AN212

Smart Sensor CAN Node using the MCP2510 and PIC16F876

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INTRODUCTION

Advances in data communications have created efficient methods for several devices to communicate over a minimum number of system wires. The Controller Area Network (CAN) is one of these methods. CAN sends and receives messages over a two-wire CAN bus. The nodes broadcast their individual messages over the CAN bus, while the receivers are setup to accept the message and anticipate an acknowledgment (ACK) signal indicating the receipt of a non-corrupted message. The protocol of the CAN has two states and the bits are either dominant (logic '0') or recessive (logic '1'). Nodes may attempt to transmit a message at the same time. To ensure that collisions do not reduce the throughput of the bus, there is an arbitration scheme in which a node will continue to transmit until a dominant bit is detected, while that node is expecting a recessive bit (in the ID field) on the CAN bus. The node(s) that lose arbitration will automatically terminate their transmission and switch to receive mode. Once the CAN bus enters an idle state, these nodes attempt to re-transmit. If the node does not lose arbitration, it completes its transmission. For additional information on the CAN protocol, refer to AN713, *"Controller Area Network* (*CAN) Basics*", DS00713.

The bus configuration operates by the multi-master principle and allows several node boards to connect directly to the bus. If one node board fails in the system, the other node boards are not affected. The probability of the entire network failing is extremely low compared to ring type networks. Ring type networks have a high probability failure rate, due to the fact that if one node malfunctions, the entire network becomes inoperable. The CAN controller seeks to solve this problem.

MCP2510 CAN Controller Benefits

- Monitors Several Devices
- Individual Node Programming
- Replaces a Large Wiring Harness

MODULE OVERVIEW

The module hardware can be divided into two components. These are:

- CAN-NET Node Board
- CAN-NET Analog Input Board

These boards can be purchased from Diversified Engineering by ordering the CAN-NET Analog Input Node Kit. The CAN-NET Analog Input Board also requires that some of the options be installed by the customer. Two additional components are: a 14.5-PSI Pressure Transducer and a LED. Table 1 gives the part numbers for these components.

TABLE 1: COMPONENT PART NUMBERS

Manufacturer	Component	Part Number
Diversified Engineering	CAN-NET Analog Input Node Kit	905190
Motorola	Pressure Transducer	MPX2010DP

This module has several key features. These include:

- High-Speed SPI™ Interface
- MPLAB® ICD Debugging Tool
- Low Power CMOS Technology
- PWM Output for Driving a Lamp
- Supports SPI modes 0,0 and 1,1

CAN-NET Node Board

The CAN-NET Node Board consists of hardware devices that are used in conjunction with software programming techniques to achieve an optimal Controller Area Network. The versatility of the CAN controller enables a wide variety of applications to be created based on the concept of this particular design.

The MCP2510 CAN controller is the heart of the CAN interface. It handles all transmitting and receiving of message packets that contain useful information for other nodes on the network via the CAN bus. The MCP2510 CAN controller is also designed to interface with the Serial Peripheral Interface (SPI) port. The SPI port is available on the PIC16F876 microcontroller and the MCP3201 Analog-to-Digital Converter (ADC).

The PIC16F876 microcontroller stores the program in memory and reads the DIP switch settings for sending and receiving messages. It controls the PWM output and enables the MPLAB ICD to be used as a debugging tool.

CAN-NET Analog Input Board

The MCP3201 ADC accepts input signals from the pressure sensor, utilizing a differential amplifier configuration. The MCP602 amplifier uses single-supply CMOS operational amplifier (op amp) technology.

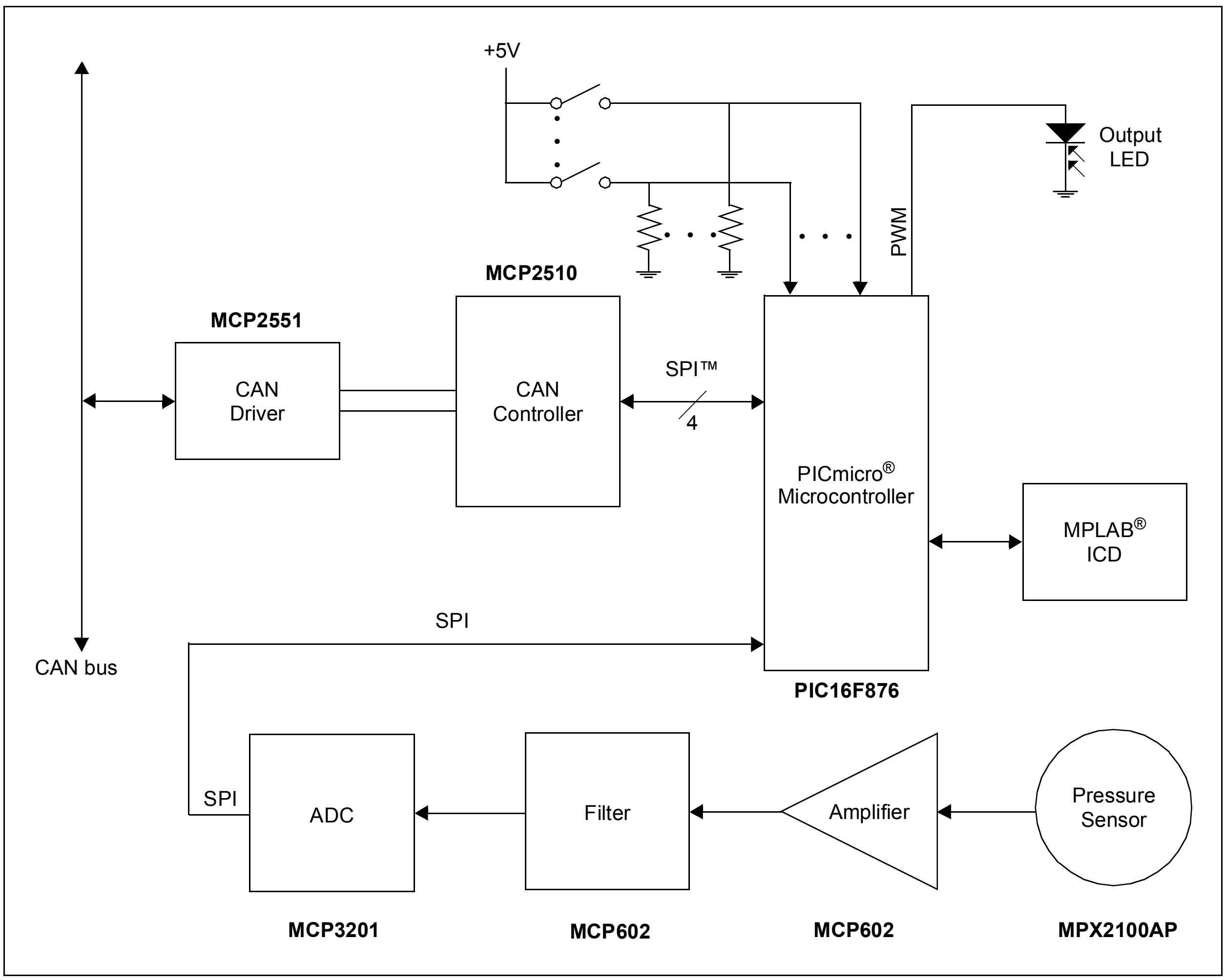
HARDWARE OVERVIEW

This section describes the CAN-NET Node board hardware and how the CAN functions in the node board system. Schematics can be found in Appendix A.

MCP2510 CAN Controller

The high-level design of this system is shown in Figure 1. The concept is to enable the MCP2510 CAN controller, the PIC16F876 microcontroller and the MCP3201 ADC to efficiently communicate with each other utilizing the SPI. The MCP2510 handles the lower-level protocols.

FIGURE 1: BLOCK DIAGRAM OF THE CAN NODE BOARD



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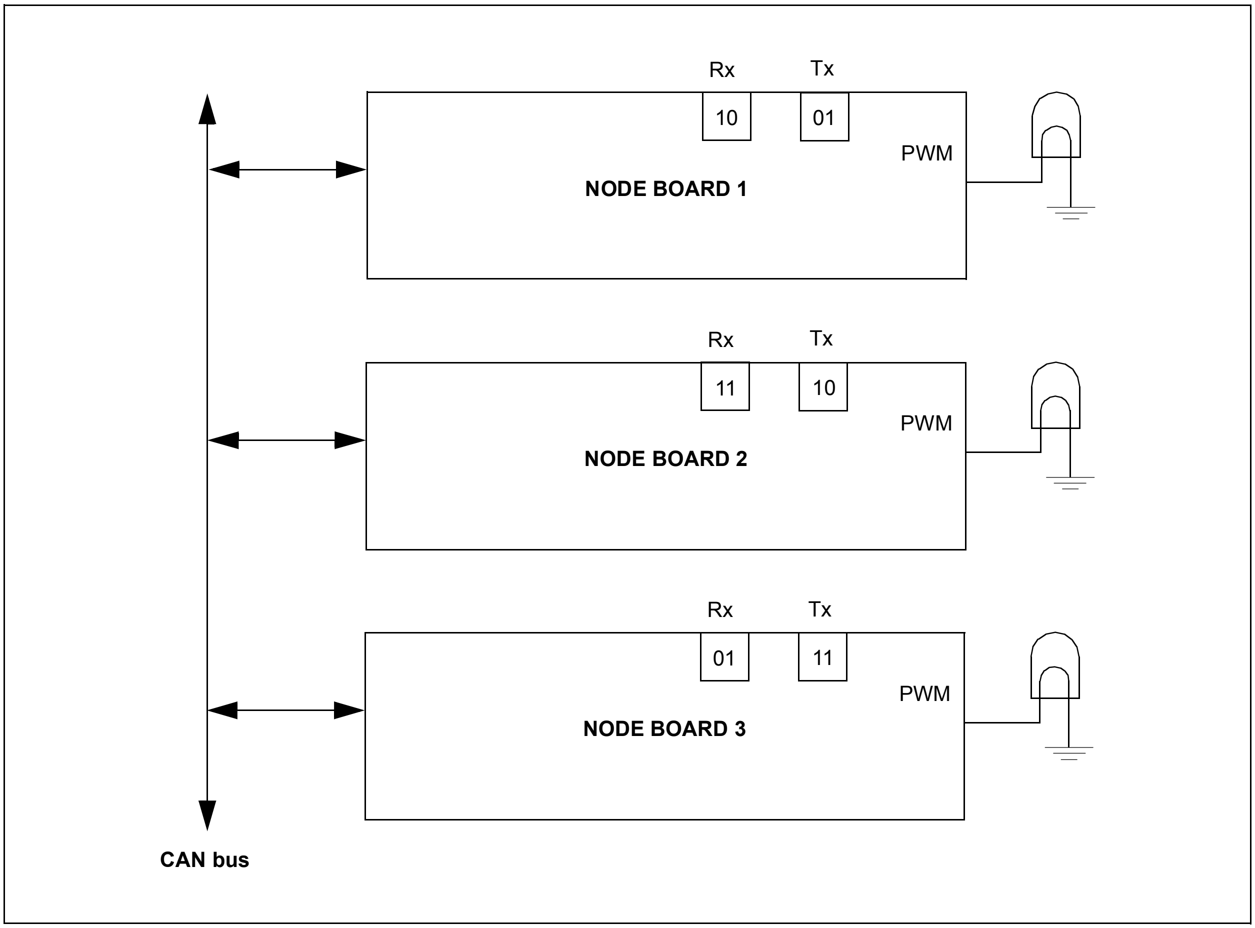
The PIC16F876 microcontroller stores the program in memory and constantly polls the MCP3201 ADC, along with the reference A/D.

In the main loop of the program, a variable is toggled. When the value of the variable is a logic '0', the PICmicro® device reads the pressure sensor and, once the value of the variable is a logic '1', the PICmicro device reads the reference A/D. The microcontroller also reads the settings of the input switches. The first two (of four) switches tells the microcontroller which message the node is allowed to receive. The last two (of four) switches tell the microcontroller the transmit address of the node. The configuration shown in Figure 2 illustrates three node boards on a CAN bus set to transmit and receive certain messages.

FIGURE 2: THREE NODE BOARDS CONNECTED TO THE CAN BUS



In this case, each node transmits its own pressure sensor value and is set to receive a value of the pressure sensor from a different node. The identification for each node board is 01, 10 and 11. These settings are transmit and receive identifiers. Node Board 1 is set to receive the pressure sensor value from Node Board 2. Node Board 2 is set to receive the pressure sensor value from Node Board 3, while Node Board 3 is set to receive the pressure sensor value from Node Board 1. The pressure sensor value of each node board is directly proportional to the PWM output of the corresponding microcontroller.

The CAN driver chip converts the input and output to the CAN bus voltages ranging from 0 to 5 volts, with a shift of ±12V.

The MCP3201 is a 12-bit ADC with on-board sample and hold circuitry.

The input to the device comes from a differential amplifier circuit that communicates over the serial interface using the SPI protocol. The MCP602 op amp is used to design a suitable differential amplifier.

