UNIVERSITI TUN HUSSEIN ONN MALAYSIA

PEPERIKSAAN AKHIR
SEMESTER II
SESI 2009/2010

NAMA KURSUS	: MIKROPENGAWAL
KOD KURSUS	: DEK 3133
PROGRAM	: 3 DET,DEE
TARIKH PEPERIKSAAN	: APRIL/MEI 2010
JANGKAMASA	: 3 JAM
ARAHAN	: JAWAB **SEMUA** SOALAN DI BAHAGIAN A DAN JAWAB **DUA (2)** SOALAN DI BAHAGIAN B

KERTAS SOALAN INI MENGANDUNGI **DUA PULUH (20)** MUKA SURAT

SOALAN DALAM BAHASA MALAYSIA

BAHAGIAN A

S1 (a) Nyatakan **definisi** bagi Mikropengawal dan berikan empat **(4) perkara** yang perlu diberi perhatian untuk memilih Mikropengawal yang sesuai.
(5 markah)

(b) Rajah **S1(b)** adalah struktur ingatan sebuah Mikropengawal. Terdapat 8 talian data dan 13 talian alamat yang dihubungkan antara CPU dan ingatan. Dengan mengambil kira 1Kb adalah bersamaan 1024bait.

(i) Kirakan saiz ruangan ingatan tersebut.

(ii) Apakah jenis talian bas yang akan menentukan saiz ingatan sebuah Mikropengwal.
(4 markah)

(c) Lakarkan sebuah litar Mikropengawal PIC16F877A yang mempunyai masukan papan kekunci 4x3.
(5 markah)

(d) Sekiranya anda menggunakan pemasa *TMR0* bersama pengayun berkelajuan 10MHz dan *Prescaler* 1:64, **kirakan masa** yang diperlukan untuk *TMR0* menghasilkan satu (1) limpahan dengan kiraan *TMR0* bermula dari 200.
(5 markah)

(e) PIC16F877A menggunakan bekalan jam berfrekuensi 22MHz.

(i) **Tunjukkan pengiraan** untuk mengetahui tempoh masa yang diambil oleh Mikropengawal menyelesaikan satu (1) suruhan.

(ii) **Berapakah** suruhan yang mampu dilaksanakan oleh Mikropengawal dalam tempoh 10.0μs dan 200.0 μs?
(6 markah)

S2 (a) PIC16F877A mempunyai resolusi 10-Bit (0b1111111111=1023) bagi penukaran analog kepada digital. Voltan rujukan adalah 4V, tentukan nilai **Saiz Langkah** dan **Keluaran Digital** bagi *ADC* tersebut sekiranya voltan masukan analog adalah 2V. Berikan jawapan dalam nombor binari mengikut turutan *bit*.

(8 markah)

(b) Sekiranya saiz ingatan *EEPROM* sesebuah Mikropengawal adalah 256byte. **Tentukan arahan** *MikroC* yang sesuai untuk memenuhkan keseluruhan ruangan ingatan tersebut dengan nilai 0b01010101.

(6 markah)

(c) Rajah **S2(c)** menunjukkan dua Mikropengawal yang berhubung antara satu sama lain dengan menggunakan modul perkakasan *USART*. **Tentukan arahan** *MikroC* yang membolehkan Mikropengawal B **membunyikan *buzzer* BUZ1** sekiranya butang **B1** ditekan pada Mikropengawal A. Kelajuan penghantaran yang digunakan adalah 9600 *bit/s*. Bina kod aturcara bagi kedua-dua Mikropengawal.

(7 markah)

(d) Merujuk pada Rajah **S2(d),** sebuah MOTOR DC disambung kepada modul *PWM* pada frekuensi 20Khz. **Tentukan arahan** *MikroC* supaya putaran MOTOR tersebut adalah 80 peratus daripada kelajuan asalnya.

(4 markah)

BAHAGIAN B

S3 Rajah S3 menunjukkan sebuah sistem kawalan untuk mengekalkan suhu sebuah bilik pada tahap 40°C hingga 50°C. Sistem ini menggunakan penderia suhu yang mengukur suhu di antara 0°C - 100°C. Keluaran litar penderia suhu adalah voltan analog (0V-5V) yang merupakan masukan kepada litar Mikropengawal. Terdapat dua komponen keluaran LED dan speaker yang berfungsi sebagai petunjuk kepada nilai suhu semasa dan sebuah kipas yang berfungsi untuk menurunkan suhu bilik sekiranya suhu tertentu dicapai. LED, kipas dan speaker akan berfungsi berdasarkan Jadual **S3**. Voltan rujukan Mikropengawal adalah 5V.

