuration consists of a point to point connection, through a cable, between two physical layer devices. Figure 1 shows a schematic for a typical transformer interface. The transmitter and the receiver of each node are DC isolated from the network cable by 1:1 transformers.

FIGURE 1: TYPICAL TRANSFORMER ISOLATION



TRANSFORMERLESS CONFIGURATION

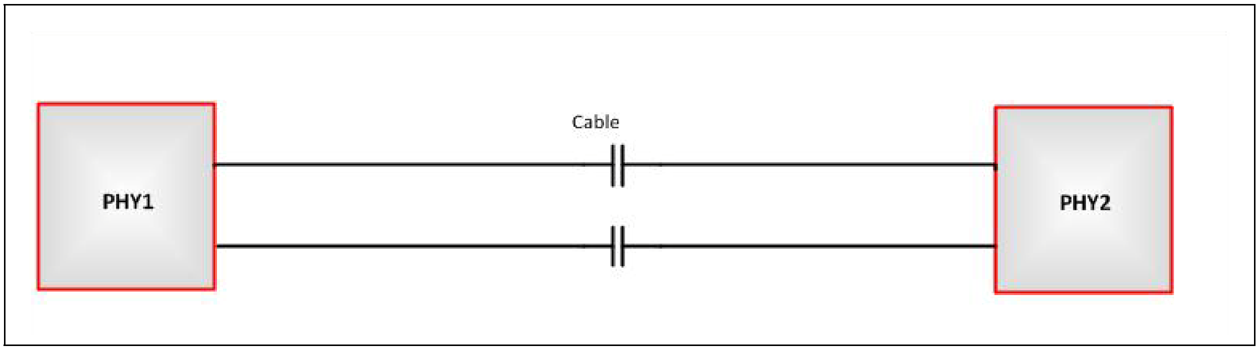
To meet the operational requirements of non-typical transformerless network applications, physical layer component transmit and receive separation and biasing as well as high voltage DC isolation to meet the specific safety requirements of the application must be implemented.

For non-typical applications, the isolation that the transformer provides in typical configurations can be realized using non-polarized capacitors.

A typical network configuration provides the services of Auto-Negotiation, Auto-MDIX, 10 Mb/s operations and 100 Mb/s operations. Auto-Negotiation and Auto-MDIX must be disabled in a transformerless application because both ends of the link are under local control. The system designer can configure a specific speed and duplex on both devices to ensure proper communication.

The IEEE 802.3–2008 specification requires the TX and RX lines to run in differential mode.The TXP and TXN lines form a differential pair and need to be designed to 100Ω differential impedance for long distances and 50Ω differential impedance for short distances. The RXP and RXN lines also form a differential pair and need to be designed to appropriate differential impedance targets.

FIGURE 2: TYPICAL TRANSFORMERLESS ISOLATION - CONNECTING TWO PHYS TOGETHER



AUTO-NEGOTIATION

The purpose of the Auto-Negotiation function is to automatically configure the transceiver to the optimum link parameters based on the capabilities of its link partner. Auto-Negotiation is a mechanism for exchanging configuration information between two link-partners and automatically selecting the highest performance mode of operation supported by both sides. In transformerless applications, Auto-Negotiation must be disabled in the Microchip device.

> **Note:** *A lowercase “x” has been appended to the end of each PHY register name in the following sections, where “x” should be replaced with “A” or “B” for the PHY A or PHY B registers respectively. In some instances, a “1” or a “2” may be appropriate instead.*

Disabling Auto-Negotiation via Registers

Auto-Negotiation can be disabled by clearing the Auto-Negotiation Enable (PHY_AN) bit of the PHY x Basic Control Register (PHY_BASIC_CONTROL_x). The transceiver will then force its speed of operation to reflect the information in the PHY x Basic Control Register (PHY_BASIC_CONTROL_x) Speed Select LSB (PHY_SPEED_SEL_LSB) and Duplex Mode (PHY_DUPLEX) bits. These bits are ignored when Auto-Negotiation is enabled.