The gain of the amplifier is determined by the following equation:

EQUATION 1: AMPLIFIER GAIN

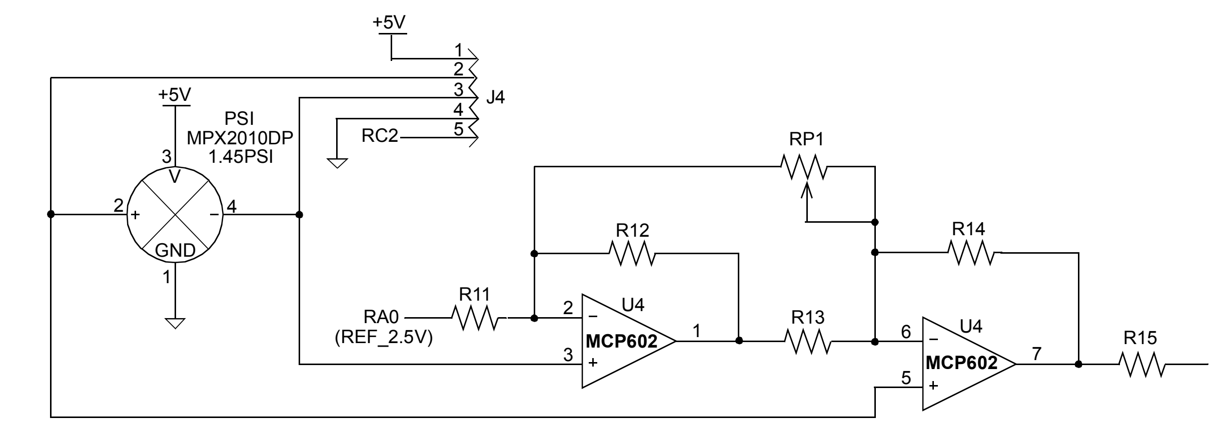
$$Gain = 1 + \frac{R14}{R13} + 2\frac{R13}{RP1}$$

Figure 3 shows a differential amplifier circuit. The input to this amplifier ranges from 0 to 5 volts and is useful for pressure applications. The pressure can be referred to as “zero pressure”. The normalized pressure setting consists of negative pressure and positive pressure. The pressure sensor produces a negative voltage when there is negative pressure and a positive voltage when there is positive pressure. The reference for the differential amplifier is 2.5 volts. Above 2.5 volts, it indicates a positive pressure. Below 2.5 volts, it indicates a negative pressure. The CAN-NET Node Board with the Analog I/O Board is designed specifically for pressure, but can easily be altered to do both.

Hardware Tools

The MPLAB ICD is a tool which enhances the code development and hardware debugging process. The debugger uses a PIC16F877 device and operates in “real time”. This low cost tool saves engineering time (“money”) by allowing the application program and circuit to be evaluated and enhanced in real time. The ICD interface also allows the PIC16F87X devices to be programmed after the board has been manufactured. This allows software changes or updates to be programmed into the device. The ICD uses the RB6 and RB7 pins of the PIC16F87X for this. For that reason, these pins are not used for any other purpose in this system. For additional information on In-Circuit Serial Programming™, please refer to Microchip’s In-Circuit Serial Programming (ICSP™) Guide, (DS30277).

FIGURE 3: DIFFERENTIAL AMPLIFIER CIRCUIT



Component	Value	Tolerance
R11	30.1 kΩ	1%
R12	10.0 kΩ	1%
R13	10.0 kΩ	1%
R14	30.1 kΩ	1%
R15	1.0 KΩ	1%
RP1	0.0 to 50.0 kΩ	N.A.

SOFTWARE OVERVIEW

Programming Style

The code for the node board is written in the PICmicro device instruction set to be assembled using Microchip's MPLAB environment. There is a significant use of macros to make the code more readable and less error prone. The macros are defined in three files:

1. Near the top of the main file,
2. CANLIB.ASM (file contains the CAN macros)
3. MACROS16.INC

If an unfamiliar instruction is found, it is probably made up of a set of familiar instructions in one of the macros. The macros in the MACROS16.INC file are used extensively in writing code for the PICmicro microcontroller family, because they increase readability and greatly reduce programming errors.

Common Code

The node board uses common software files to maximize the program's efficiency. The routines that enable communication with the MCP2510 CAN chip are in the file CANLI.ASM, whle the definitions for the MCP2510 registers are in MCP2510.INC. The common macros are in MACROS16.INC.

SPI Communications

Communication from a device on the node (such as a microcontroller) to the MCP2510 is accomplished through the SPI bus. The PICmicro device used on the node board fully supports the SPI in the master mode. Command strings are sent and received using a single software buffer. To send a string, the software buffer (called `pSPIBufBase`) is loaded with the bytes to send and the SPI interrupt is turned on. The interrupt handler exchanges bytes with the MCP2510. The bytes received from the MCP2510 replace the bytes that were sent from the software buffer so that, once the string has been sent, the buffer will contain the bytes received from the MCP2510. All communication with the MCP2510 is handled in this manner and is encapsulated in the routines in the CANLIB.ASM.

General ID Structure

The ID structure used by the node boards is determined by the settings on the DIP switches on power-up or after a reset. Changing the DIP switches while running has no effect on the ID structure.

Receive ID Structure

The node board uses the settings in Table 2 for receiving:

TABLE 2: RECEIVING SETTINGS FOR THE NODE BOARD

Register	Value
RxMask0	0xFFF
RxMask1	0xFFE
RxFilter0	0xFFF
RxFilter1	0xFFF
RxFilter2	0xn00 (1)
RxFilter3	0xn10
RxFilter4	0xFFF
RxFilter5	0xFFF

Note: This value is the Base Receive ID for receiving. The DIP #1 and DIP #2 settings are used to determine this value.

The DIP settings for receiving are shown in Table 3.

TABLE 3: DIP SWITCH ID SETTINGS FOR RECEIVING

DIP #1	DIP #2	ID
0	0	0x000
0	1	0x100
1	0	0x200
1	1	0x300

A message received for RxFilter2 (Base Receive ID) is assumed to be a two-byte integer that contains a 12-bit value between 0 and 4095. The 12-bit data is used to generate a PWM output, where a '`0`' generates a 0% duty cycle and 0xFFF generates a 100% duty cycle.

Transmit ID Structure

The node board transmits a CAN message every 131 ms. A message contains two data bytes that represent a 12-bit value, with least significant byte (LSB) sent first.

The pressure switch is assigned to the Base Transmit ID and is measured and transmitted with that ID every 393 ms as a two-byte integer in the range 0 to 4095. The reader should note that, while the A/D measurement is 8 bits, it is shifted by 4 bits before transmission. Thus, its actual range is 0x0000 to 0x0FF0.

Each data source has its own unique Base Transmit ID obtained from the settings of DIP #3 and DIP #4. These settings are shown in Table 4.

TABLE 4: DIP SWITCH ID SETTINGS FOR TRANSMITTING

DIP #3	DIP #4	ID
0	0	All transmissions are disabled
0	1	0x100
1	0	0x200
1	1	0x300

The MCP2510 CAN controller has a 125 kbit rate and the polling method is used. The use of interrupts would be easier in the system, but polling allows the interrupt pins to remain free for other potential functions in the system.

There are three methods for transmitting information:

1. Responding to an external event (event driven).
2. Sending messages at regular intervals (timed transmission). The time of the event may be unknown.
3. A combination of the first two. The receiver can expect messages at a maximum known interval.

The flowcharts for the operation of the source code are shown in Figure 4 through Figure 24. The subroutines contain the actual name and the function it performs within the flowchart, so that it can be easily referenced with the source code. Table 5 gives the function names used and a brief description of the function. In the electronic version of this document, clicking of the function name will take you (link you) to the page for that function.

TABLE 5: SOFTWARE FUNCTION DESCRIPTIONS

Function Name	Function Description	Figure Number
`Main`	This is the main loop of the program.	Figure 4
`Hardstart`	Does a full initialization of the system.	Figure 5
`Init`	Initializes the PIC16F87X registers.	Figure 6
`InitSPIPort`	Initializes the PIC16F87X SPI port.	Figure 7
`Init2510`	Initializes the MCP2510's registers.	Figure 8
`Read3201`	Reads the specified register in the MCP3201 (A/D converter).	Figure 9
`ReadA2D`	Reads the specified register in the MCP3201 (A/D converter).	Figure 10
`WaitANDeqZ`	Waits for pending messages.	Figure 11
`CheckCANMsg`	Checks for messages in the receive buffer.	Figure 12
`ParseCAN`	Setup messages for the PWM output.	Figure 13
`Reset2510`	Resets the MCP2510.	Figure 14
`BitMod2510`	Modifies the value of a specified bit in the MCP2510.	Figure 15
`Wrt2510Reg`	Writes the specified register in the MCP2510 (CAN interface).	Figure 16
`SetNormalMode`	Sets the MCP2510 to normal operating mode.	Figure 17
`Rd2510Reg`	Reads the specified register in the MCP2510 (CAN interface).	Figure 18
`OutputPWM`	Loads the PWM duty cycle registers with the values in the specified registers.	Figure 19
`InitSPIBuf`	Initializes SPI buffer for transaction.	Figure 20
`LoadSPIByte`	Loads the value in the W register into the SPI buffer.	Figure 21
`ExchangeSPI`	Initiates the SPI transaction.	Figure 22
`WaitSPIExchange`	Waits for the SPI transaction to be completed.	Figure 23
`LoadSPIZeros`	Clears the value in the SPI buffer.	Figure 24

CONCLUSION

The MCP2510 offers a simple method to interface a CAN network in order to maximize the transmitting and receiving of data via the CAN Bus. This efficient method allows a wide variety of I/O devices to be connected to the network using a node board. An advantage in utilizing this type of system is the ability to monitor several node boards at any given time. If an error occurs, it is detected and re-transmitted over the bus line until the receiver acknowledges the message. Another advantage is that several node Boards can work from one bus line rather than using a large wiring harness that connects to a main control panel. Our design demonstrates a way to implement a simple input pressure switch connected to a node board, along with a visual light source to display the value in terms of brightness. By this example, several uses for different types of inputs and outputs can be implemented by using the basic techniques from this design.

Table 6 shows the resource requirements for the major functions.

TABLE 6: PIC16CXXX REQUIREMENTS

Function	Memory		Instruction Cycles
	Program	Data	
Assemble Message	TBD	TBD	TBD
Transmit	TBD	TBD	TBD
Receive	TBD	TBD	TBD
Disassemble Message	TBD	TBD	TBD
Test Error Conditions	TBD	TBD	TBD

CONTACTING DIVERSIFIED ENGINEERING

Additional information and CAN related products may be acquired from Diversified Engineering. You may contact them by either calling:

(203) 799-7875

or by visiting their web site:

www.DiversifiedEngineering.net

FIGURE 4: MAIN PROGRAM LOOP (Main)

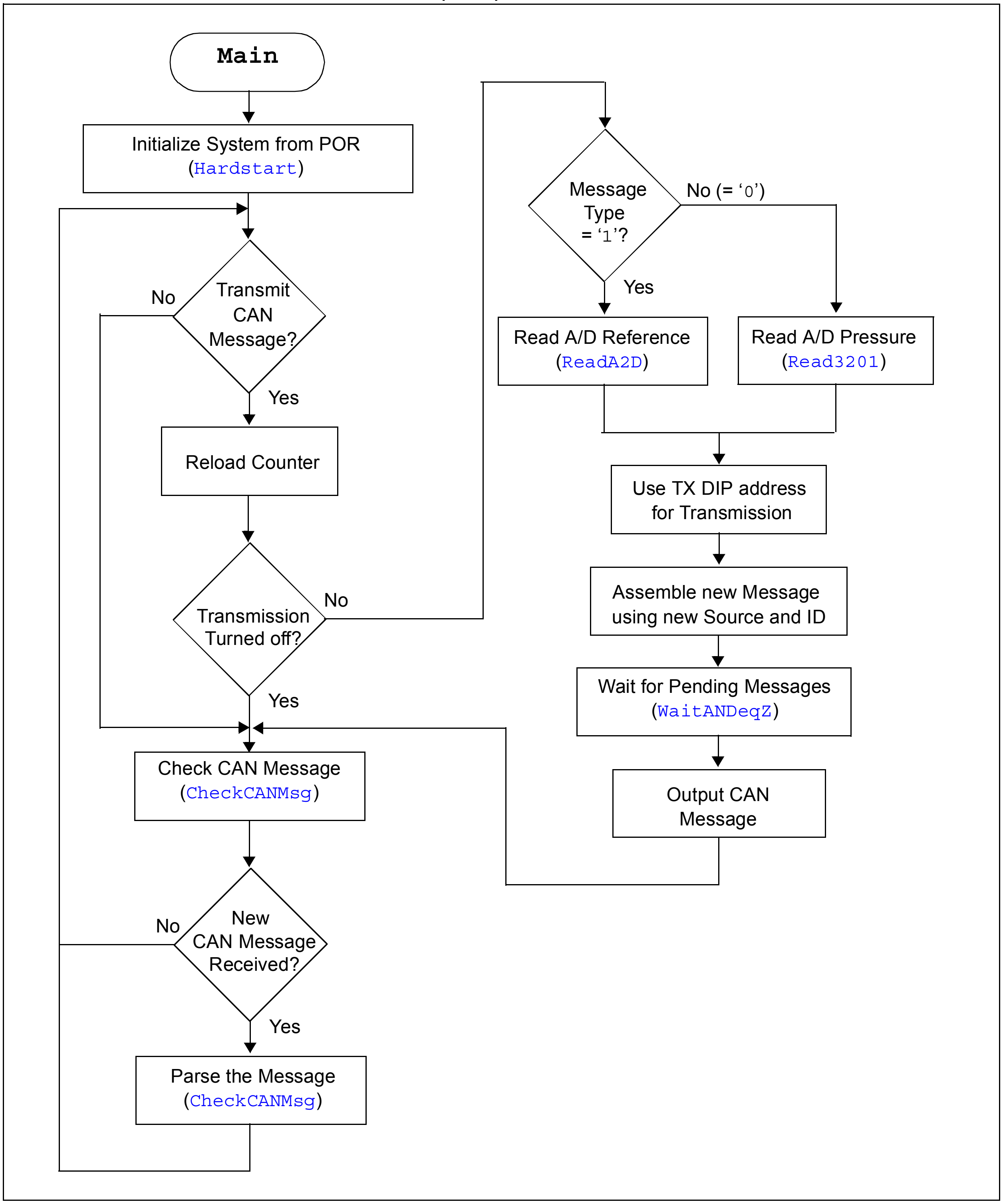


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FIGURE 5: HARDSTART (Hardstart)

