AN829

LightKeeper Automotive Lighting Control Module

Author: *Chuck Simmers*
Microchip Technology Inc.

OVERVIEW

This Application Note describes an automotive exterior lighting control module using a PIC16C433. This unit also communicates over a Local Interconnect Network (LIN) bus as a slave controller. The non-networked functions are similar to General Motors' Twilight Sentinel®. Networked functions allow lighting control to be taken over by the integrated body computer, a remote keyless entry unit, or a security system.

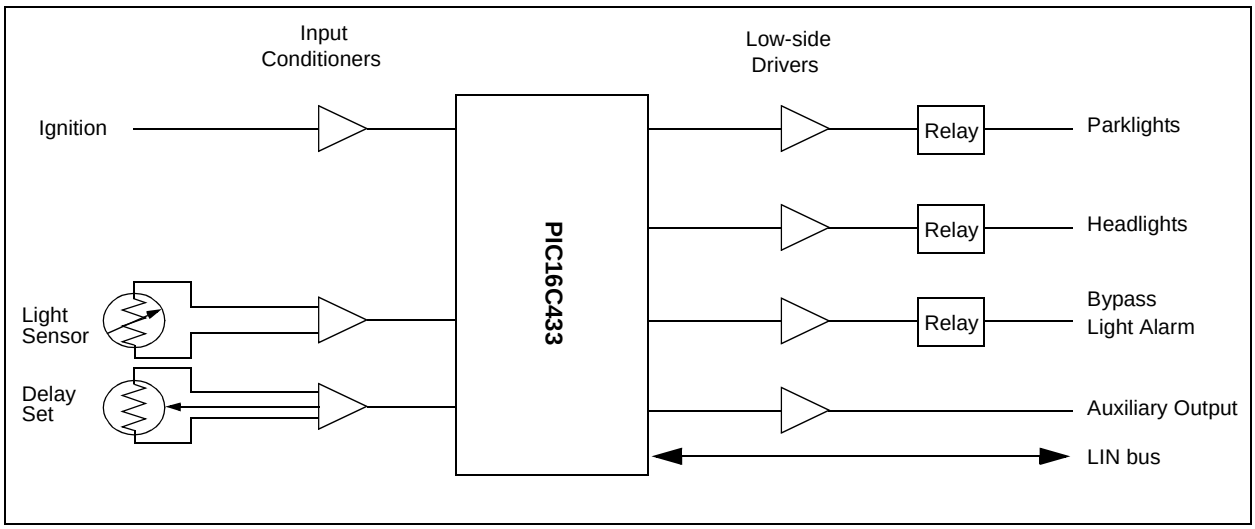
Features

- Self-Contained Unit Functions
  - Turn on lights in dim light (Light conditions persistent for greater than 30 accumulated seconds)
  - Turn off lights in daylight (Light conditions persistent for greater than 30 accumulated seconds)
  - Turn off headlights after a selected time after ignition off (Time interval selected by potentiometer)
- Network Functions
  - Commanded by a remote master node (Body Computer, RKE, etc.)
  - LIN slave node
  - Flash parking lights (*n*-times to forever)
  - Flash headlamps (*n*-times to forever)
- Can be added to existing wiring harness without modification

The LIN protocol was devised to address low cost automotive networks. The LIN standard is meant to replace the myriad of low end multiplex wiring solutions in current use.

The LIN standard includes the specification of the transmission protocol, the transmission medium, the interface between, development tools, and the interfaces for software programming.

FIGURE 1: SYSTEM BLOCK DIAGRAM



© 2002 Microchip Technology Inc.

GENERAL DESCRIPTION

This control module provides automatic on-off control of the exterior lamps. It will also keep the exterior lamps turned on for a preselected period of time after the ignition switch is turned "OFF".

The system consists of a CdS photocell, a time delay rheostat with an on-off switch, and the microcontroller module with built-in relays. Connections to the vehicle lamps parallel the regular lamp switch connections. The headlamp switch must be in the "OFF" position to allow automatic control.

The photocell is mounted in the upper surface of the instrument panel to obtain an unobstructed view through the windscreen. The control module and time delay control/on-off switch is mounted adjacent to the headlamp switch.

Automatic Operation

The LightKeeper automatically switches the lights on or off by sensing the ambient light level.

The module operates automatically when the ignition switch is "ON", the headlight switch is "OFF", and the control rheostat is in the "ON" position

When the headlamp switch is in "PARK" or "ON", or the control unit is powering the exterior lamps and instrument panel lamps, the "Lights-ON" warning will function.

As the intensity of light reaching the photocell decreases, its resistance increases. When the module senses a high resistance in the photocell, the module allows battery voltage to be applied to the headlamps, parking, side-marker, and tail lamps.

With the headlamp dimmer switch in the "DIP" position, the low beam headlamps are "ON". With the headlamp dimmer switch in the "MAIN" position, the high beam headlamps and indicator are "ON".

As the intensity of light reaching the photocell increases, the resistance decreases. When the resistance is low enough, the module turns all lamps "OFF".

A delay timer routine in the module reduces the chance of switching the lamps on and off while passing under viaducts, trees, bright lights, or any other condition where lamp control is not wanted.

If you move the control all the way to "MAX", the lights will remain on for approximately three minutes after the engine has been turned off. If the control is set to “MIN”, so it is just on, the lights will go off almost immediately after the ignition is off. This delay time can be changed from less than a second to almost three minutes.

Manual Lamp Operation

The system can be turned off by setting the time delay rheostat to the "OFF" position. This allows non-automatic control of the exterior lamps to be used instead of the regular switch.

If exterior lamps are desired during daylight, either of two methods can be used.

Exterior lamps can be operated with the regular headlamp switch. The headlamp switch is wired in parallel with the control module and can bypass the system, whether the rheostat is "ON" or "OFF". If the headlamp switch is turned "ON", all lamps will remain on after the ignition is turned "OFF"; however, when a vehicle is equipped with a tone alarm package, a warning tone sounds as a reminder.

The photocell can be covered to block out light. This causes the lamps to turn on and still enables the system to turn the lamps off automatically when the ignition is turned "OFF". If the photocell has been exposed to light, the time delay must elapse before the lamps will turn on.

Network Operation

The network message protocol conforms to the Local Interconnect Network standard as outlined in the following documents:

- “LIN Specification Package”, Revision 1.2, November 17, 2000
- Microchip’s Application Note AN729, “LIN Protocol Implementation Using Picmicro® MCUs” (DS00729)

The LightKeeper unit is connected to a LIN interface bus as a slave node. Two command frames and one interrogation frame are decoded by the firmware.