PHY x Basic Control Register (PHY_BASIC_CONTROL_x)			
Bits	**Description**	**Type**	**Default**
13	<u>**Speed Select LSB (PHY_SPEED_SEL_LSB)**</u> This bit is used to set the speed of the PHY when the Auto-Negotiation Enable (PHY_AN) bit is disabled. 0: 10 Mbps 1: 100 Mbps	R/W	1’b1
12	<u>**Auto-Negotiation Enable (PHY_AN)**</u> This bit enables/disables Auto-Negotiation. When enabled, the Speed LSB (PHY_SPEED_SEL_LSB) and Duplex Mode (PHY_DUPLEX) are overridden. 0: Auto-Negotiation disabled 1: Auto-Negotiation enabled	R/W	1’b0 when in 100BASE-FX mode else 1’b1
8	<u>**Duplex Mode (PHY_DUPLEX)**</u> This bit is used to set the duplex when the Auto-Negotiation Enable (PHY_AN) bit is disabled. 0: Half Duplex 1: Full Duplex	R/W	1’b1

HP AUTO-MDIX

HP Auto-MDIX facilitates the use of CAT-3 (10BASE-T) or CAT-5 (100BASE-TX) media UTP interconnect cable without consideration of the interface wiring scheme. If a user plugs in either a direct connect LAN cable or a cross-over patch cable, the transceiver is capable of configuring the TXPx/TXNx and RXPx/RXNx twisted pair pins for correct transceiver operation.

The internal logic of the device detects the TX and RX pins of the connecting device. Since the RX and TX line pairs are interchangeable, special PCB design considerations are needed to accommodate the symmetrical magnetics and termination of an Auto-MDIX design. For transformerless applications, it is recommended to disable HP Auto-MDIX.

Note: The HP Auto-MDIX feature may be useful if the TX and RX lines are accidentally swapped in the transformerless application.