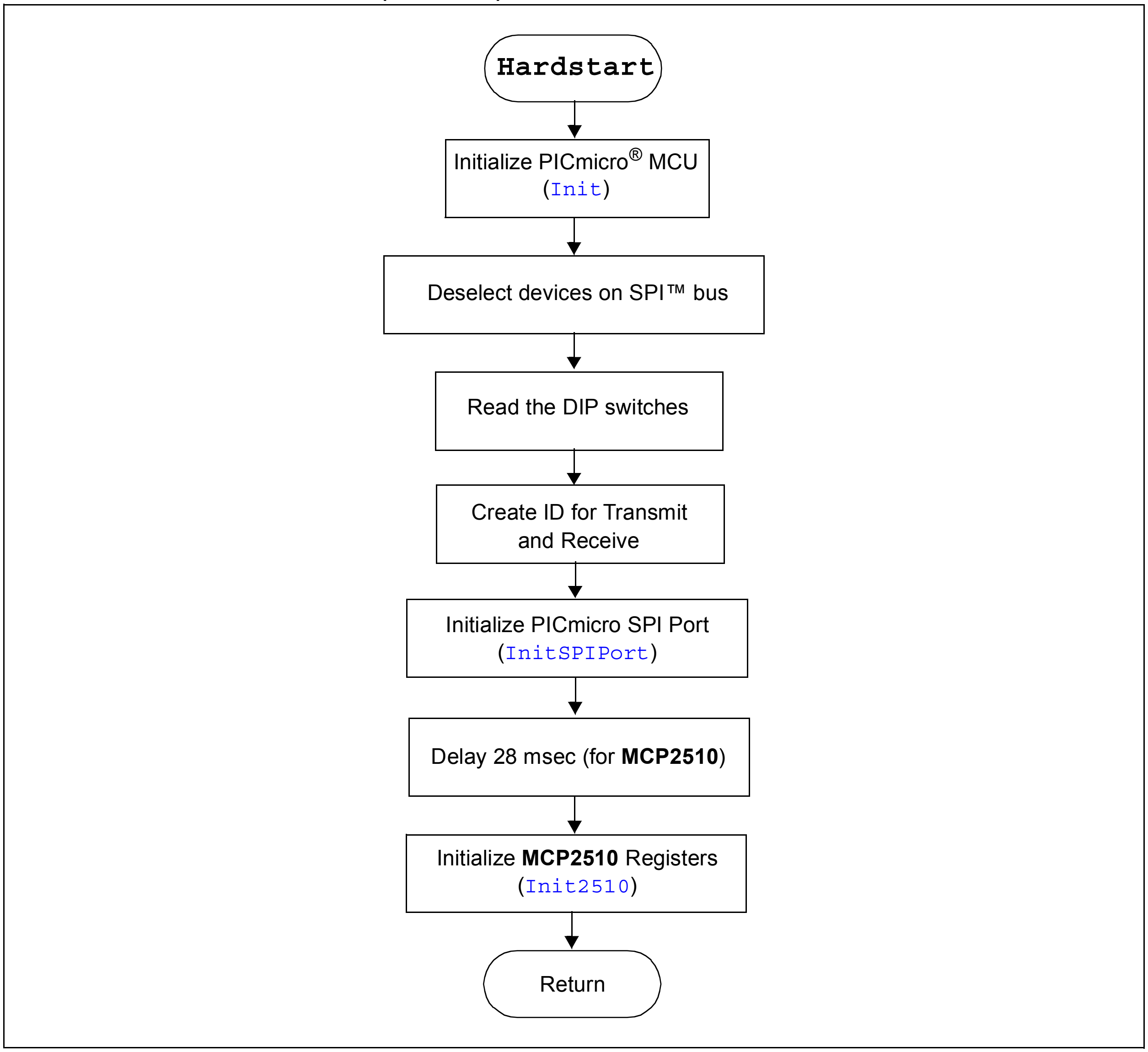

FIGURE 6: INITIALIZE PICmicro® (Init)

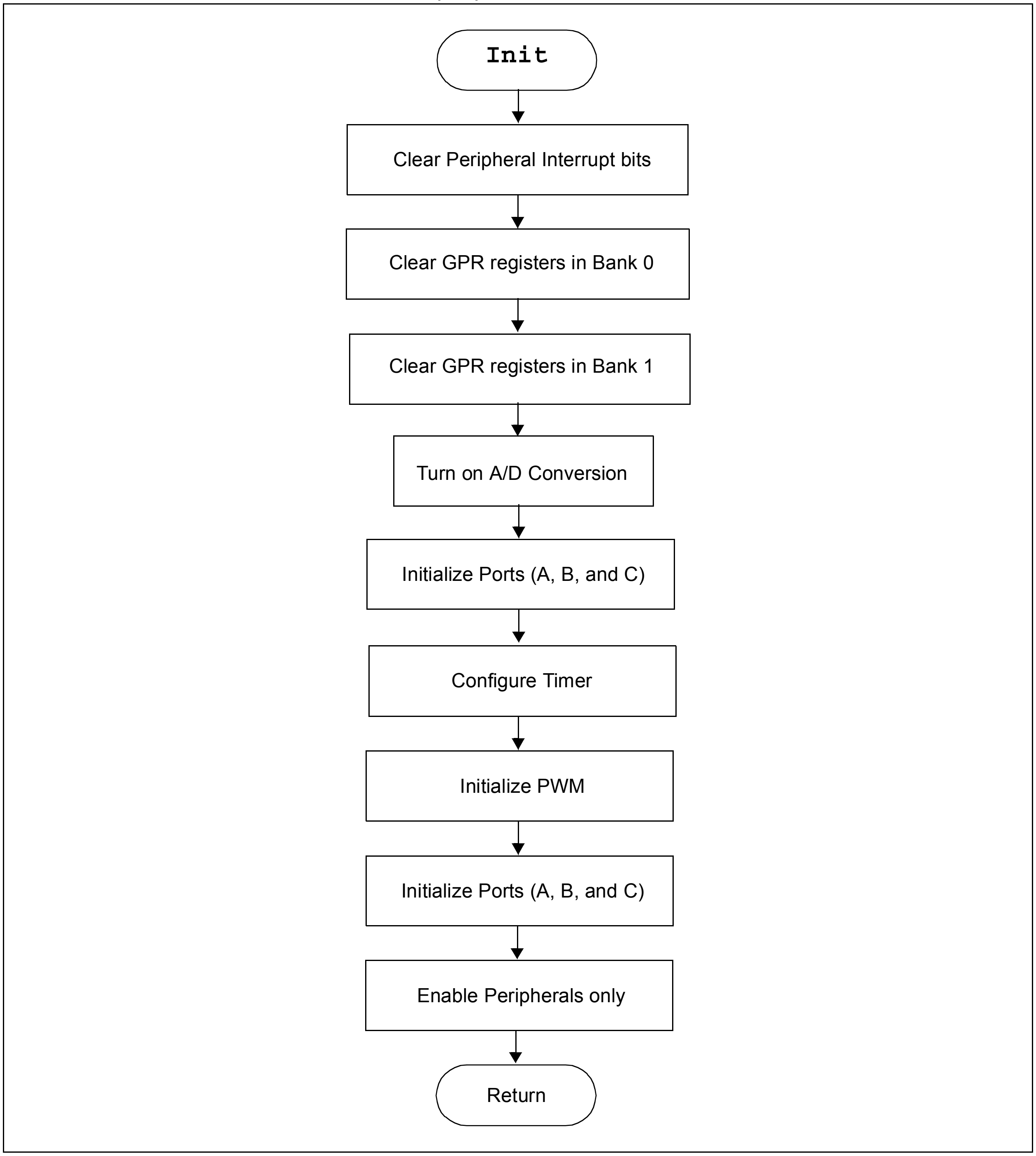

FIGURE 7: SETUP SPI™ PORT (InitSPIPort)

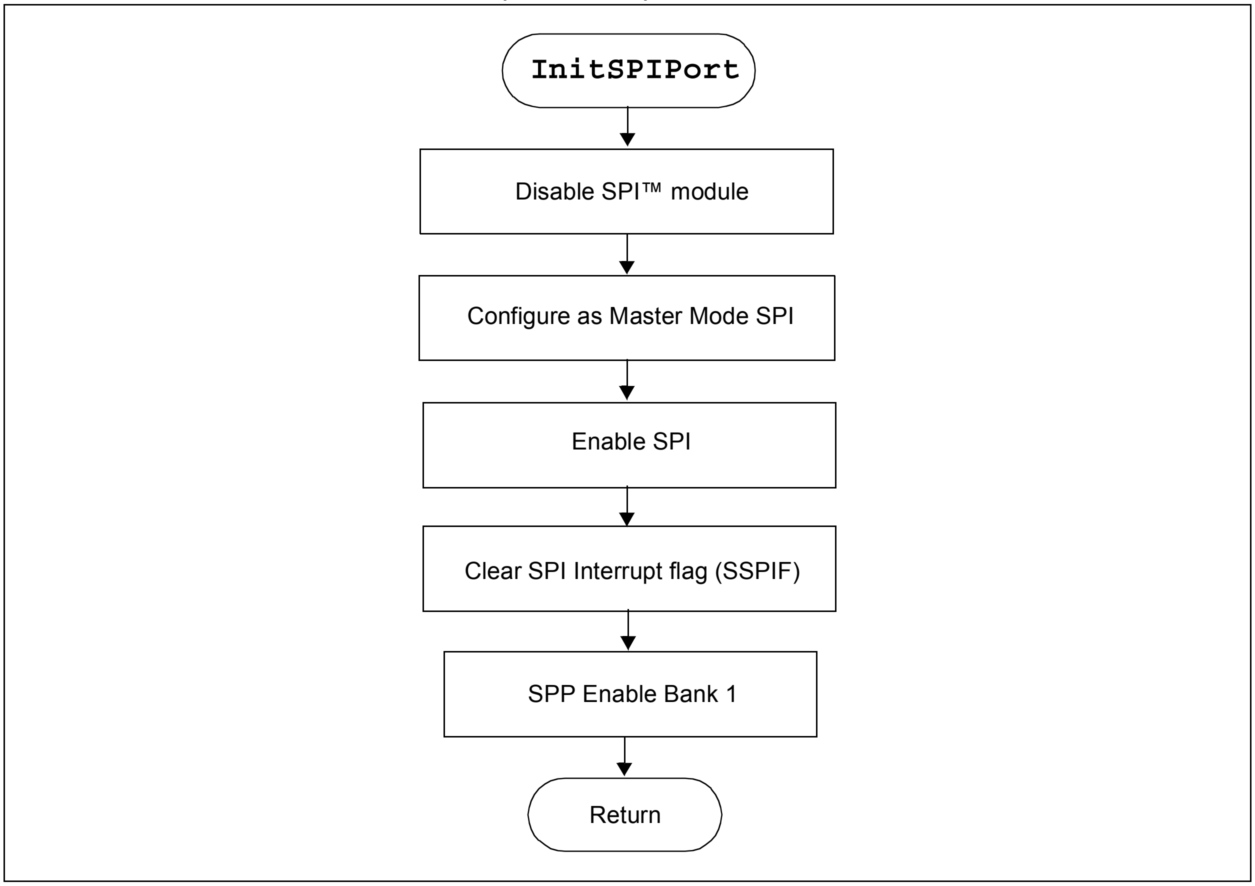

FIGURE 8: SETUP MCP2510 REGISTERS (Init2510)

