

**Deep Down N.E.D.
(Nautical Exploration Device)**

**Nova Scotia Community College
Explorer Class**

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Life at the Poles

The International Polar Year (2007-2008) is a program which is interested in the research based on the Arctic and Antarctic regions. This value of this research is growing, especially given the concerns of the influence of global warming on these regions, and their impact on the planet as a whole. While these regions are sparsely populated by humans, their impact on human society has been and continues to be important.

The arctic is generally considered to be the area north of the Arctic Circle, which is at 66°33'N latitude. It includes territory in several countries, including Canada, Russia, Greenland (Denmark), the United States (Alaska), and certain northern European countries. The ocean in this area is mostly covered by ice year round. What land there is in this area is usually frozen, with mostly grass like vegetation in addition to lichens and mosses. Despite the amount of snow, the annual precipitation is less than 50 cm on average.

The wildlife in the region is made up of both herbivores and their predators. Caribou and musk ox frequent the tundra regions of the arctic, as well as the arctic hare. These help to maintain the population of wolves and arctic fox that are found there. The polar bear is also found in the arctic, but does not commonly prey on these animals. They prefer to feed on the marine life from the ice floes. This marine life included seals, as well as many species of fish and whales.

The indigenous cultures of the Arctic Circle are spread out over the countries mentioned above, but are most found in Canada, Greenland, and Russia, as these countries contain the bulk of the land in the region. The term "Eskimo" is generally used to refer to all indigenous peoples of the arctic region, but is in fact an Algonquian term which translates to "eater of raw meat." Most peoples of this region would rather be referred to by terms of their regional cultures. Inuit, Yup'ik, Inupiat, and Inuvialuit are all tribes that exist in the arctic regions. The language between regions is generally distinct, in that the dialect only differs slightly among tribes of the larger geographical regions, like Canada and Russia. These peoples have learned to adapt to the harsh winter environment by hunting the animals and the marine life near the coast. The costal areas of the arctic are more adaptable for human survival, since the climate at the coast is

influenced by the ocean and experiences warmer temperatures and heavier snowfall than the interior.

Historically, people of European descent have always explored the arctic region, both for scientific purposes and to discover new resources. In fact, the land north of the Arctic Circle is rich in oil, gas, and minerals. Much of these resources have yet to be recovered, due in part to their remote location and to the preservation of certain wildlife areas where these resources exist.

Antarctica is the southern most continent on the Earth, and is also the fifth largest, covering over 14 million square kilometers. The vast majority of the continent is covered by a sheet of ice which is an average of 1.6 km thick. It is by far the coldest place on the planet, with temperatures reaching -90°C in the winter months. This is due in part to its elevation: much of the ice surface is 3 kilometers above sea level. Also, the ocean plays less of a part in the influence on the climate in Antarctica. While the temperatures in the arctic can be influenced by water underneath the surface of the ice, a large part of the underside of the Antarctic ice sheet is rock and is less prone to ocean influence. In fact, volcanic activity is a large part of the geographical history of the Antarctic. An active volcano still exists on Ross Island, and some undersea volcanic activity has been detected nearby. A volcano erupted on Deception Island as recently as 1970.

The plant life in Antarctica is limited to mosses and lichens, due in part to the low temperatures, lack of moisture, poor quality of available soil, and lack of sunlight. Life on land is mostly small invertebrates. Much of what people would consider to be animal life exists in the ocean surrounding the continent. This includes fish, whales and seals for the most part. Certain species of birds exist on the coast and will breed on land, such as the Snow Petrel, as well as several species of penguins.

The human population of Antarctica is non-indigenous. It is made up of research stations from varying countries. While the continent is remote, the lack of indigenous peoples in Antarctica can be attributed to the climate. For this reason, no government exists and no country owns it. Several countries have made territorial claims to portions of Antarctica, but these claims are generally only recognized by the countries that make them.