(a) Tentukan :

(i) Saiz Langkah.
(ii) Nilai ADC apabila nilai V_{in} pada AN0 adalah 1.3V.
(i) Nilai suhu dalam *Celsius* sekiranya V_{in} = 1.3V

(5 markah)

(b) Sekiranya PIC menggunakan Voltan rujukan +5V, **tuliskan aturcara** *MikroC* yang menghasilkan proses penukaran analog kepada digital dan seterusnya dapat mengawal suhu bilik.

(20 markah)

S4 Litar dalam Rajah **S4** beroperasi dengan memaparkan turutan nyalaan *Running Light* samada turutan atas ke bawah atau bawah ke atas dengan sela masa setiap LED selama satu saat. Bagi LEDTMR0 pula, ia akan sentiasa berkelip setiap dua (2) saat. Pemasa lengahan PIC adalah daripada pemasa TMR0 dengan skala 1:64 dan nilai awalan TMR0 adalah 0. Sekiranya PIC dibekalkan pengayun (***Fosc)*** dengan frekuensi 65536Hz.

(a) Tentukan:

(i) Tempoh masa bagi limpahan TMR0 bermula dari 0 hingga 255.
(ii) Bilangan limpahan TMR0 yang diperlukan untuk mendapatkan tempoh lengahan selama satu (1) saat.

(5 markah)

(b) Dengan menggunakan pemasa TMR0 binakan **kod pengaturcaraan *MikroC*** di mana LEDTMR0 akan berkelip setiap dua (2) saat manakala setiap LED *Running Light* akan berkelip setiap satu (1) saat dengan menggunakan arahan *Delay_ms()*.

(20 markah)

S5 Litar dalam Rajah **S5** beroperasi dengan memaparkan arah putaran motor pada paparan LCD dan pada nyalaan LED apabila butang arah putaran ditekan.

(a) (i) Terangkan fungsi pemacu ULN2003A.
(ii) Tentukan bagaimanakah kelajuan sesebuah *STEPPER* MOTOR boleh dikawal?

(5 markah)

(b) Binakan **kod pengaturcaraan *MikroC*** di mana *stepper motor* akan berpusing mengikut arah butang yang ditekan dan seterusnya LED dan *LCD* akan memaparkan arah putaran yang dipilih.

(20 markah)

SOALAN DALAM BAHASA INGGERIS

PART A

Q1 (a) Give definition of Microcontroller and give four (4) important aspects required attention to choose suitable Microcontroller.

(5 marks)

(b) Figure **Q1(b)** shows the memory structure of microcontroller. There are 8 data buses and 13 address buses connected between CPU and memory. Considering 1Kb is equal to 1024bytes:

(i) Calculate the size of the memory for thus microcontroller.
(ii) Identify what type of buses will determine the memory size of the microcontroller?

(4 marks)

(c) Draw a circuit of Microcontroller PIC16F877A with keypad 4x3 as input.

(5 marks)

(d) If you use TMR0 timer with 10MHz Oscillator and Prescaler 1:64, **calculate the time required** for TMR0 to produce one (1) Overflow when TMR0 started from 200.

(5 marks)

(e) A PIC16F877A uses a clock frequency of 22MHz.

(i) **Show the calculation** to know a time period taken by Microcontroller to complete one (1) instruction

(ii) **How many Instructions** can be executed by microcontroller within 10.0μs and 200.0μs?

(6 marks)

Q2 (a) A PIC16F877A has 10-Bit resolutions (0b1111111111=1023) for analog to digital conversion (ADC). By using the voltage reference of 4V, determine the **Step Size** and **Digital Output** of ADC when the analog input is 2V. Express your answer in binary format by following the bit order.

(8 marks)

(b) If the Microcontroller's EEPROM size is 256byte, identify the suitable ***MikroC* instruction** to load all the memory space with value of 0b01010101.

(6 marks)

(c) Figure S2 (c) are two Microcontroller interconnect between each other using the USART module hardware. Give the instructions of *MikroC* that allows the Microcontroller B to produce sound on buzzer **BUZ1** when button **B1** at Microcontroller A is pressed. Speed transmission used is 9600 bits/s. Construct your code for both microcontroller.

(7 marks)

(d) By Referring to Figure **S2(d)**, a DC MOTOR is connected to the PWM module at frequency 20Khz. Determine the instructions of *MikroC* to rotate the MOTOR about 80 percent of its original speed.

(4 marks)

PART B

Q3 Figure Q3 shows a control system to maintain room temperature between 40°C to 50°C. The system is used a temperature sensor to measure the temperature between 0°C to 100°C. The output of temperature sensor is analog voltage (0V-5V) which is the input to the PIC circuit. There are two output (LED & Speaker) which work as indicator for the current temperatures level and a fan which operate to cool down the room temperature when a certain temperature is achieved. LED, speaker and fan will functioned based on Table S3. Voltage reference used by PIC is 5V.