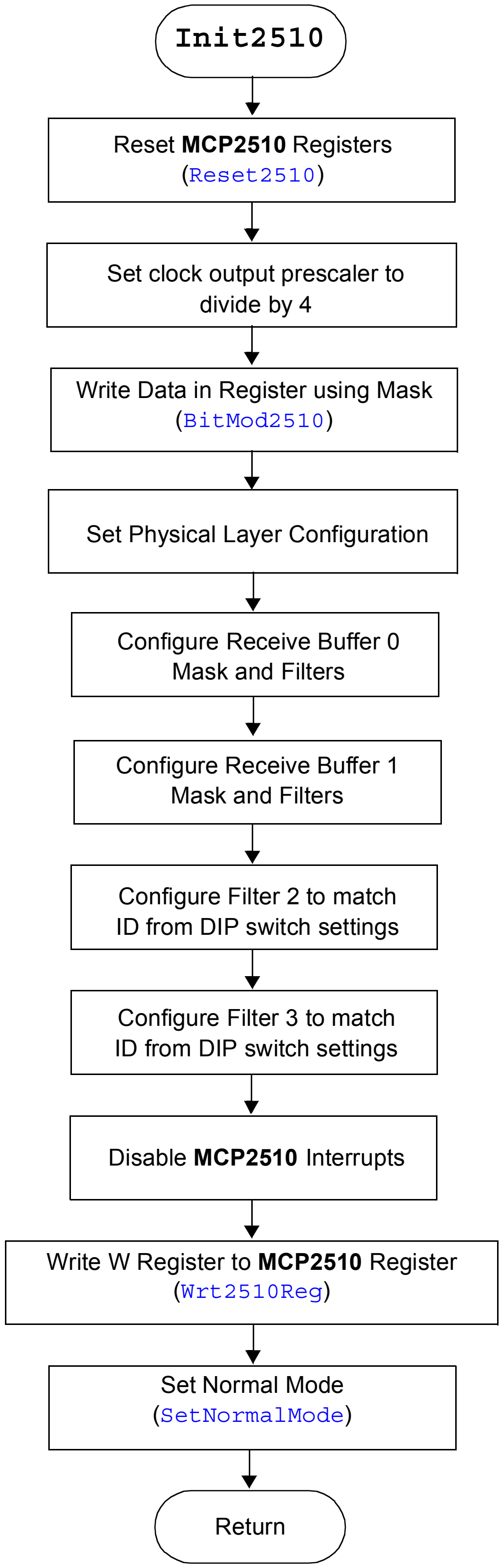

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FIGURE 9: READ A/D PRESSURE (Read3201)

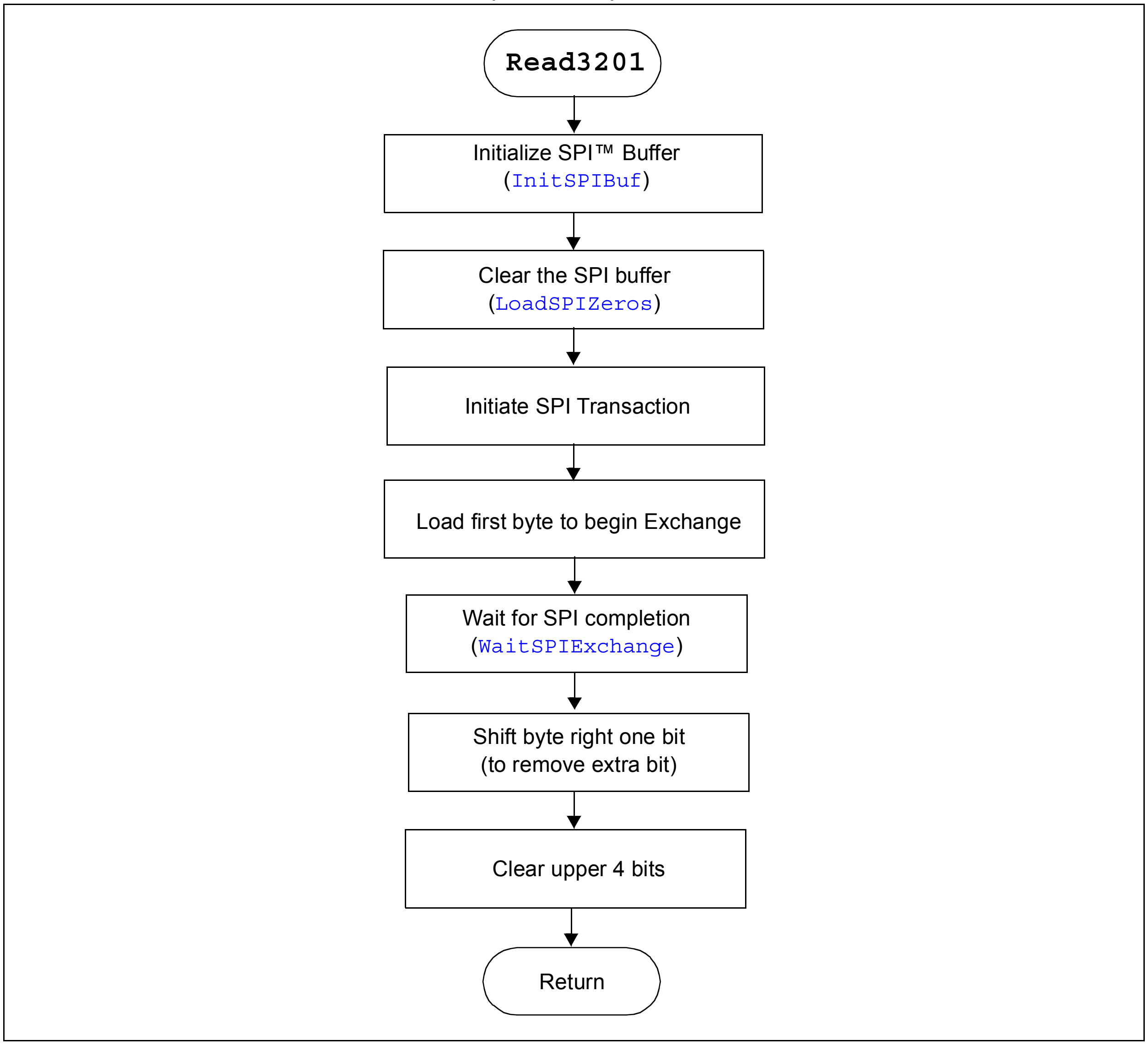

FIGURE 10: READ A/D REFERENCE (ReadA2D)

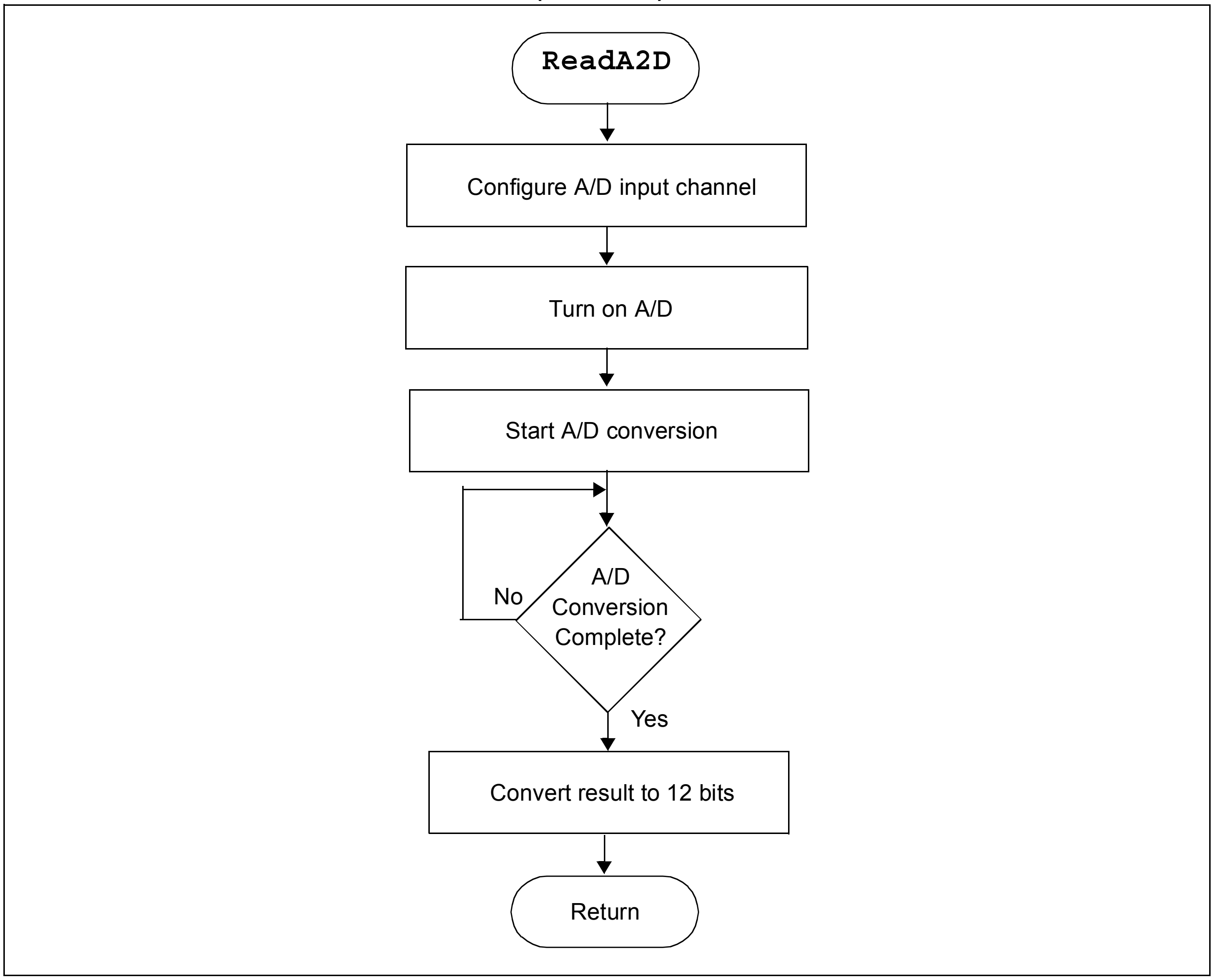

FIGURE 11: WAIT FOR PENDING MESSAGES (WaitANDeqZ)

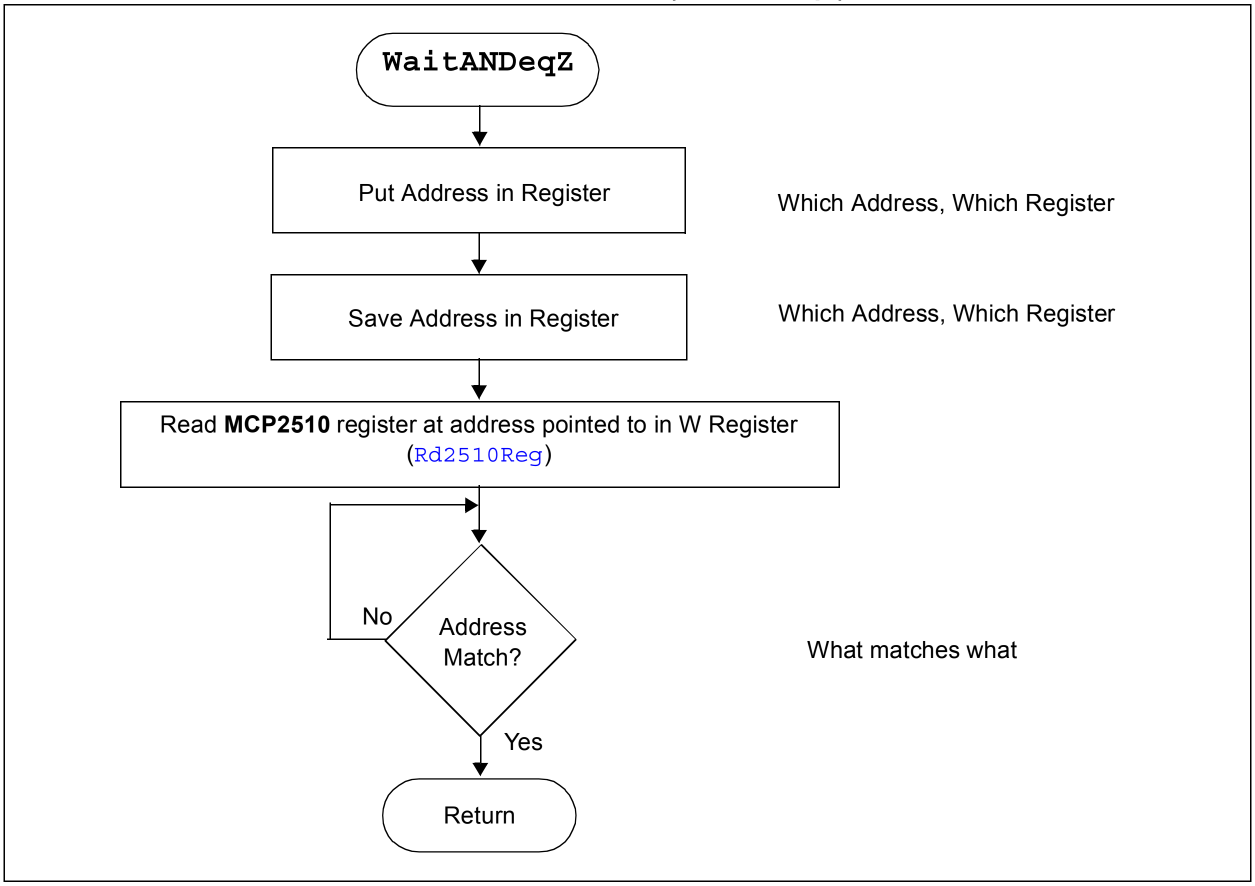

FIGURE 12: CHECK CAN MESSAGE (CheckCANMsg)