Electrical System Overview

The electrical system for Deep Down N.E.D. is supplied by two 12V, 7Ah batteries which are installed onboard the vehicle. This voltage is required to power each of the five fractional horsepower motors. The onboard electronics are supplied by the same batteries and fed through a 5V regulator. The entire system is fused through a 25A fuse.

Each of the four lateral motors is supplied through a chopper circuit. This circuit is essentially a transistor which is switched on and off by means of Pulse Width Modulation (PWM). The PWM is provided by means of a PIC microcontroller. By varying the duty cycle of the PWM, the level of DC voltage supplied to each motor can be adjusted. This provides the operator with proportional control and a high degree of accuracy when moving the vehicle to perform tasks. The motors are arranged on the vehicle so that none of the lateral motors would have to be reversed, which simplifies the design.

The vertical thrust motor is the only motor which has the requirement of being able to run in reverse. To accomplish this task, a pair of relays are used to create an H-bridge circuit. By using button control on the joystick, the voltage can be applied to the vertical thrust motor in either polarity, thus providing up/down maneuverability via the same motor.

PIC Microcontroller Details

PIC16F88

The PICC being used for team Blues ROV is Microchips PIC16F88. Three of these devices are used in the ROV for various reasons. The functions of each of these chips are:

1. User interface- Control input to the ROV
2. Motor Control- One device is dedicate to the control of the vector drives
3. Manipulator control and Telemetry Collection

Some of the reasons that this IC was selected are:

Built in Oscillator:

The 16F88 has an internal RC oscillator built into it, which means that no external crystal or oscillating circuit is required. Not only does the lack of an external oscillator simplify the total circuit, it also keeps the price of the board much lower then it would be with an external crystal oscillator.

Integrated Universal Asynchronous Receive and Transmit (UART) Device:

For the radio transmission of the data a serial stream is required, and the 16F88 has a built in serial device.

Integrated Analog to Digital module (A/D):

The on board module multiplexes to 7 different pins, which means that no external circuitry is necessary for analogue interface. This A/D converter has a 10 bit resolution which means that it is capable of discerning 1024 different steps within the voltage range. Because I have used a 5 volt range each step in the conversion is 4.88mV wide. The significance of this will be discussed later.

Communications

Communication between the embedded controllers is accomplished via a single length of RJ45 cable. The 1 of the 4 sets of twisted pairs sends data down to the ROV, while 1

other is used to transmit information from the ROV back to the surface. All the information is transmitted at in a serial data stream at 2400 baud.

Joystick Interface

In order to create the proportional control system for the ROV it was necessary to read the position of the joystick into the PIC. Explanations of how the analog to digital module are explained further on in this paper.

The joystick being used is a simplified computer joystick that uses two potentiometers as voltage dividers. The centre position of the joystick when calibrated gives a x and y voltage reading of ~2.5 Volts.

However, when converted by the ADC module of the PIC this voltage is read as a 10 bit number. This means that for a 0-5 volt reading a corresponding number between 0 and 1024 is generated. Based on the integer value of this number the position of the joystick can be determined as x /y coordinate. The centre position of the joystick is read by the PIC as ~512.

The program that was developed for the ROV looks at the two voltage readings generated by the position of the joystick, and based on those readings decides which direction the user wishes to go, and at what rate to go at.

In addition to the lateral direction of travel the joystick controls the vertical motor in the ROV. When either one of the buttons is pressed on the joystick the local PIC sends a command serially to the motor control PIC to either engage the up bit or the down bit. If for some reason both buttons are depressed at the same time neither bit will be set.

This PIC also monitors the positions of the switches that are used to control the manipulation devices on the ROV. Like the up/down bits when any button is pressed the PIC serially transmits a command to the ROV, this time to the manipulator control PIC, to activate the appropriate control bit.

Analogue to Digital Function

When the analog function that was designed for this project is called it must be passed an integer value which corresponds to the analog channel that is to be read.