(a) Evaluate:
(i) Step size value.
(ii) ADC result when V_{in} to AN0 is 1.3V.
(iii) Temperature Value in degree *Celsius* when V_{in} = 1.3V.

(5 marks)

(b) If the PIC uses voltage reference of +5V, **produce a C program** to show the conversion process from analog to digital and then control the room temperature.

(20 marks)

Q4 Circuit in Figure Q4 operates by showing the LED lit in running light sequence with interval one(1) second for each LEDs whether from top to down or down to top . The LEDTMR0, it's always blinking every two (2) second. Delay Timer PIC is from Hardware Timer (TMR0) with prescaler 1:64 and preload value TMR0 is set to 0. If the PIC is provided with Oscillator frequency (Fosc) 65536 Hz,

(a) Determine:

(i) The time taken for TMR0 to overflow starting from 0 to 255.
(ii) Number of TMR0 **overflows required** to get 1 second delay.

(5 marks)

(b) By using the TMR0 Timer **write a *MikroC* program** to ensure that the LEDTMR0 will blinking every two (2) second, while the running light LEDs will running with interval one (1) second by using *Delay_ms()* instruction.

(20 marks)

Q5 Circuit in Figure Q5 operates by showing the direction of stepper motor rotation into LCD display and also on LED when one of the direction buttons is pressed.

(a) (i) Explain the function of ULN2003A driver.
(ii) Evaluate how the speed of stepper motor can be controlled?.
(5 marks)

(b) Develop a **MikroC** program to rotate the stepper motor with direction of button pressed and show the direction of rotation on LED and LCD.
(20 marks)

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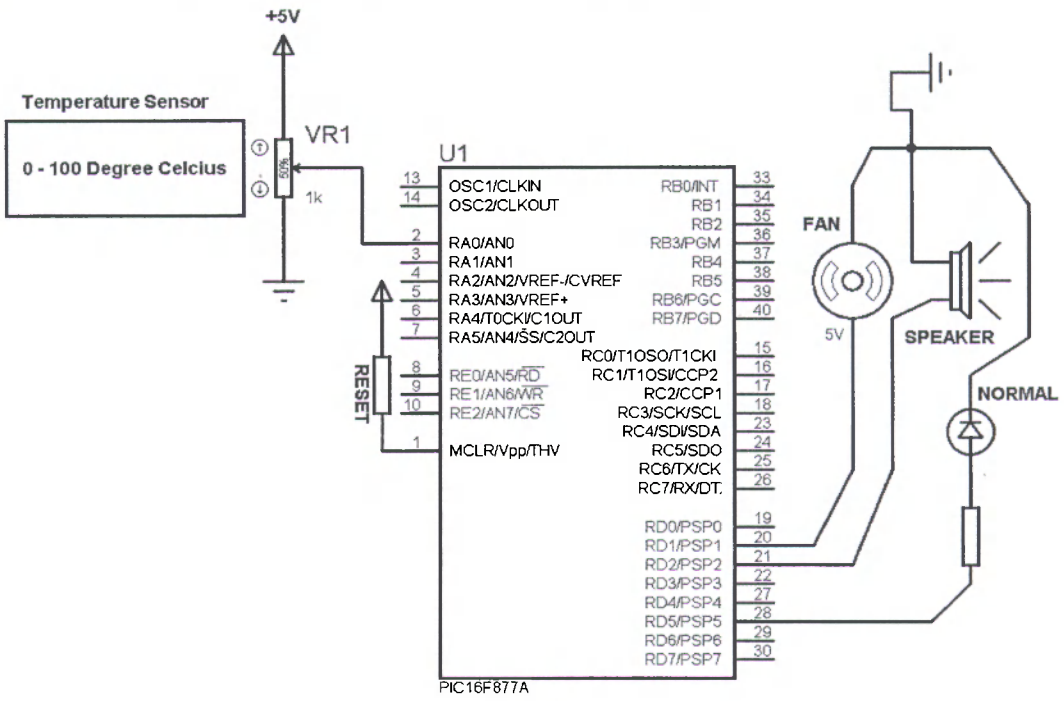

Rajah S3 / Figure Q3

Temperatures	LED and Fan Status
Above 50°C	Fan = Rotate, Speaker = ON, LED Normal = OFF
Below 45°C	Fan = Stop, Speaker = MUTE
Below 40°C	LED Normal = ON