- Flash parking lights (*n*-times to forever)
- Flash headlamps(*n*-times to forever)
- Report status (2, 4, or 8 bytes)

Any of these commands can be initiated by either the body computer, or the Remote Keyless Entry (RKE) module.

Two LIN identifiers have been selected for this application, ‘0Ah’ and ‘0Bh’. Identifier ‘0Bh’ denotes a two-byte master message frame. Two subcommands are selected by the first data byte following the identifier ‘0Bh’.

© 2002 Microchip Technology Inc.

TABLE 1: LIN COMMAND FRAMES FOR IDENTIFIER 0Bh

ID	1st Data Byte	2nd Data Byte	Action
0Bh	00h	x	Reserved
0Bh	01h	Flash Number	Flash Park
0Bh	02h	Flash Number	Flash Main
0Bh	03h-0fh	x	Not Used

Note: ('01h' = Flash Park, '02h' = Flash Main). The number of flashes are defined by the second data byte. Values between 1 and 254 are valid. A value of 255 will cause continuous flashing. If the ignition should be turned on at any time, the flash sequence will abort.

The '0Ah' identifier can be a 2-, 4-, or 8-byte slave response frame. The number of status bytes requested depends on the amount of data needed by the master.

Currently, the status frame returned is shown in Table 2. Notice that data bytes 3, 5, and 9 are reserved for checksum values. These data bytes will be used as checksum scratchpad areas for the three frame sizes. This allows the other status fields to be updated without regard to the response frame size requested by the master. If these fields were to be used for storing status data, their values would be over-written, if the master requests a smaller response frame. This would require the slave to be aware of the last status frame size requested and to rewrite the corrupted data value.

User status bytes 0 and 1 are not currently defined, so their values are zeros.

TABLE 2: STATUS RESPONSE FRAME FOR IDENTIFIER '0Ah'

STATUS	Data 1	Data 2	Data 3	Data 4	Data 5	Data 6	Data 7	Data 8	Data 9
2-byte Response	User Status 0	User Status 1	*Checksum*(1)	NA	NA	NA	NA	NA	NA
4-byte Response	User Status 0	User Status 1	*not used*(4)	Integral Counter Value	*Checksum*(2)	NA	NA	NA	NA
8-byte Response	User Status 0	User Status 1	*not used*(4)	Integral Counter Value	*not used*(5)	System Status Flags	Delay Control Value	Light Sensor Value	*Checksum*(3)

Note 1: This is the checksum value of the current 2-byte response frame.
2: This is the checksum value of the current 4-byte response frame.
3: This is the checksum value of the current 8-byte response frame.
4: This is the checksum value from a previous 2-byte response frame, not valid information.
5: This is the checksum value from a previous 4-byte response frame, not valid information.
6: The values and definitions of the variables described above are in the software source code.

© 2002 Microchip Technology Inc.

HARDWARE

Refer to Figure 7, Module Schematics.

Power Supply

The power supply is built around an automotive-grade, low dropout, linear voltage regulator. It is internally protected from reverse polarity connection, load dump, and short circuit. The diodes, D10 and D8, provide some level of protection if simple commercial-grade regulators are used.

Input Circuits

R3 and R4 provide input current limiting and, along with C3 and C5, isolate the analog channels from high frequency noise. Although the variable resistor inputs are powered from the onboard V_{CC} bus and referenced to system ground, high speed Schottky diodes D5-7 and 9, make sure that the input voltages are clamped to V_{CC} and ground.

R5 and R6 constitute a voltage divider to reduce the incoming signal from 0 to 12-14 V_{DC}, down to a nominal 0-5 V_{DC}. Again, diodes (D11,12) are used to clamp the input between V_{CC} and ground.

The photocell and R2 form a voltage divider reference to V_{CC} and ground, connected to Analog Channel 0. The value of R2 is dependent on the type and specification of the chosen CdS photocell. The value is selected by measuring the voltage at J12 in total darkness and full sunlight. The resistor is sized to obtain a reasonably close reading to the voltage rails at both extremes. The final voltage threshold is adjusted in software.

The delay time rheostat is connected between V_{CC} and ground (J15 and J13, respectively) and its wiper terminal is a variable voltage divider connected to Analog Channel 1.

The switched ignition voltage is connected to J16.

Output Circuits

Three high current SPDT automotive relays are driven by a quad 1.5A Darlington low-side driver (U1). This driver interfaces the low level logic signals from the microcontroller. The driver outputs can handle inductive loads, sustaining voltage of 50V at 100 mA.

Channels 1 and 2 are independently controlled by the PIC16C433. Channels 3 and 4 can be assembled to either be a wired-OR of channels 1 and 2, or directly controlled by a third output. These options are selected by jumpers at E1. The wired-OR function is enabled by installing D3 and D4.

TABLE 3: JUMPER E1

Jumper Position	Driver Channel	Input Source	Selected Function
1-2	4	GND	Channel 4 not used
1-3	4	GP2	Channel 4 controller by GP2
2-4(1)	3	GND	Channel 3 not used
3-4(1)	3	GP2	Channel 3 controller by GP2
3-5(2)	$\overline{BACT}$	GP2	Wake-up signal to GP2/INT
5-6	$\overline{BACT}$	n.c.	Invalid, Do Not Select
4-6	n.c.	D3 or D4	Invalid, Do Not Select
1-4	3 and 4	D3 or D4	Channels 3 and 4 together
2-3	GND	GP2	Invalid, Do Not Select

Note 1: Diodes D3 and D4 must not be installed for these selections.

2: This is the default selection for this firmware implementation.

Network Interface

JP1 is the LIN bus interface port and can be used as an alternative power connection to battery. Depending on the bus capacitance of a specific implementation, C2 may or may not be needed, or its value changed. D2 is meant to shunt any spurious transients that may occur on the LIN bus.

© 2002 Microchip Technology Inc.

SOFTWARE

The software for this application is composed of three major sections:

- Main program loop, which includes:
  - Light sensor interrogation loop
  - Lights on delay loop
  - SLEEP routine
  - Wake-up routine
- Interrupt routine
- Clock event scheduler

Main Program Loop

LIGHT SENSOR INTERROGATION LOOP

While the ignition switch is "ON", interrogate the photocell and turn the lights on or off, as appropriate. If the ignition is turned "OFF" while in this loop, the program falls through to the Lights On Delay Loop.

LIGHTS ON DELAY LOOP

After the ignition has been turned "OFF", check if the lights were "ON". If they were, wait a period of time equal to the duration set by the delay control rheostat, then turn "OFF" all the lights and go to SLEEP.

If no lights were on when the ignition was turned "OFF", go directly to SLEEP.

SLEEP ROUTINE

When no other events are pending to be executed, the interrupt-on-pin change is setup and the system is put into low power state.