Using a switch statement the function changes the channel bits to the correct pattern to read the channel requested. It then begins the conversion and waits for the GO/DONE bit to be cleared by hardware.

The function then collects the data in ADRESH and shifts the bits over to their appropriate places then sums the result with the remainder of the result in the ADRESL register. The total ten bit value is then 'cast' into the integer data type, and then returned by the function to the main body of the program.

Analogue to Digital Registers

As mentioned earlier the 16F88 has an analogue to digital module. This module has several registers associated with it, they are:

- A. ANSEL – Analog channel selection register
- B. TRISA and TRISB - Input control ports (the Analogue channels are split between PORTA and PORTB)
- C. ADCON0 – analogue control register 0
- D. ADCON1 – analogue control register 1
- E. ADRESH – Analogue to digital result register high
- F. ADRESL – Analogue to digital result low

When programming the IC for an analog to digital conversion the first four of these registers need to be set for successful operation of the A/D module.

*ANSEL Analog Select Register***REGISTER 12-1: ANSEL:ANALOG SELECT REGISTER (ADDRESS 9Bh) PIC16F88 DEVICES ONLY**

U-0	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
—	ANS6	ANS5	ANS4	ANS3	ANS2	ANS1	ANS0
bit 7							bit 0

The ANSEL register determines which of the 7 analogue channels available will be used, and in the case of this project there are 5 channels required. For the sake of simplicity I have enabled the entire analogue port by setting all 8 bits in this register to 1.

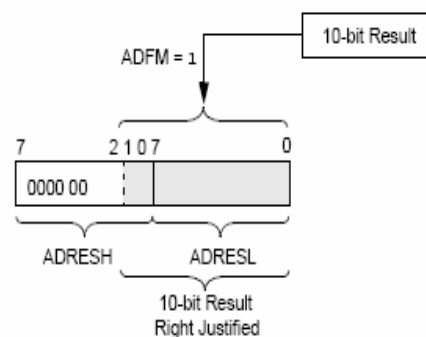
The next registers that need to be configured were the TRIS registers. These registers control whether the pins of there corresponding ports will be inputs, or outputs. Both of these registers were set to all 1s, so they are inputs only (Serial transmission requires RB2 and 5 to be set as inputs as well this will be discussed later).

*ADCON1 Register***REGISTER 12-3: ADCON1: A/D CONTROL REGISTER 1 (ADDRESS 9Fh) PIC16F88 DEVICES ONLY**

R/W-0	R/W-0	R/W-0	R/W-0	U-0	U-0	U-0	U-0
ADFM	ADCS2	VCFG1	VCFG0	—	—	—	—
bit 7							bit 0

settings that must be configured to ensure proper operation of the module.

Bit 7 of this register determines the format of the A/D result, which will be a 10 bit number. Because the 16F88 is an 8 bit device its registers are only contain 8 positions. Because the result of the A/D conversion will be 10 bits it must be stored in two registers (ADRESH and ADRESL). By setting bit 7 of this register I have told the PIC to right justify the result. This means that the two highest bits will be stored in the fist two bit positions in the ADRESH register (see the Figure below).



To obtain the total result it is necessary to bit shift the ADRESH bits over to their appropriate values. This is accomplished by multiplying by 256 and then adding the result to the ADRESL value.

Bit 6 of this register tells the A/D module whether or not to divide the clock by two or not. If the system clock is being used as in this project this bit must be set to 1 for the A/D module to work.

The final two bits in this register that must be configured are bits 5 and 4. These two bits determine what reference voltage source is to be used by the A/D module. The expected voltages from the transducers are well within the rail voltages of the PIC, so I used the VDD (5V) and VSS (GND) as the reference by clearing these two bits (see table below).

VCFG<1:0>: A/D Voltage Reference Configuration bits

Logic State	VREF+	VREF-
00	AVDD	AVSS
01	AVDD	VREF-
10	VREF+	AVSS
11	VREF+	VREF-

The remaining bits in this register are unimplemented and were left as 0s to avoid future confusion.