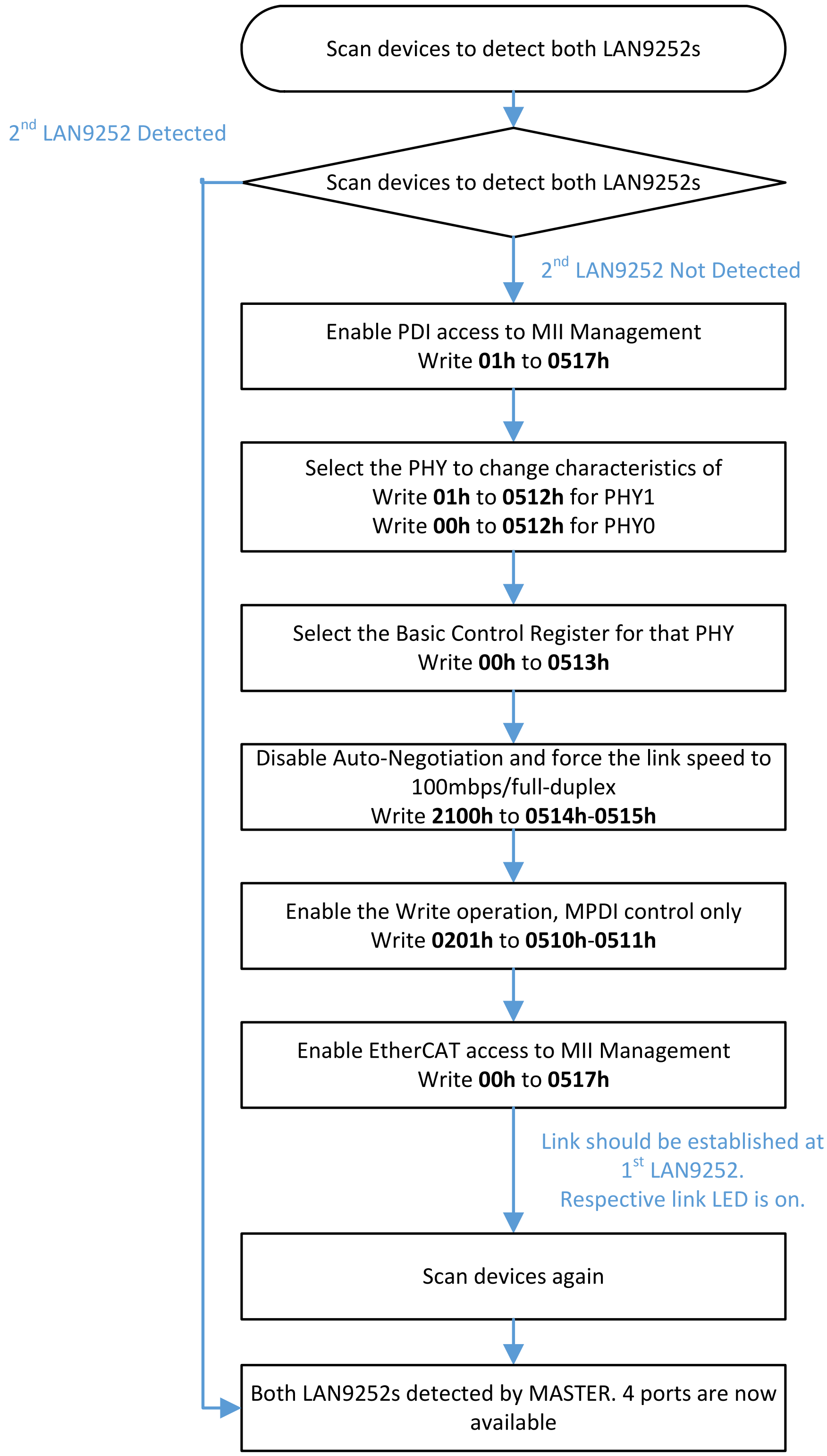
LAN9252 PHY REGISTER ACCESS BY PDI

The LAN9252 PHY x registers can be accessed by the PDI via the MII Management Interface Registers, as detailed in the LAN9252 Data Sheet, DS00001909A. These registers are summarized below.

EtherCAT® Core Address	MII Management Interface Register Name
0510h-0511h	MII Management Control/Status Register
0512h	PHY Address Register
0513h	PHY Register Address Register
0514-0515h	PHY DATA Register

STEPS TO DISABLE AUTO-NEGOTIATION VIA LAN9252 REGISTERS BY PDI

FIGURE 3: AUTO-NEGOTIATION DISABLE VIA LAN9252 REGISTERS BY PDI



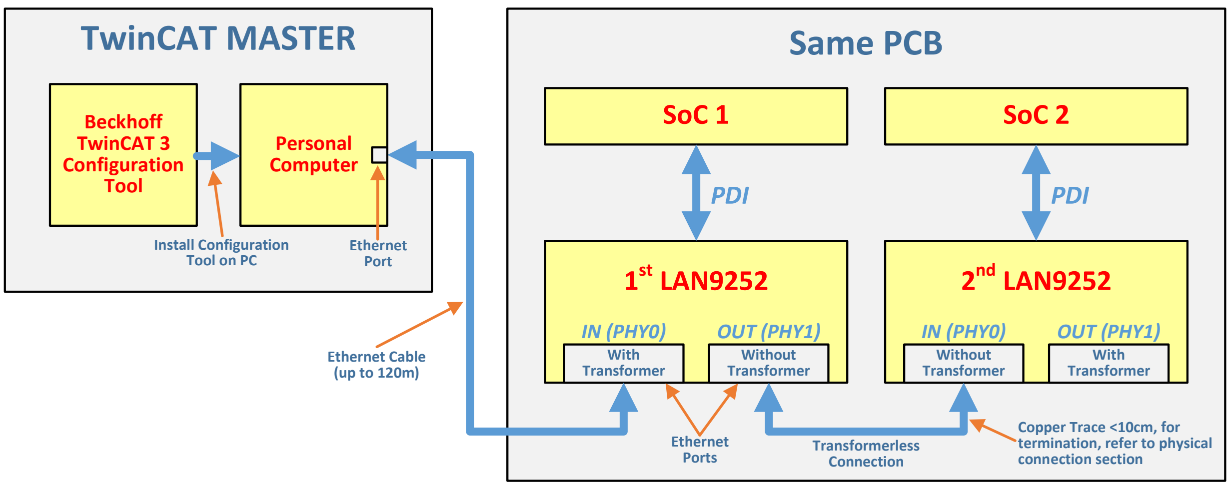
LAN9252 TRANSFORMERLESS PHY OPERATION

Per Figure 5, the transformerless PHY connection is used between the first LAN9252 (PHY1) and the second LAN9252 (PHY0). The following operations must be performed to establish a transformerless connection link:

- Disable auto-negotiation on the first LAN9252 (PHY1) and the second LAN9252 (PHY0), and force the link speed to 100Mbps full-duplex (follow procedure shown in Figure 4).
- Disable “MI Link Detection” in the MII Management Control/Status Register via EEPROM on both the first and second LAN9252 (refer to the “EEPROM Configurable Registers” in the LAN9252 Data Sheet).
- Disable “Enhanced Link Detection” in th ESC Configuration Register via EEPROM on both the first and second LAN9252 (refer to the “EEPROM Configurable Registers” in the LAN9252 Data Sheet).