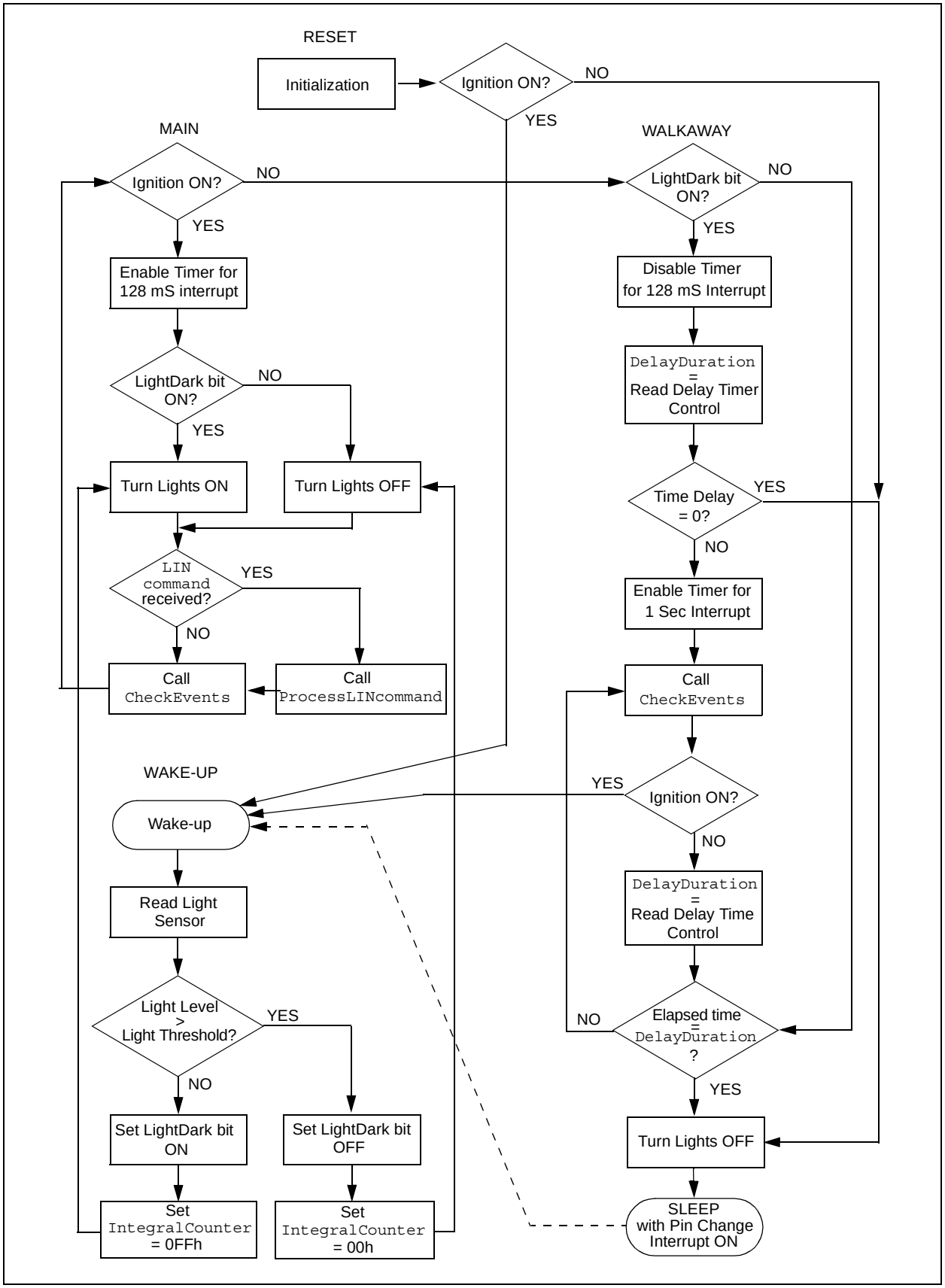
A jump to the RESET vector (0000h) is done when any change is detected in an I/O port pin

WAKE-UP

After either a RESET, or a wake-up from SLEEP, a global initialization is performed and the wake-up routine clears the pin change flags. A reading is taken immediately from the light sensor. If the light level is lower than the threshold, the lights are turned on without any time delay. The program transfers control to the Main Light Sensor Interrogation Loop.

© 2002 Microchip Technology Inc.

FIGURE 2: MAIN PROGRAM LOOP



© 2002 Microchip Technology Inc.

Interrupt Routine

The two interrupt sources are sorted by inspecting the pending interrupt flags. If the source of the interrupt is the timer, the 16-bit system clock word is incremented. If the source should be the pin change detection circuit, the flags are cleared and no further action is taken before resuming main program execution.

Clock Event Scheduler

The first test performed is to determine which event is currently selected.