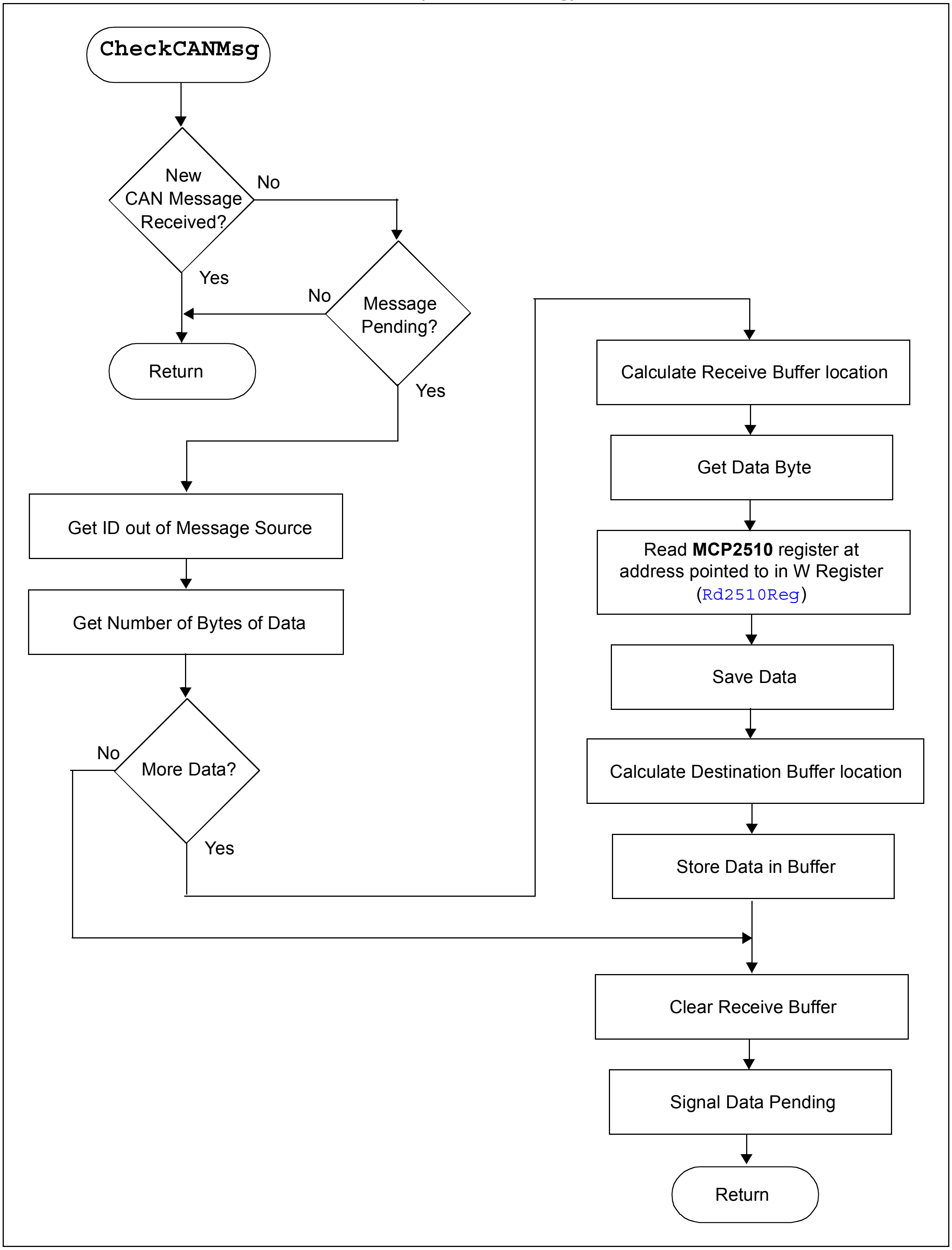

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FIGURE 13: PARSE THE MESSAGE (ParseCAN)

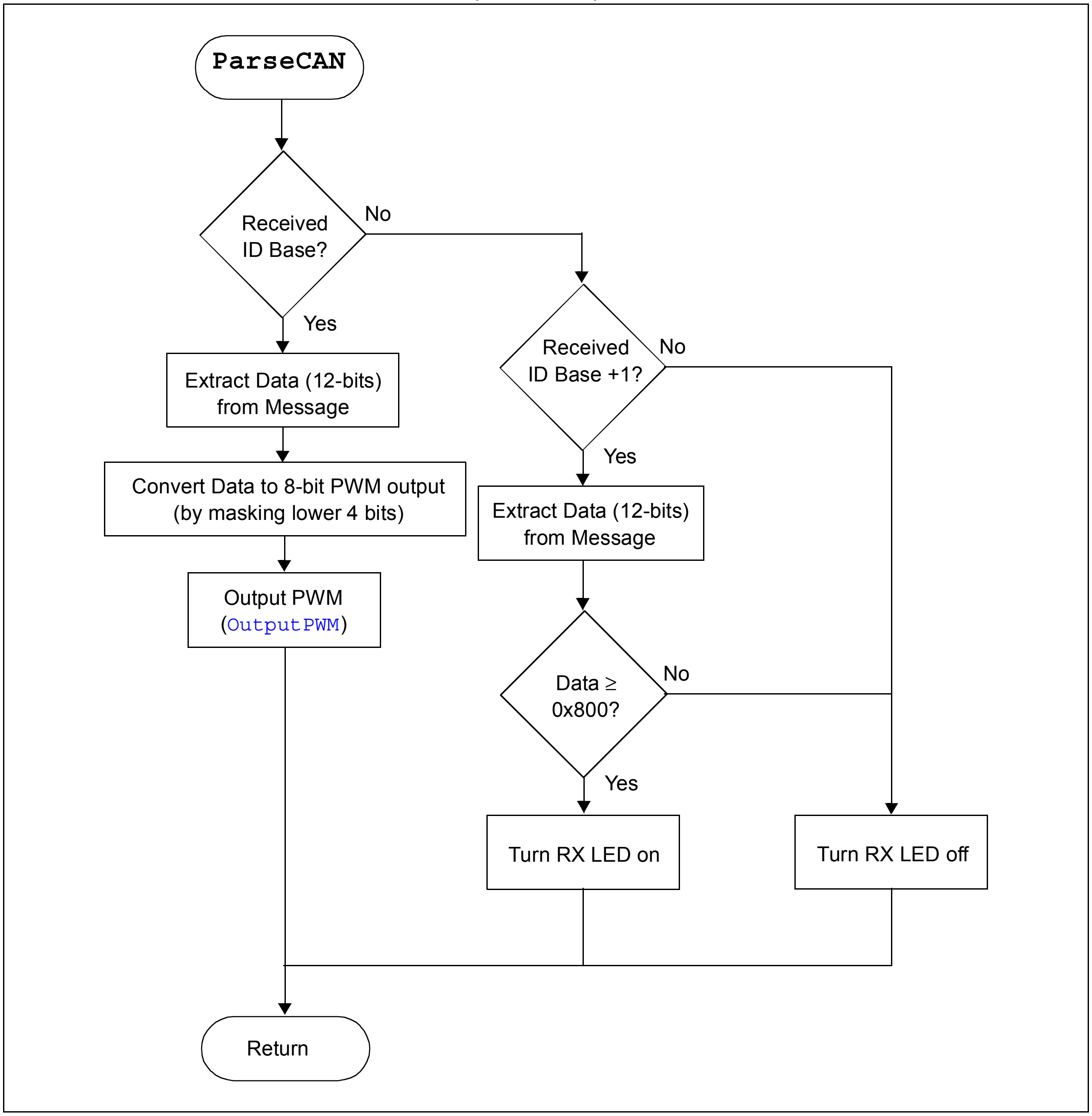


FIGURE 14: RESET MCP2510 REGISTERS (Reset2510)

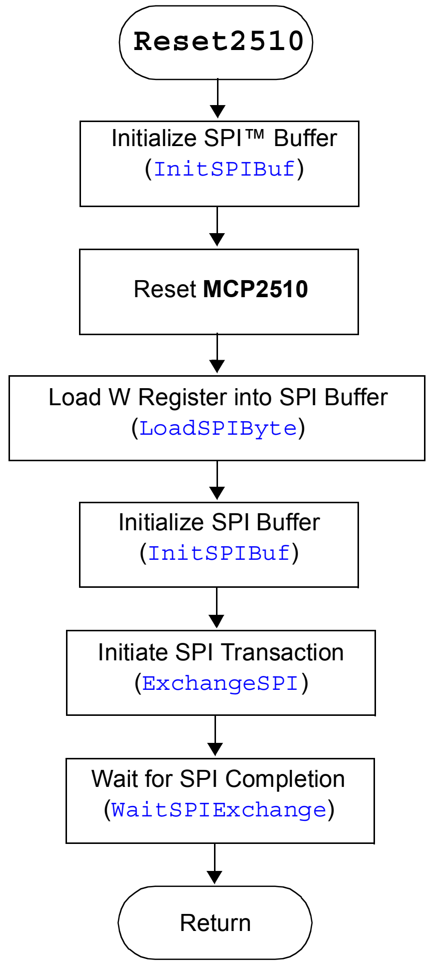


FIGURE 15: WRITE DATA IN REGISTER USING MASK (BitMod2510)

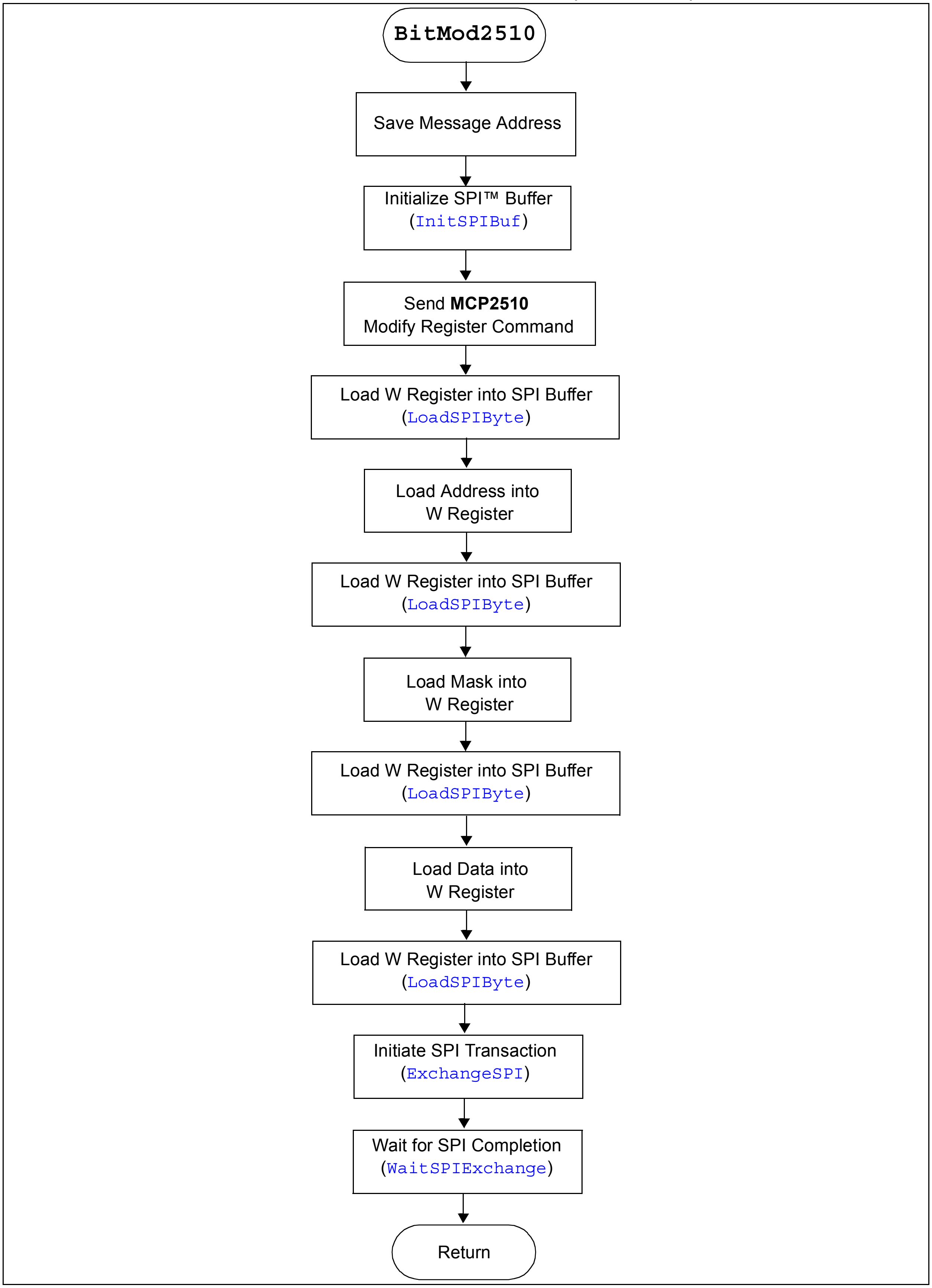


FIGURE 16: WRITE BYTE IN MCP2510 REGISTER IN W (Wrt2510Reg)