Bits 8, 12, and 13 of the PHY x Basic Control Register are used to control the Auto-Negotiation, link-speed and duplex (refer to the LAN9252 Data Sheet, DS00001909A). The LAN9252 PHY x Basic Control Register can be accessed via the EtherCAT MASTER or PDI.

FIGURE 4: LAN9252 SIMPLE TRANSFORMERLESS PHY CONNECTION EXAMPLE



Note:	A magnetic-less design could be applied anywhere when two fixed LAN9252 devices need to communicate over a known distance.

The following examples show how to disable auto-negotiation, MI Link Detection and Enhanced Link Detection in the EEPROM.

Auto-Negotiation Disable Example in PIC32 Code

1. In the SDK, navigate to the following folder: EVB-LAN9252-HBI_PIC32_SDK_V1.3\SSC
2. Copy and paste the SSC folder, naming one copy “SSC0” and another copy “SSC1”
3. Go to the “common” folder in each new copy
4. Open the 9252_HW.c file and add the following lines of code shown in Figure 6. In Figure 6 where it says “Select PHY0”, change the data value to 0x0100 to reflect PHY1 or leave as-is for PHY0.

FIGURE 5: AUTO-NEGOTIATION DISABLE EXAMPLE IN PIC32 CODE

```
    intMask = 0;
    HW_EscReadWord(intMask, ESC_AL_EVENTMASK_OFFSET);
} while (intMask != 0x93);

//Enable PDI access to MII management
data = 0x01;
HW_EscWriteWord(data, 0x0517);

//Select PHY0
data = 0x0000;
HW_EscWriteWord(data, 0x0512);

//Disable Auto-Negotiation and force link speed to 100mbps / full duplex
data = 0x2100;
HW_EscWriteWord(data, 0x0514);

//Enable write operation, MDPI control only
data = 0x0201;
HW_EscWriteWord(data, 0x0510);

//Enable PDI access to MII management
data = 0x00;
HW_EscWriteWord(data, 0x0517);
```

5. Use these new files to program the PIC32 software. Refer to the Software Quick Start Guide for more information.

Updating the EEPROM Settings

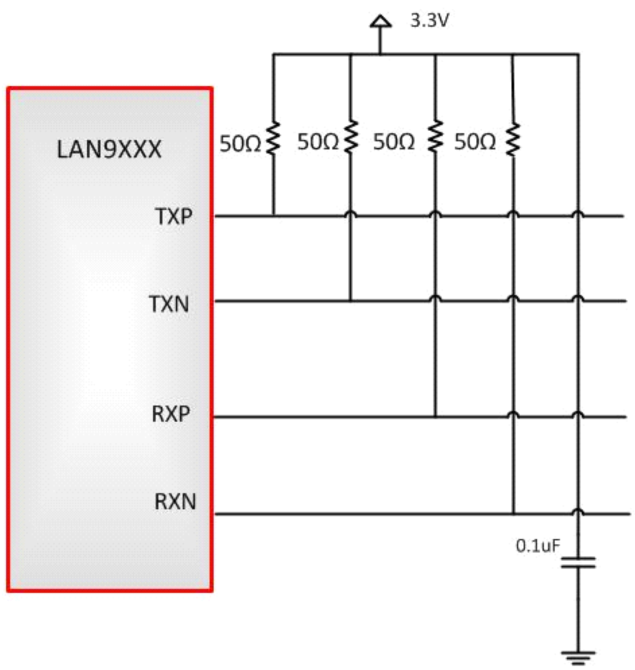
1. In the SDK, navigate to the following folder: EVB-LAN9252-HBI_PIC32_SDK_V1.3\ESI files
2. Open the desired mode XML file in a text editor.
3. Change line 1508 as seen below for either PHY1 or PHY0:
   Original: <ConfigData>80**0E**00CC8813ff00000000**8**00000</ConfigData>
   PHY1: <ConfigData>80**2C**00CC8813ff00000000**0**00000</ConfigData>
   PHY0: <ConfigData>80**1C**00CC8813ff00000000**0**00000</ConfigData>
4. These two changes will disable Enhanced Link Detection as well as MI Link Detection.

PHYSICAL CONNECTION

The transmitter output is designed to sink current into a transformer. When the transformer is not used, load resistors must be connected at each device to develop the output voltage as shown in Figure 3.