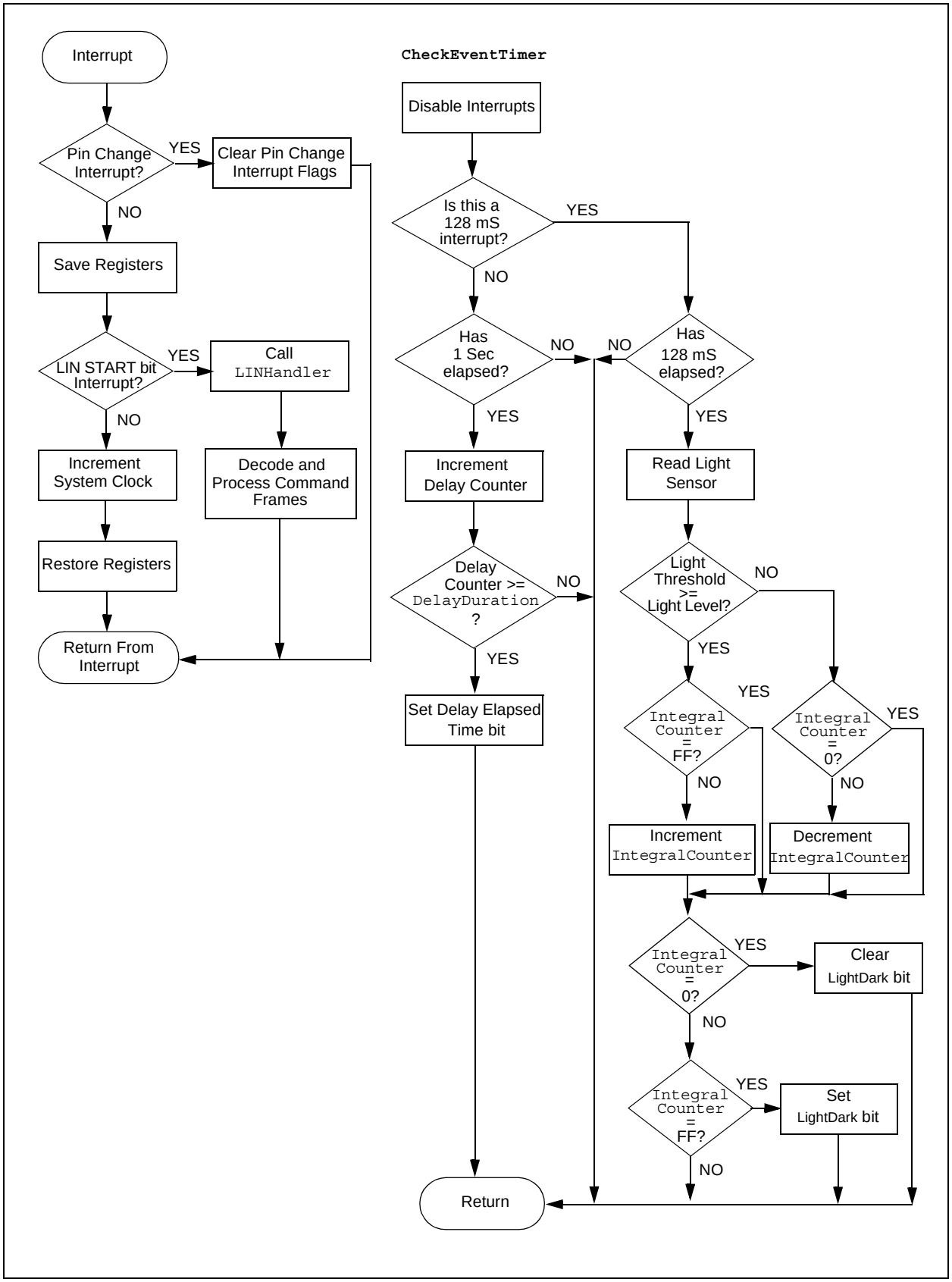
If the main code being executed is the Light Sensor Interrogation routine, then the system clock is measured in 128 millisecond ticks. Every 128 mS, the photocell is sampled and the value compared to the threshold. If the light level is below the threshold, an internal counter is incremented to a maximum value of 255. If the light level is above the threshold, the counter is decremented to a minimum of 0. The LightDark bit is set when the counter reaches 255, and reset when the counter drops to 0. A continuous light condition will result in a state change in approximately 30 seconds.

If the Light Delay loop was being executed, the system clock is measured in 1 second periods. Every second an internal delay count is incremented and then compared to the time duration value set by the delay control rheostat. When the delay counter is equal to, or greater than the duration value, the time duration bit is cleared, to indicate that the required time has elapsed.

Control is returned to the calling routine.

© 2002 Microchip Technology Inc.

FIGURE 3: INTERRUPT AND EVENT SCHEDULER



© 2002 Microchip Technology Inc.

LIN Protocol Handling Routines

The firmware that receives and transmits a LIN message frame is outlined in the flow charts in Figure 4, LIN Handler Routine, Figure 5, LIN UART Routines, and Figure 6, LIN Data Integrity Routines. This software is described in Microchip's Application Note *AN729, "LIN Protocol Implementation Using PICmicro® MCUs* (DS00729).

AUTOBAUD COUNTER

The signal is sampled every 6 instruction cycles. This means the number of counts accumulated over one character time equals 8*TBIT / 6TCY.

EXAMPLE 1:

Given:

Desired transmission rate = 19.2 Kbaud

TBIT = 1 / 19200 = 52 µs

FOSC = 4 MHz, TCY = 1 / FOSC = 1 µs

Therefore:

8*52 µs / 6*1 µs = 69 µs or counts.

To this base count are added a constant of 8 counts to account for software overhead and 2 counts for bus propagation delay. The individual bit time is derived by dividing the total by eight and adding a 2 count delay for the bit timing routines.

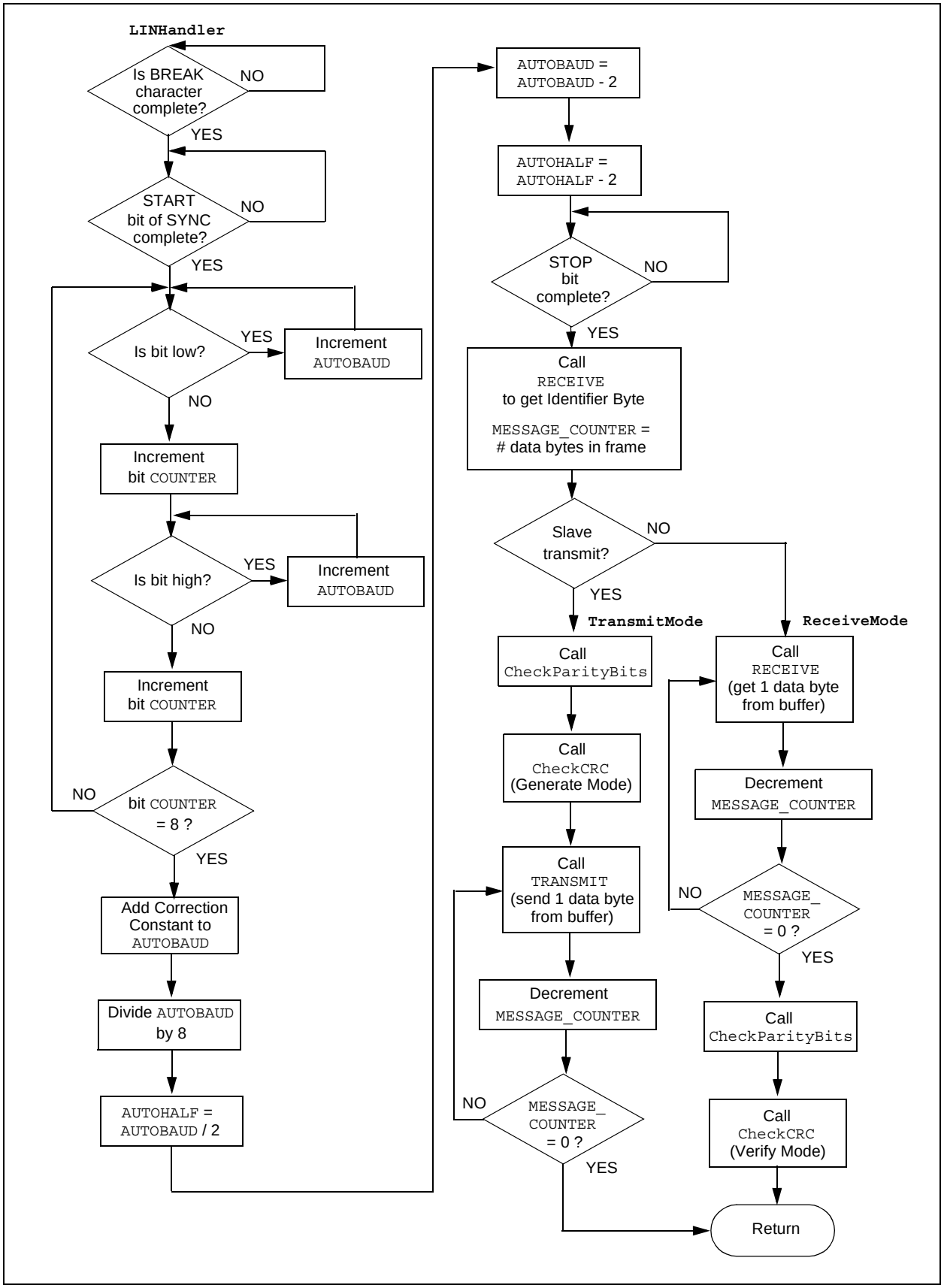
((69 + 10) / 8) -2 = 7.875 = AUTOBAUD value 8.