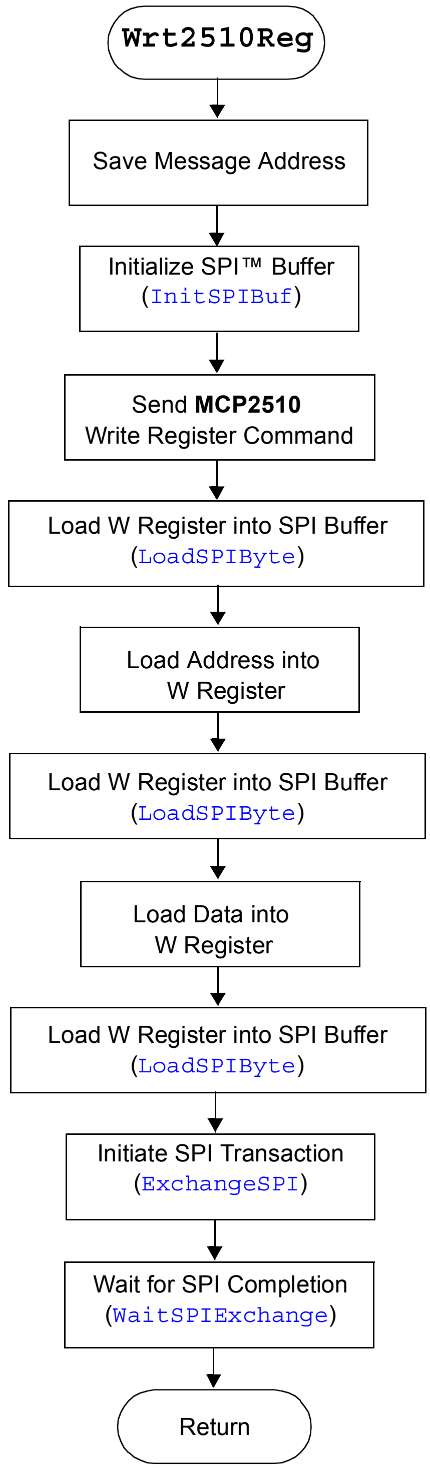


FIGURE 17: SET NORMAL MODE (SetNormalMode)

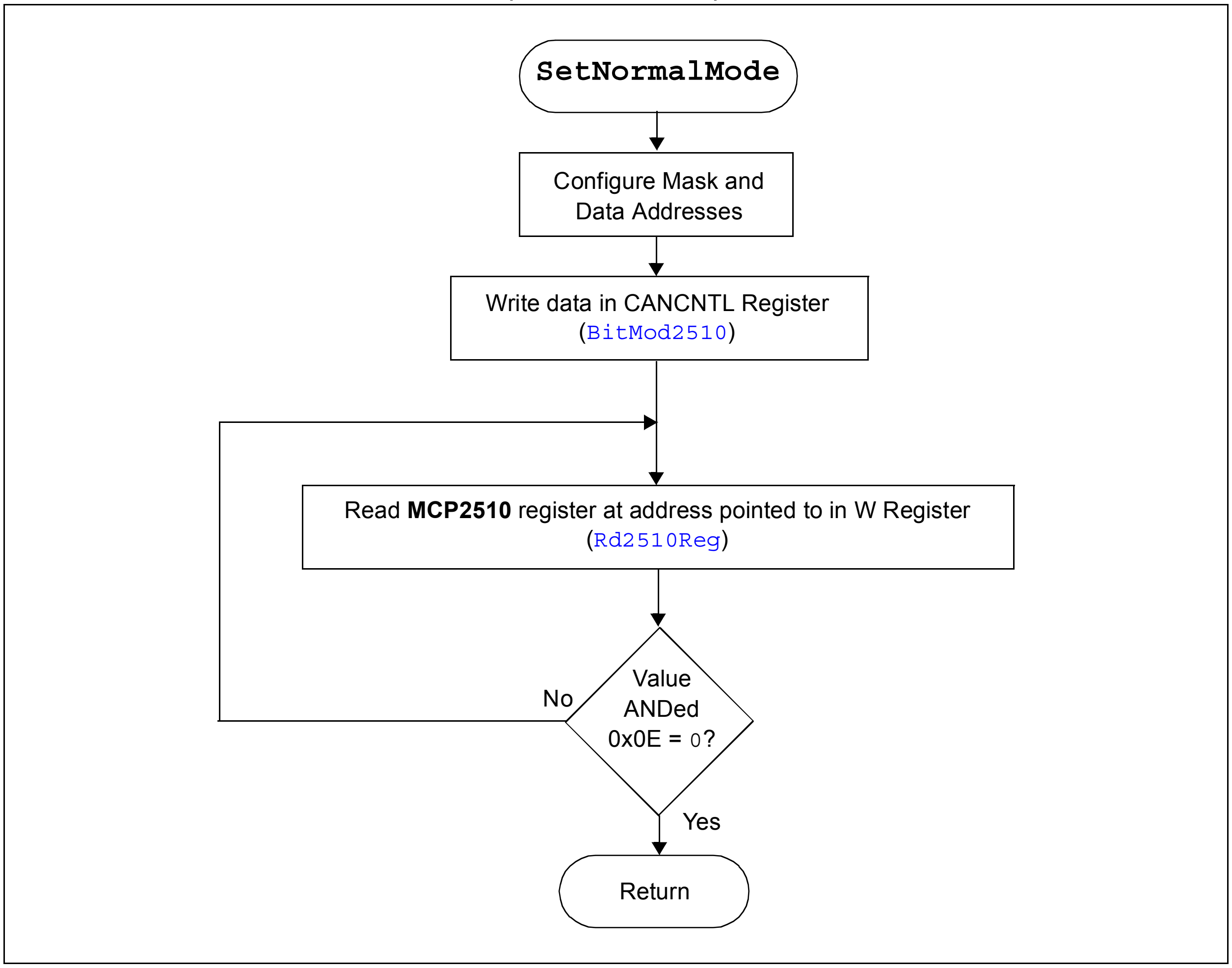


FIGURE 18: READ REGISTER ADDRESS IN W (Rd2510Reg)

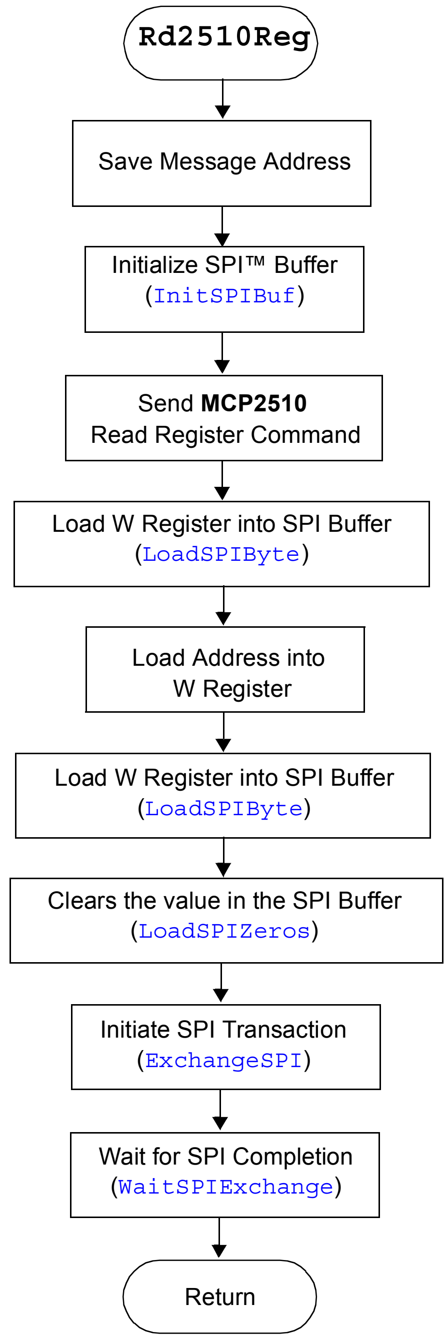


FIGURE 19: OUTPUT PWM (OutputPWM)

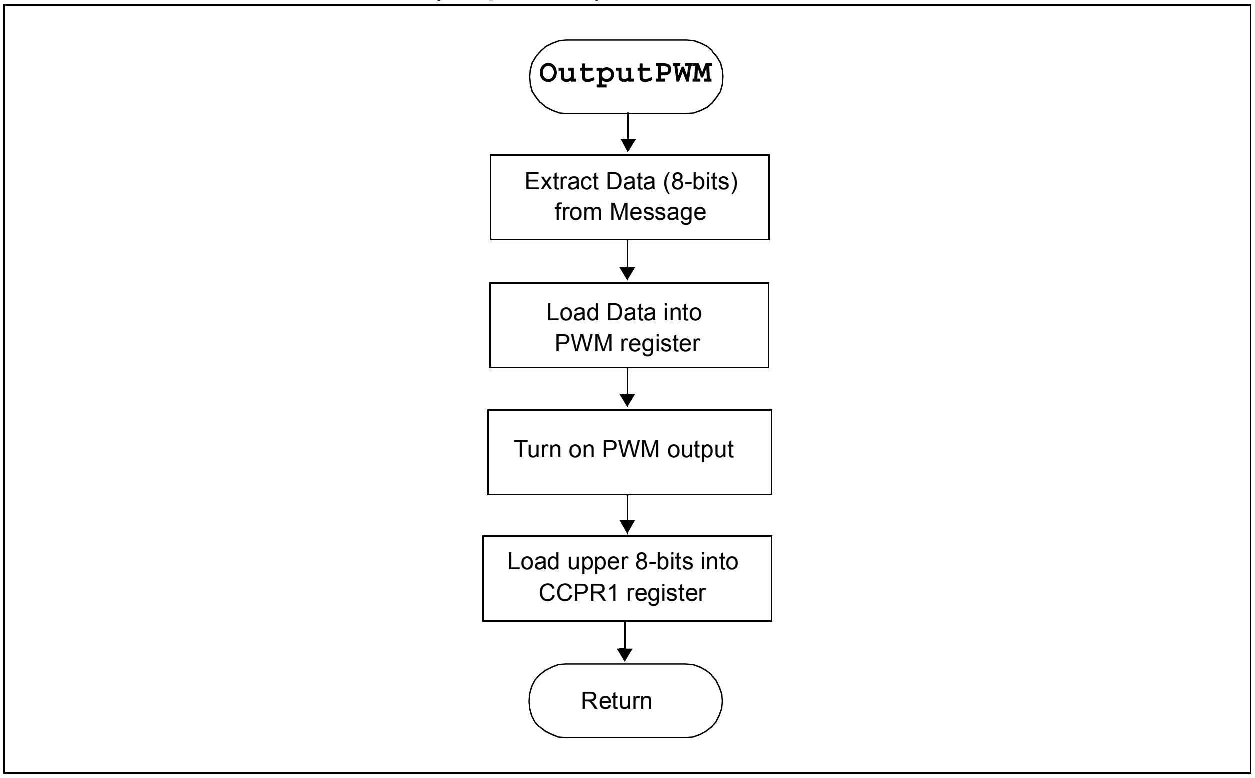


FIGURE 20: INITIALIZE SPI BUFFER (InitSPIBuf)

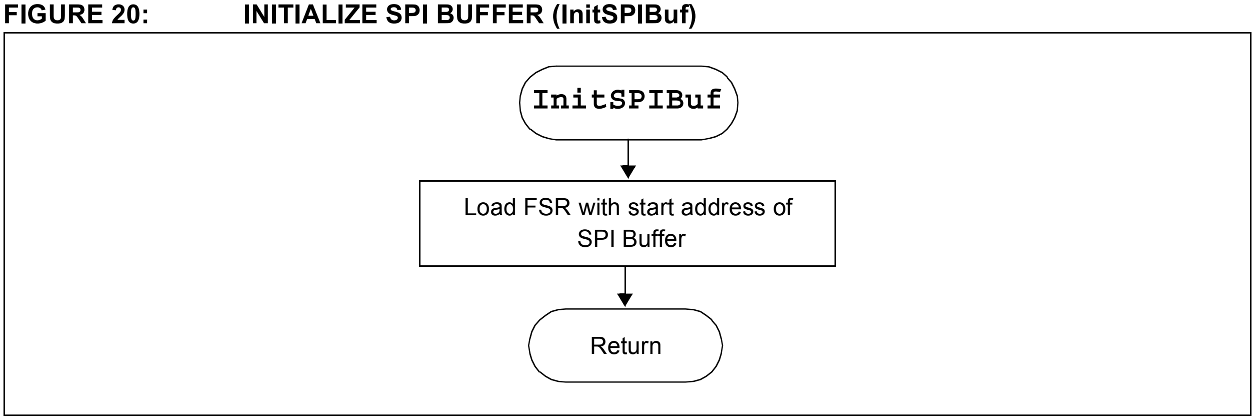


FIGURE 21: LOAD BYTE IN W TO SPI BUFFER (LoadSPIByte)