ADCON0 Register

REGISTER 12-2: **ADCON0: A/D CONTROL REGISTER (ADDRESS 1Fh) PIC16F88 DEVICES ONLY**

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/DONE	—	ADON
bit 7							bit 0

This register is the actual control register for the A/D module. The bits in this register determine which clock source to use, channel to read, when to begin a conversion, when a conversion is done, and whether or not the A/D module is powered up or not.

Bit 7 and 6 tell the module which clock to use, since I have set the ADCS2 to 1 in the ADCON1 register, and am using the internal oscillator these bits must be set to 1's.

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bit 7-6   ADCS<1:0>: A/D Conversion Clock Select bits
          If ADCS2 = 0:
          00 = Fosc/2
          01 = Fosc/8
          10 = Fosc/32
          11 = FRC (clock derived from the internal A/D module RC oscillator)
          If ADCS2 = 1:
          00 = Fosc/4
          01 = Fosc/16
          10 = Fosc/64
          11 = FRC (clock derived from the internal A/D module RC oscillator)

```

Bits 5 through to 3 in this register are the channel selection bits. They must be modified each time in order to read the appropriate channel.

Bit 2 serves two purposes, when set to one by software an A/D conversion begins. Once the conversion is done this bit is cleared by hardware telling the program that the result is in the ADRESH/ADRESL registers and ready to be read.

Bit 1 is unimplemented so is left as zero, but bit 0 tells the PIC to power the A/D module or not. Bit 0 must be set to 1 for the module to work. In the interest of power conservation this bit is set to zero while data is not being collected by the PIC.

Serial Transmission Registers

For the serial capabilities of the PICC to be utilized it is necessary to configure three registers before sending serial data. These registers are:

- A. TXSTA - Transmission configuration registers
- B. SPRG - Serial Baud Rate Generator register
- C. TXREG - This register is where the byte is moved to be transmitted

TXSTA

REGISTER 11-1: TXSTA: TRANSMIT STATUS AND CONTROL REGISTER (ADDRESS 98h)

R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0	R-1	R/W-0
CSRC	TX9	TXEN	SYNC	—	BRGH	TRMT	TX9D
bit 7							bit 0

This register is used to configure the settings for serial transmission. The bits in this register determine the clock source, number of bits to be transmitted, if transmission module is enabled, selection of baud ranges, and when a transmission is taking place.

Bit 7 of this register tells the module what clock source will be used. However because the port is being configured for asynchronous transmission this bit is not implemented.

Bit 6 of the register enables 9 bit transmission. The 9th bit can be used as a parity bit but for this application it is not required. This bit is set to zero for the purposes of this project.

Bit 5 enables the transmission module of the UART module.

Bit 4 determines whether the transmission mode is to be asynchronous or synchronous. Since communication of data in this project is only in one direction this bit has been set to a 0 to enable asynchronous transmission.

Bit 3 is unimplemented so has been set to a 0.

Bit 2 determines the baud rate range. If this bit is set to 1 the SPRG register will be configured for higher speed ranges, however since the data is being transmitted using a basic FM transmitter receiver arrangement the maximum reliable baud rate is 4800 bps. Therefore, this bit is set to 0 in order to access the lower range of baud rates.

Bit 1 of this register is controlled by hardware. When a transmission is taking place hardware sets this bit to a 1. Once the transmission is complete the hardware clears this bit.

Bit 0 of this register is used for 9 bit transmission. A parity bit can be placed in this position in order to achieve a basic error correction method. However, since only 8 bit transmission has been implemented for this project this bit has been left as a 0

SPRG