The actual transmission baud rate is then:

((((8 + 2) * 8) - 10) * (6*1 µs) / 8) = 19048 baud

This value lies within the frequency range (1 kHz to 20 kHz) allowed in the LIN specification.

FIGURE 4: LIN HANDLER ROUTINE



© 2002 Microchip Technology Inc.

FIGURE 5: LIN UART ROUTINES

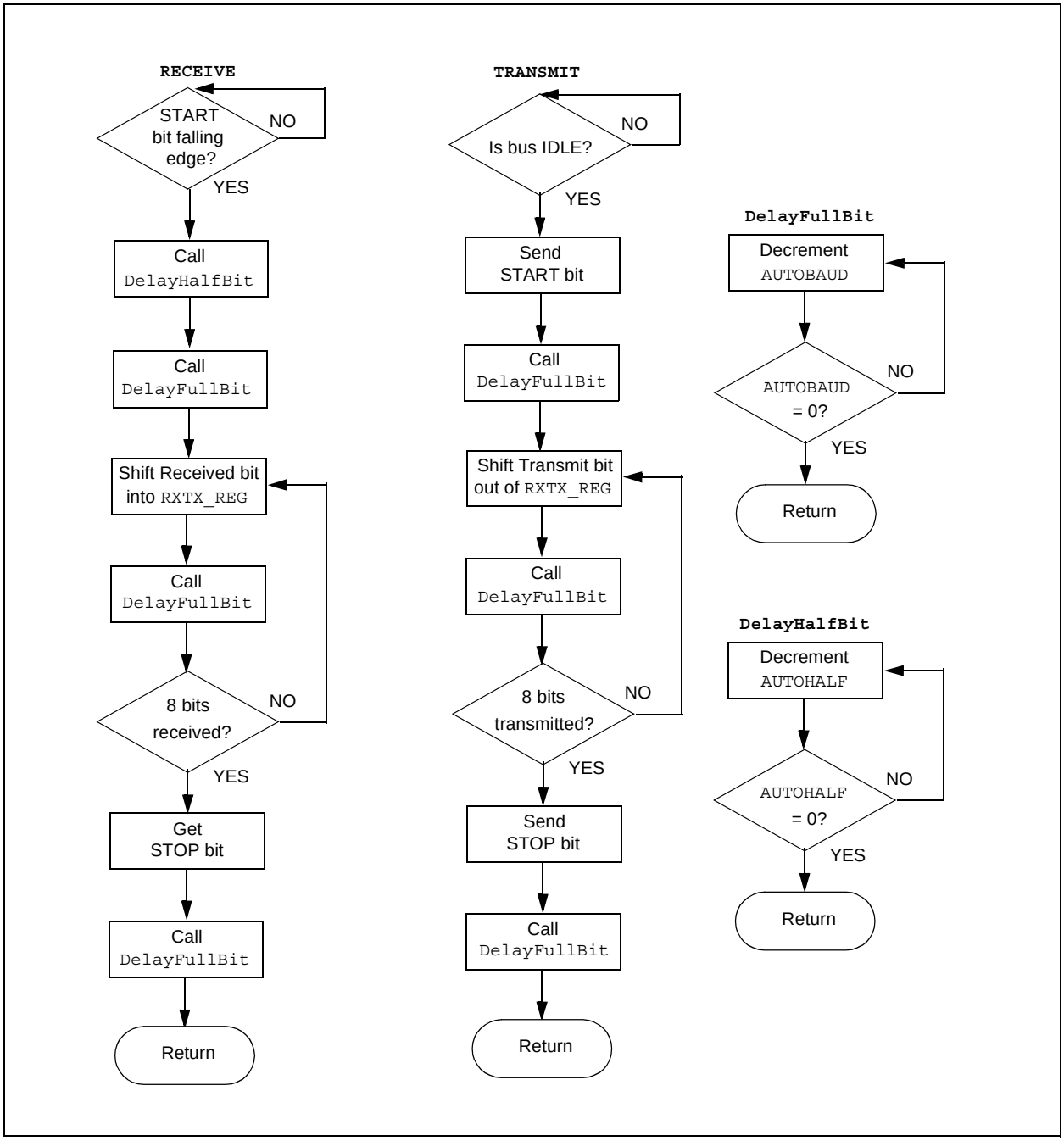
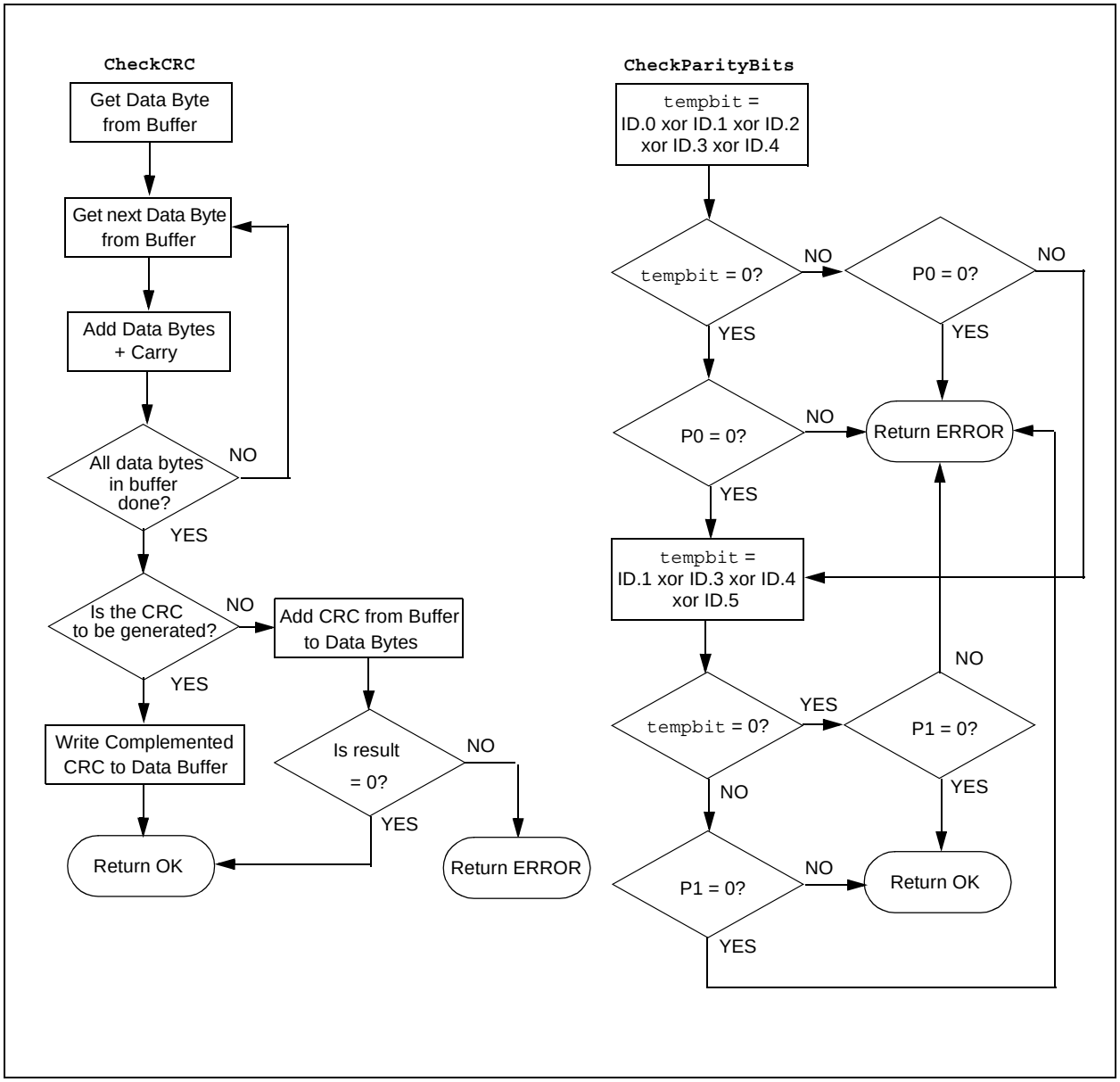