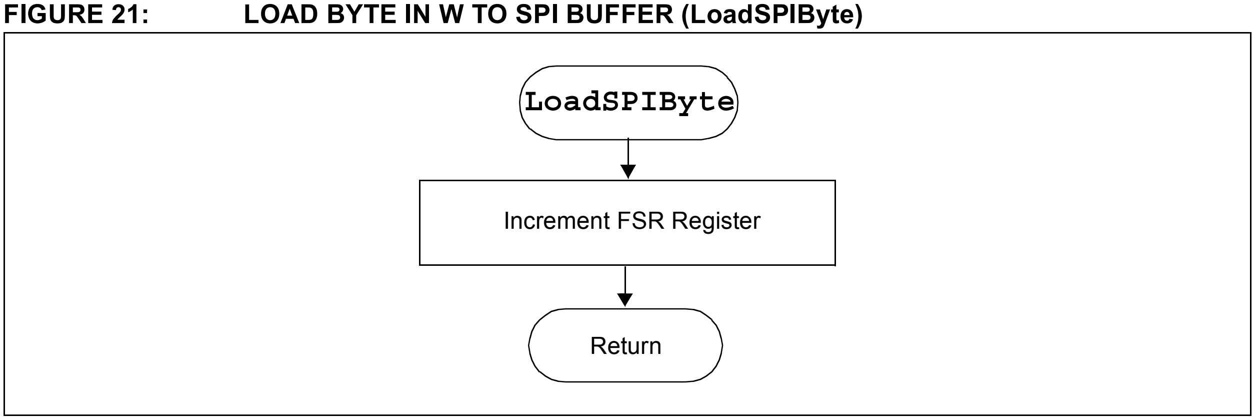


FIGURE 22: INITIATE SPI TRANSACTION (ExchangeSPI)

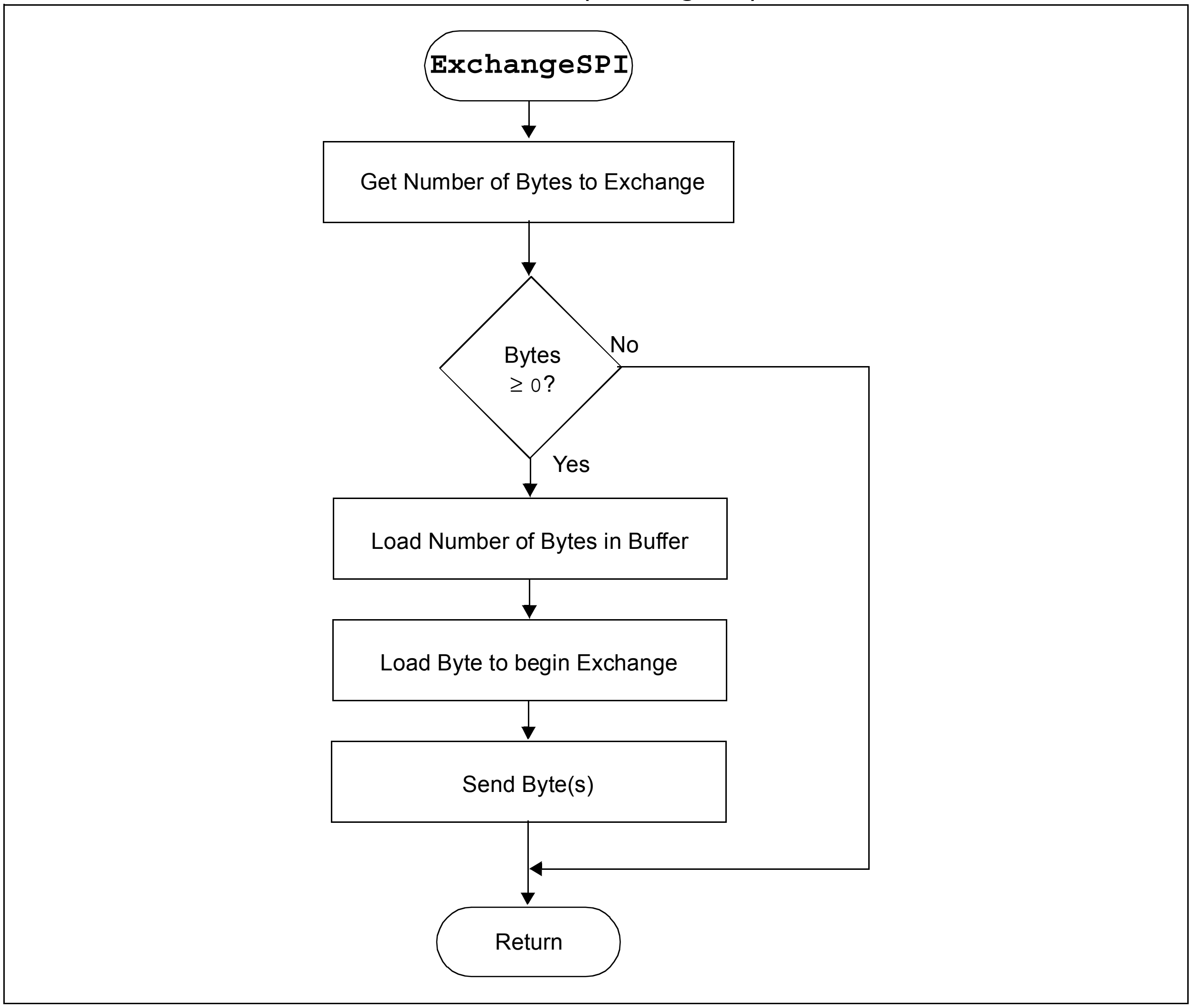


FIGURE 23: WAIT FOR SPI COMPLETION (WaitSPIExchange)

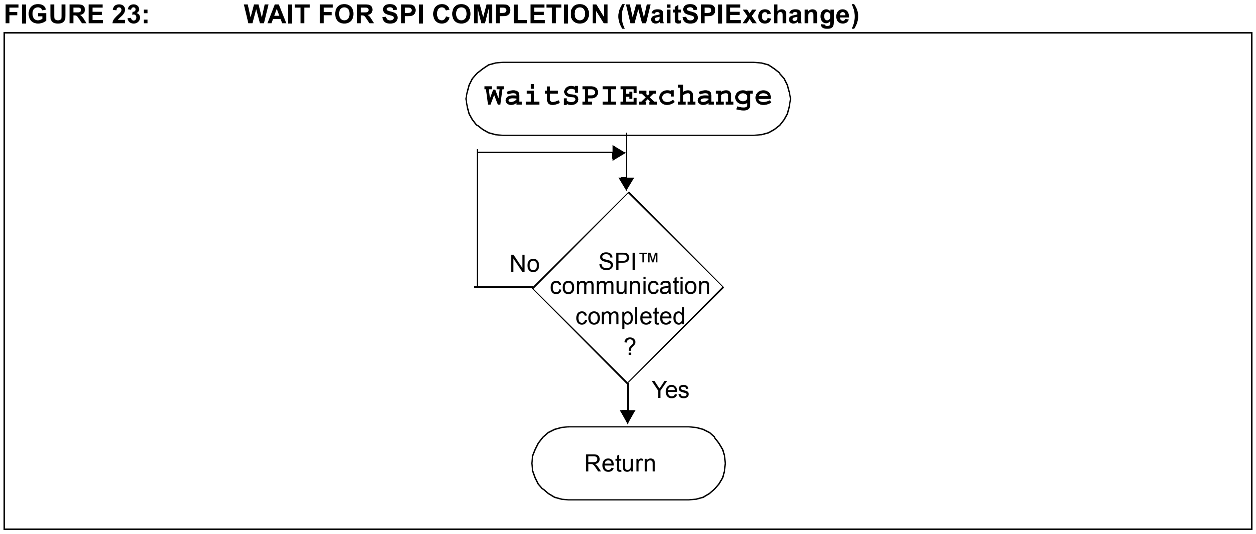
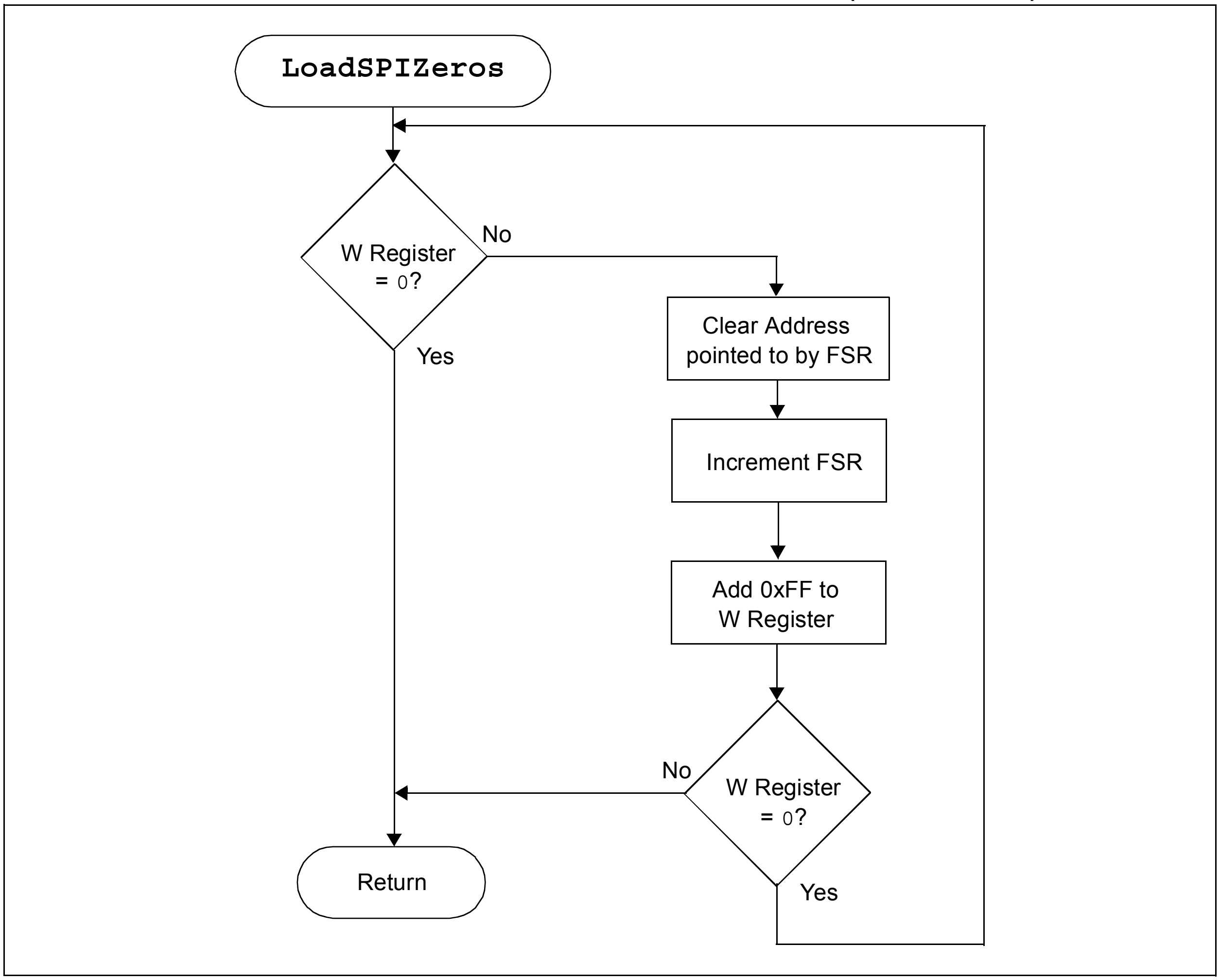


FIGURE 24: LOAD NUMBER OF ZEROS IN W TO SPI BUFFER (LoadSPIZeros)