Note:	*RX pins are configured with 50 Ohm to the supply for AMDIX operation where they may be configured as TX pins. If AMDIX is disabled and RX pins are for receive mode only, then the external termination can be tied any way possible as long as there is 100 Ohm differential across the pins.*

FIGURE 6: LOAD RESISTORS IN TRANSFORMERLESS APPLICATION

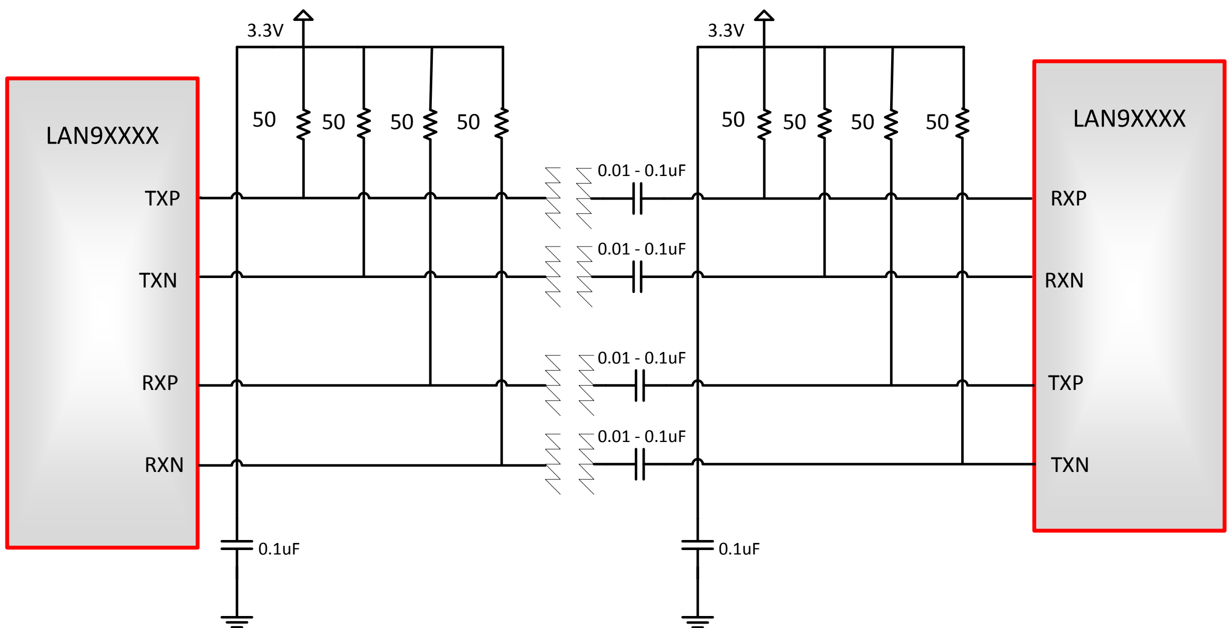


DISTANCE CONSIDERATIONS

Microchip recommends that both Ethernet devices have terminating resistors on each analog pin. Proper lab validation should be performed to provide optimum resistor placement using the configuration shown in Figure 4.

Cable connections over very long distances without transformers are not encouraged due to the risk for potential high voltage build-up and noise effects.

FIGURE 7: EXAMPLE CONNECTION



Note:	*50 Ohm termination at each device with no AC coupling capacitance can be used for PCB traces greater than 12”, assuming both Microchip devices are sharing the same power domain within the same PCB.*

Note:	*AC coupling capacitors are required for any board to board communications using different power domains. Due to the possible shift in power/ground domains between boards, the coupling capacitor is required to minimize DC balancing issues.*

SUMMARY

Microchip Ethernet devices may be configured in non-typical transformerless network applications to transmit and receive reliably. Recommendations include the use of non-polarized capacitors for DC isolation from a network cable, with a minimum DC isolation rating which suits the individual application.

APPENDIX A: APPLICATION NOTE REVISION HISTORY

TABLE A-1: REVISION HISTORY

Revision Level & Date	Section/Figure/Entry	Correction
DS00002189A (06-14-16)	All	Initial release.

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.

Trademarks

The Microchip name and logo, the Microchip logo, AnyRate, dsPIC, FlashFlex, flexPWR, Heldo, JukeBlox, KeeLoq, KeeLoq logo, Kleer, 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, KleerNet, KleerNet 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, SQI, 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.

ISBN:9781522407027

QUALITY MANAGEMENT SYSTEM CERTIFIED BY DNV

== ISO/TS 16949 ==

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.

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

07/14/15