FIGURE 6: LIN DATA INTEGRITY ROUTINES



© 2002 Microchip Technology Inc.

SCHEMATICS

The first schematic shown is of the module itself. The second is of a typical system application.

Power can be applied to the unit, either from the LIN connector (JP1) and/or through the individual power connections, JP2 and JP3.

FIGURE 7: MODULE SCHEMATICS

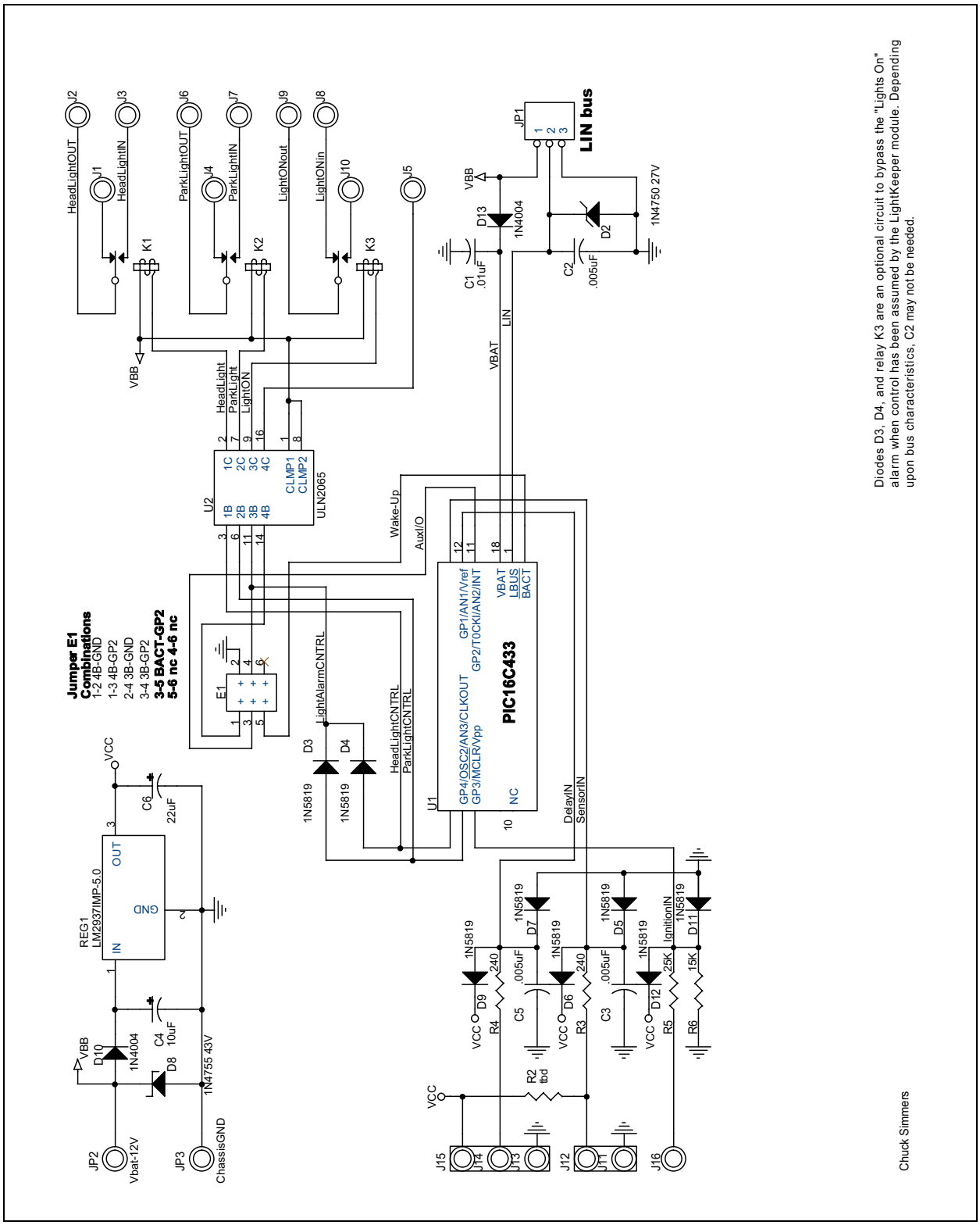
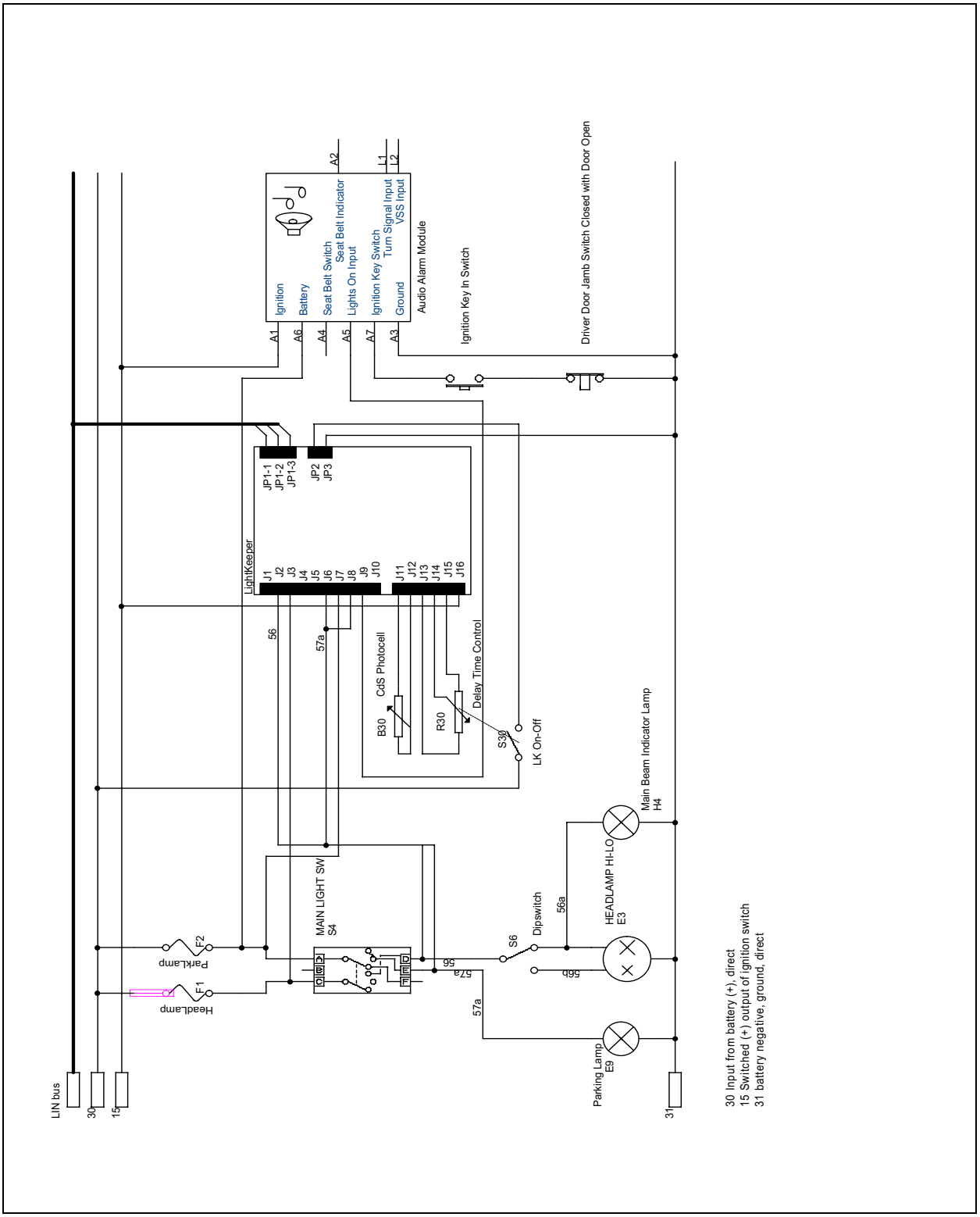
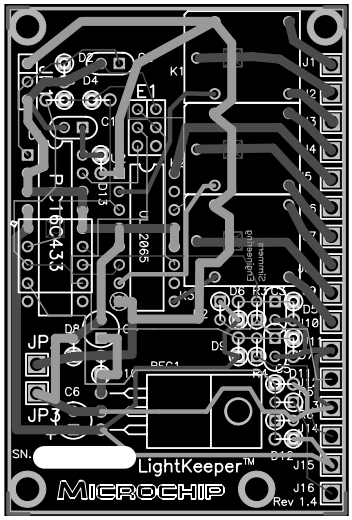


FIGURE 8: SYSTEM SCHEMATIC



© 2002 Microchip Technology Inc.

FIGURE 9: TWO-LAYER PCB LAYOUT



Referenced Documents:

- "LIN Specification Package", Revision 1.2, November 17, 2000
- Microchip's Application Note *AN729, "LIN Protocol Implementation Using PICmicro® MCUs",* (DS00729)

"Twilight Sentinel" is a registered trademark of General Motors Corp.

NOTES:

© 2002 Microchip Technology Inc.

Note the following details of the code protection feature on PICmicro® MCUs.

- The PICmicro family meets the specifications contained in the Microchip Data Sheet.
- Microchip believes that its family of PICmicro microcontrollers is one of the most secure products 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 PICmicro microcontroller in a manner outside the operating specifications contained in the data sheet. The person doing so may be 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 product.

If you have any further questions about this matter, please contact the local sales office nearest to you.

Information contained in this publication regarding device applications and the like is intended through suggestion only and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. No representation or warranty is given and no liability is assumed by Microchip Technology Incorporated with respect to the accuracy or use of such information, or infringement of patents or other intellectual property rights arising from such use or otherwise. Use of Microchip’s products as critical components in life support systems is not authorized except with express written approval by Microchip. No licenses are conveyed, implicitly or otherwise, under any intellectual property rights.

Trademarks

The Microchip name and logo, the Microchip logo, FilterLab, KEELOQ, microID, MPLAB, PIC, PICmicro, PICMASTER, PICSTART, PRO MATE, SEEVAL and The Embedded Control Solutions Company are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

dsPIC, ECONOMONITOR, FanSense, FlexROM, fuzzyLAB, In-Circuit Serial Programming, ICSP, ICEPIC, microPort, Migratable Memory, MPASM, MPLIB, MPLINK, MPSIM, MXDEV, PICC, PICDEM, PICDEM.net, rfPIC, Select Mode and Total Endurance are trademarks of Microchip Technology Incorporated in the U.S.A.

Serialized Quick Turn Programming (SQTP) is a service mark of Microchip Technology Incorporated in the U.S.A.