APPENDIX A: SCHEMATICS

FIGURE 1: CAN NODE BOARD

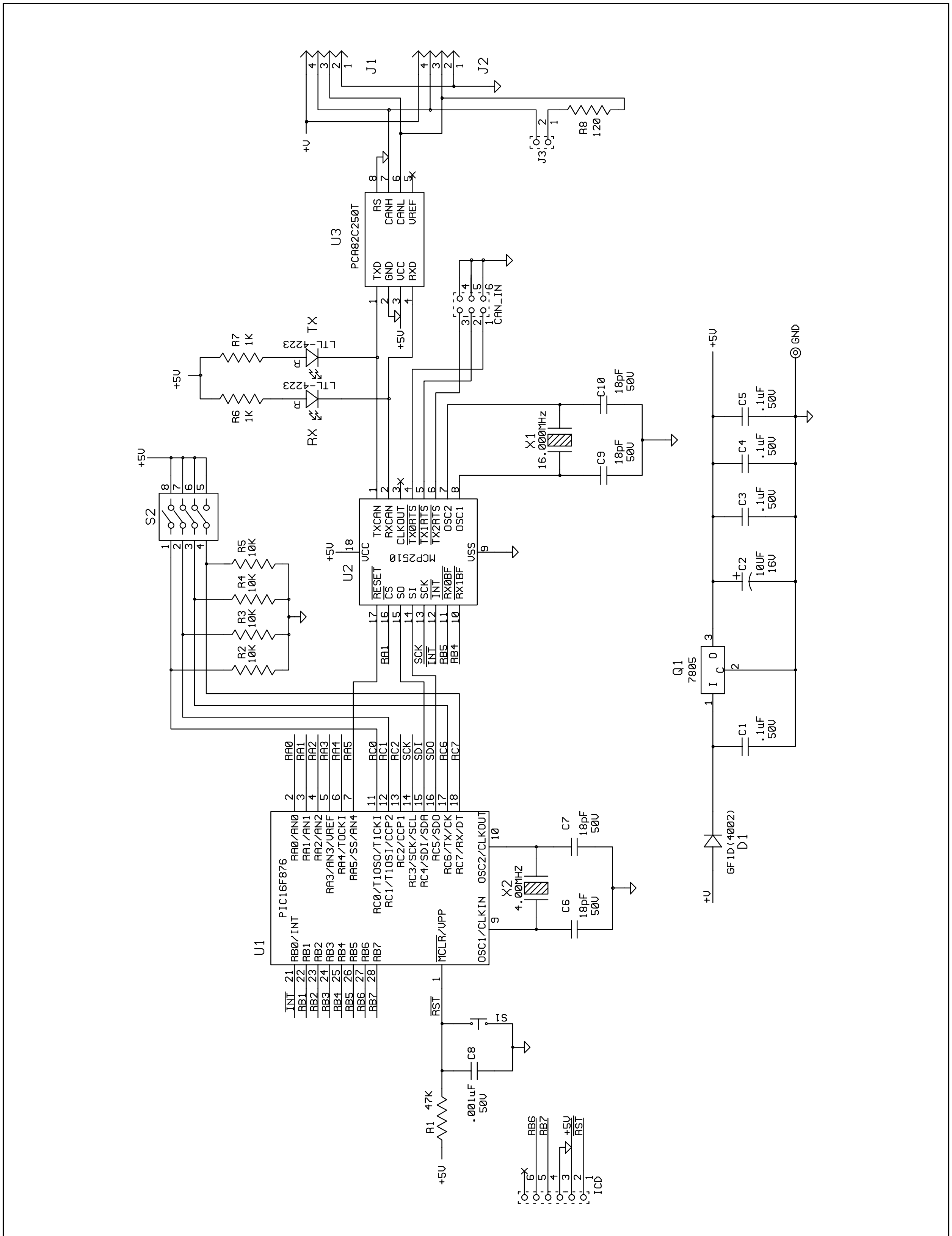


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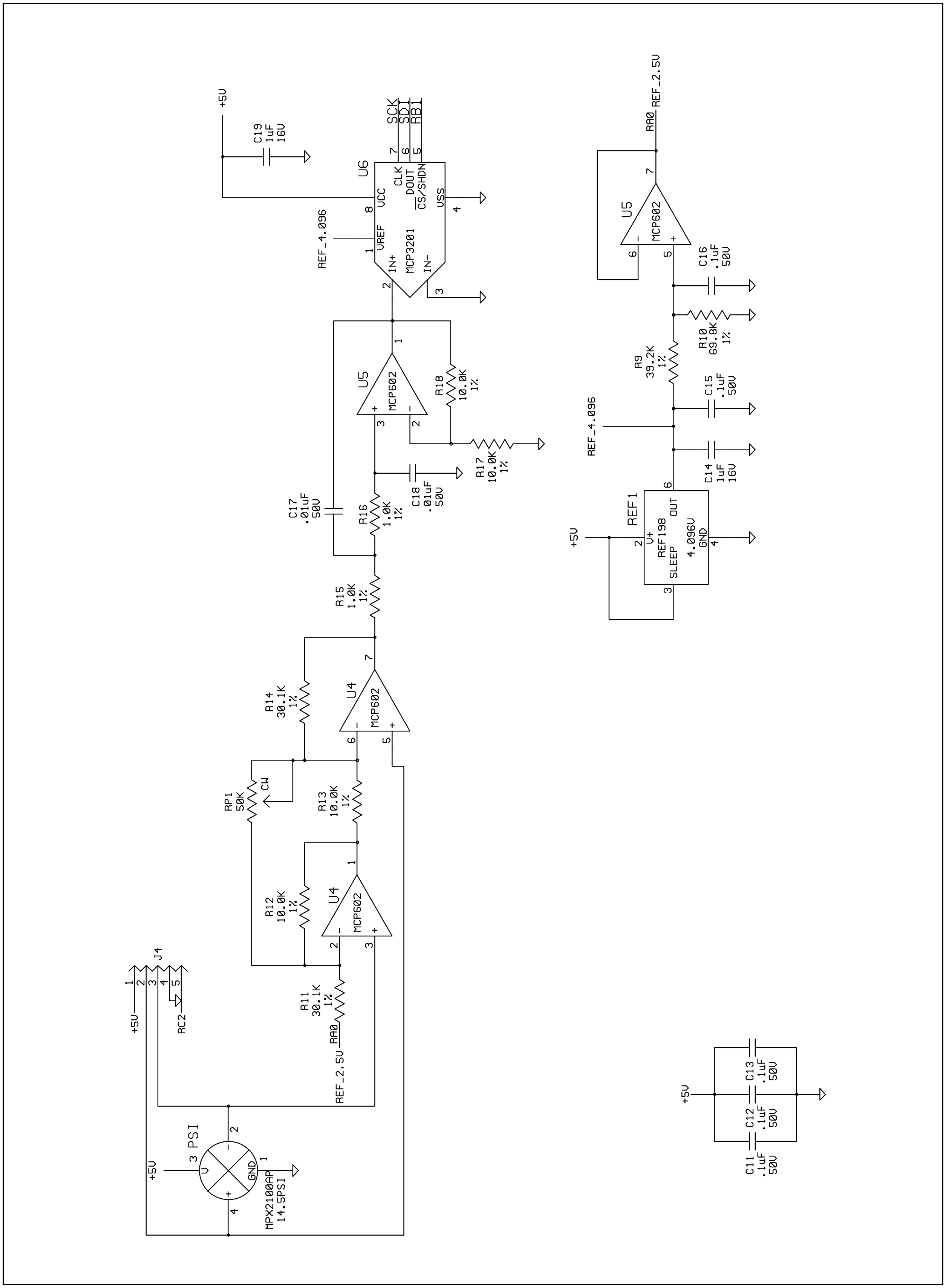
FIGURE 2: ANALOG INPUT BOARD



APPENDIX B: BILL OF MATERIALS

TABLE 1: BILL OF MATERIALS (PAGE 1 OF 2)

BILL OF MATERIALS (NODE BOARD)				
Qty	**Reference**	**Description**	**Mfg Part**	**Manufacturer**
1	PC BRD	PC BROAD	110501 A/A	
4	C9-C12	CAP, MLC,50V, NPO, 5%, 0805, 18PF	MCH215A180JK	ROHM
1	C8	CAP, MLC, 50V, X7R, 10%, 0805, 1000PF	MCH215C102KK	ROHM
5	C1, C3-C6	CAP, MLC, 50V, X7R, 10%, 0805, .1UF	C0805C104K5RAC7210	KEMET
1	C2	CAP, ELEC, 16V, 20%, VA-B, 10UF	EEV-HB1C100R	PANASONIC
1	D1	DIODE, 200V, 1A, DO-214BA	GF1D	GI
1	(J4)	DIP SHUNT, GOLD, 2 POS.	SNT-100-BK-G	SAMTEC
1	GND	TEST POINT	2305-3-00-44-0000070	MILLMAX
1	(U6)	SOCKET, 250V, DIP18, TIN BER COP	2-641611-1	AMP
1	(U4)	SOCKET, 250V, ROUND PIN, 28PIN, F	110-99-328-41-001	MILLMAX
2	J1, J2	CONN, MTA100, 4 PIN MALE	640456-4	AMP
1	J4	CONN, .025SQX.1, 250V, 3A, 2PIN, M, .230	"TSW-102-07-T-S	SAMTEC
1	J3	CONN, SINGLE ROW, RA, 15POS, F	CES-115-02-T-S-RA	SAMTEC
5	RX, TX, ICD, CAN-IN, U5	DO NOT INSTALL		
2	R6, R7	RES, .1W, 5%, 0805, 1K	MCR10J102	ROHM
4	R2-R5	RES, .1W, 5%, 0805, 10K	MCR10J103	ROHM
1	R8	RES, .1W, 5%, 0805, 120OHM	MCR10J121	ROHM
1	R1	RES, .1W, 5%, 0805, 47K	MCR10J473	ROHM
1	S1	SWITCH, PUSH, MOM, 6MM	TL1105EF250	E-SWITCH
1	S4	SWITCH, DIP8, SPST, 50V, 100MA, 4_POS	206-4ST	CTS
1	U6	IC, CAN_CONTROLLER, DIP18, CMOS, I	MCP2510-I/P	MICROCHIP TECHNOLOGY INC.
1	U4	IC, MICRO, DIP28, FLASH	PIC16F873-20/P	MICROCHIP TECHNOLOGY INC.
1	U7	IC, CAN_INTERFACE, SO8	MCP2551	MICROCHIP TECHNOLOGY INC.
1	Q5	REG, 5V, .1A, SOT-89	NJM78L05UA	NJR
1	X2	CRYSTAL, 4MHZ, CSM-7	ECS-40-20-5P	ECS
1	X1	CRYSTAL, PARALLEL, CSM-7, 16.00MHZ	ECS-160-20-5P	ECS
1	110500	OSDA LABOR	110500	OSDA

TABLE 7: BILL OF MATERIALS (PAGE 2 OF 2)

BILL OF MATERIALS (NODE BOARD)				
Qty	**Reference**	**Description**	**Mfg Part**	**Manufacturer**
1	PCB	PCB, CAN-NE ANALOG IN	110511 A/A	PCB
2	C6, C10	CAP, MLC,16V, Y5V, +80-20, 0805, 1UF	MCH213F105ZP	ROHM
2	C5, C13	CAP, MLC, 50V, X7R, 10%, 0805, .01UF	MCH215C103KK	ROHM
7	C1-C4, C8, C11, C12	CAP, MLC, 50V, X7R, 10%, 0805, .1UF	C0805C104K5RAC7210	KEMET
1	C7	CAP, ELEC, 16V, 20%, VA-B, 10UF	EEV-HB1C100R	PANASONIC
1	D1	DIODE, 200V, 1A, DO-214BA	GF1D	GI
1	TB1	TERM BLOCK, TH, 5POS, .1PITCH	1725685	PHOENIX
1	(J8)	SHUNT, DUAL, TIN, 2X2	MNT-102-BK-T	SAMTEC
1	J8	CONN, DUALROW, .025SQ, 3A, 8POS	TSW-104-07-T-D	SAMTEC
1	J3	CONN, SINGLE_ROW, RA, 15POS, M	TSW-115-08-T-S-RA	SAMTEC
2	XDUCER1, R11	DO NOT INSTALL		
2	R8, R9	RES, .1W, 1%, 0805, 1K	MCR10F1001	ROHM
5	R1, R3, R5, R6, R10	RES, .1W, 1%, 0805, 10.0K	MCR10F1002	ROHM
2	R4, R7	RES, .1W, 1%, 0805, 30.1K	MCR10F3012	ROHM
1	R13	RES, 1/10W, 1%, 0805, 39.2K	MCR10F3922	ROHM
1	R12	RES, 1/10W, 1%, 0805, 61.9K	MCR10F6192	ROHM
1	RP3	RES, POT, 1/2W, 10%, 20K	3299Y-203	BOURNS
1	RP1	RES, POT, 1/2W, 10%, 50K	3299Y-503	BOURNS
1	R2	THERMISTOR, tc-4.6, 10k, 1s .1", disc, TH	ERT-D2FHL103S	PANASONIC
1	U4	IC, MEMORY, DIP8, E2PROM, 512X8	25C040/P	MICROCHIP TECHNOLOGY INC.
1	U3	IC, ADC, DIP8, 12BIT, CMOS, +/-2LSB	MCP3201-C/P	MICROCHIP TECHNOLOGY INC.
2	U1, U2	IC, CMOS, DIPS8, DUAL_OPAMP, LOW_POWER	MCP602/P	MICROCHIP TECHNOLOGY INC.
1	REF1	REG, VOLTAGE_REFERENCE, 4_096V, SO8, F	REF198FA	ANALOG_DE
1	VR1	REG, 5V, .1A, SOT-89	NJM78L05UA	NJR
1		CAN-NET ANALOG IN	110510	OSDA

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