This register generates the baud rate for the serial transmission. It is possible to mathematically determine the value that is required for this register to generate an appropriate baud rate, but a table is provided in the 16F88's manual (see below).

TABLE 11-5: INTRC BAUD RATES FOR ASYNCHRONOUS MODE (BRGH = 0)

BAUD RATE (K)	Fosc = 8 MHz			Fosc = 4 MHz			Fosc = 2 MHz			Fosc = 1 MHz		
	KBAUD	% ERROR	SPBRG value (decimal)	KBAUD	% ERROR	SPBRG value (decimal)	KBAUD	% ERROR	SPBRG value (decimal)	KBAUD	% ERROR	SPBRG value (decimal)
0.3	NA	—	—	0.300	0	207	0.300	0	103	0.300	0	51
1.2	1.202	+0.16	103	1.202	+0.16	51	1.202	+0.16	25	1.202	+0.16	12
2.4	2.404	+0.16	51	2.404	+0.16	25	2.404	+0.16	12	2.232	-6.99	6
9.6	9.615	+0.16	12	8.929	-6.99	6	10.417	+8.51	2	NA	—	—
19.2	17.857	-6.99	6	20.833	+8.51	2	NA	—	—	NA	—	—
28.8	31.250	+8.51	3	31.250	+8.51	1	31.250	+8.51	0	NA	—	—
38.4	41.667	+8.51	2	NA	—	—	NA	—	—	NA	—	—
57.6	62.500	+8.51	1	62.500	8.51	0	NA	—	—	NA	—	—

TXREG Register

Once all of the necessary registers have been configured moving a byte of data into this register will set the TRMT flag to a zero, and begin a serial transmission. Once the transmission is completed the TRMT flag will be set to one signifying the completion of transmission.

Serial Reception Registers

For the PIC to receive data via the serial reception pin is necessary to configure one more register in addition to the registers that were required for serial transmission. The three registers that are associated with serial reception are:

- A. RCSTA – Receive status register
- B. RCREG – Storage Register for incoming bytes
- C. PIR1 – Peripheral Interrupt Request register

RCSTA Register

REGISTER 11-2: RCSTA: RECEIVE STATUS AND CONTROL REGISTER (ADDRESS 18h)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R-0	R-0	R-x
SPEN	RX9	SREN	CREN	ADDEN	FERR	OERR	RX9D
bit 7				bit 0			

This register configures the serial reception parameters of the 16F88. This register contains the enable it, number of bits to be received, control bits, and error bits associated with serial reception.

Bit 7 of this register enables the serial reception pin of the PIC so it must be set to 1 for serial reception to occur.

Bit 6 enables nine bit reception and has been left as a 0 for this project since only 8 bit transmission has been enabled.

Bit 5 is for single bit reception, and if set will only receive 1 bit of data before clearing itself. Since 8 bits transmission is implemented in this project this bit has been set to 0.

Bit 4 will be set to 1 for this project when sampling data. This bit enables continuous data reception, and when set to zero clears any error flags that were set in the reception of data.

Bit 3 enables address detection, so that the PIC can be set on a common data bus and will only respond to data sent specifically to its address. This feature is not implemented in this project so this bit has been set to zero.

Bits 2 and 1 are error flags which are set by hardware when either a buffer overrun, or framing error occur. When CREN is set to 0 these flags are cleared.

Bit 0 is where the 9th bit of data would be stored if 9 bit transmission was being implemented. Since only 8 bit transmission has been enabled this bit is ignored entirely by the serial reception function.

RCREG Register

This register is where incoming bytes of data are stored. Once this register is read it is automatically cleared by hardware, so if multiple bytes are to be received it is necessary to move each byte out of this register into a storage place such as a character array.

This register is a 2 byte first in first out (FIFO) register . Meaning that two bytes of data can be moved into it before an overflow error is generated. When the reading of the register clears the first byte the second byte moves up into the first's position.

PIR1 Register

This register contains several of the interrupt flags generated by the peripheral hardware of the PIC. The RCIF bit of this register is set if a byte of information is stored in the RCREG and is cleared when the register is read.