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

© 2002, Microchip Technology Incorporated, Printed in the U.S.A., All Rights Reserved.

Printed on recycled paper.

DNV Certification, Inc. USA — ANSI-RAB QMS ACCREDITED — DNV — DNV MSC The Netherlands Accredited by the RvA — ISO 9001 / QS-9000 REGISTERED FIRM

Microchip received QS-9000 quality system certification for its worldwide headquarters, design and wafer fabrication facilities in Chandler and Tempe, Arizona in July 1999. The Company’s quality system processes and procedures are QS-9000 compliant for its PICmicro® 8-bit MCUs, KEELOQ® code hopping devices, Serial EEPROMs and microperipheral products. In addition, Microchip’s quality system for the design and manufacture of development systems is ISO 9001 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: 480-792-7627
Web Address: http://www.microchip.com

Rocky Mountain
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7966 Fax: 480-792-7456

Atlanta
500 Sugar Mill Road, Suite 200B
Atlanta, GA 30350
Tel: 770-640-0034 Fax: 770-640-0307

Boston
2 Lan Drive, Suite 120
Westford, MA 01886
Tel: 978-692-3848 Fax: 978-692-3821

Chicago
333 Pierce Road, Suite 180
Itasca, IL 60143
Tel: 630-285-0071 Fax: 630-285-0075

Dallas
4570 Westgrove Drive, Suite 160
Addison, TX 75001
Tel: 972-818-7423 Fax: 972-818-2924

Detroit
Tri-Atria Office Building
32255 Northwestern Highway, Suite 190
Farmington Hills, MI 48334
Tel: 248-538-2250 Fax: 248-538-2260

Kokomo
2767 S. Albright Road
Kokomo, Indiana 46902
Tel: 765-864-8360 Fax: 765-864-8387

Los Angeles
18201 Von Karman, Suite 1090
Irvine, CA 92612
Tel: 949-263-1888 Fax: 949-263-1338

New York
150 Motor Parkway, Suite 202
Hauppauge, NY 11788
Tel: 631-273-5305 Fax: 631-273-5335

San Jose
Microchip Technology Inc.
2107 North First Street, Suite 590
San Jose, CA 95131
Tel: 408-436-7950 Fax: 408-436-7955

Toronto
6285 Northam Drive, Suite 108
Mississauga, Ontario L4V 1X5, Canada
Tel: 905-673-0699 Fax: 905-673-6509

ASIA/PACIFIC

Australia
Microchip Technology Australia Pty Ltd
Suite 22, 41 Rawson Street
Epping 2121, NSW
Australia
Tel: 61-2-9868-6733 Fax: 61-2-9868-6755

China - Beijing
Microchip Technology Consulting (Shanghai) Co., Ltd., Beijing Liaison Office
Unit 915
Bei Hai Wan Tai Bldg.
No. 6 Chaoyangmen Beidajie
Beijing, 100027, No. China
Tel: 86-10-85282100 Fax: 86-10-85282104

China - Chengdu
Microchip Technology Consulting (Shanghai) Co., Ltd., Chengdu Liaison Office
Rm. 2401, 24th Floor,
Ming Xing Financial Tower
No. 88 TIDU Street
Chengdu 610016, China
Tel: 86-28-6766200 Fax: 86-28-6766599

China - Fuzhou
Microchip Technology Consulting (Shanghai) Co., Ltd., Fuzhou Liaison Office
Unit 28F, World Trade Plaza
No. 71 Wusi Road
Fuzhou 350001, China
Tel: 86-591-7503506 Fax: 86-591-7503521

China - Shanghai
Microchip Technology Consulting (Shanghai) Co., Ltd.
Room 701, Bldg. B
Far East International Plaza
No. 317 Xian Xia Road
Shanghai, 200051
Tel: 86-21-6275-5700 Fax: 86-21-6275-5060

China - Shenzhen
Microchip Technology Consulting (Shanghai) Co., Ltd., Shenzhen Liaison Office
Rm. 1315, 13/F, Shenzhen Kerry Centre,
Renminnan Lu
Shenzhen 518001, China
Tel: 86-755-2350361 Fax: 86-755-2366086

Hong Kong
Microchip Technology Hongkong Ltd.
Unit 901-6, Tower 2, Metroplaza
223 Hing Fong Road
Kwai Fong, N.T., Hong Kong
Tel: 852-2401-1200 Fax: 852-2401-3431

India
Microchip Technology Inc.
India Liaison Office
Divyasree Chambers
1 Floor, Wing A (A3/A4)
No. 11, O'Shaugnessey Road
Bangalore, 560 025, India
Tel: 91-80-2290061 Fax: 91-80-2290062

Japan
Microchip Technology Japan K.K.
Benex S-1 6F
3-18-20, Shinyokohama
Kohoku-Ku, Yokohama-shi
Kanagawa, 222-0033, Japan
Tel: 81-45-471- 6166 Fax: 81-45-471-6122

Korea
Microchip Technology Korea
168-1, Youngbo Bldg. 3 Floor
Samsung-Dong, Kangnam-Ku
Seoul, Korea 135-882
Tel: 82-2-554-7200 Fax: 82-2-558-5934

Singapore
Microchip Technology Singapore Pte Ltd.
200 Middle Road
#07-02 Prime Centre
Singapore, 188980
Tel: 65-6334-8870 Fax: 65-6334-8850

Taiwan
Microchip Technology Taiwan
11F-3, No. 207
Tung Hua North Road
Taipei, 105, Taiwan
Tel: 886-2-2717-7175 Fax: 886-2-2545-0139

EUROPE

Denmark
Microchip Technology Nordic ApS
Regus Business Centre
Lautrup hoj 1-3
Ballerup DK-2750 Denmark
Tel: 45 4420 9895 Fax: 45 4420 9910

France
Microchip Technology SARL
Parc d'Activite du Moulin de Massy
43 Rue du Saule Trapu
Batiment A - ler Etage
91300 Massy, France
Tel: 33-1-69-53-63-20 Fax: 33-1-69-30-90-79

Germany
Microchip Technology GmbH
Gustav-Heinemann Ring 125
D-81739 Munich, Germany
Tel: 49-89-627-144 0 Fax: 49-89-627-144-44

Italy
Microchip Technology SRL
Centro Direzionale Colleoni
Palazzo Taurus 1 V. Le Colleoni 1
20041 Agrate Brianza
Milan, Italy
Tel: 39-039-65791-1 Fax: 39-039-6899883

United Kingdom
Arizona Microchip Technology Ltd.
505 Eskdale Road
Winnersh Triangle
Wokingham
Berkshire, England RG41 5TU
Tel: 44 118 921 5869 Fax: 44-118 921-5820

03/01/02

© 2002 Microchip Technology Inc.