Jadual S3 / Table Q3

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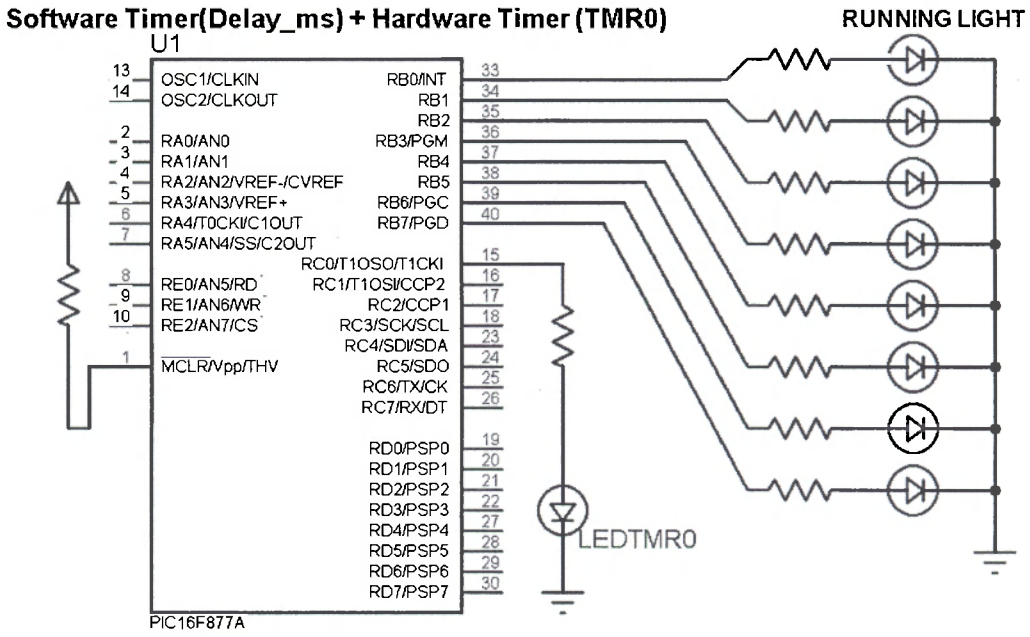

Rajah S4 / Figure Q4

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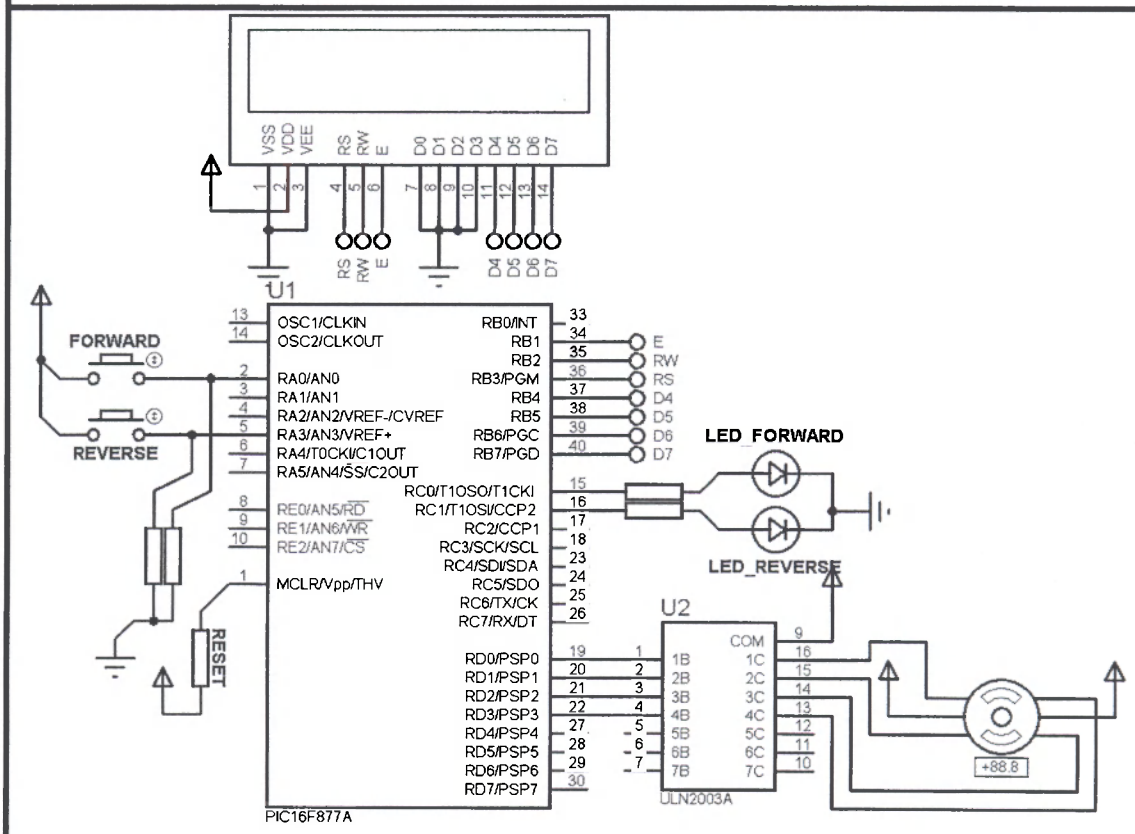

Rajah S5 / Figure Q5

Forward	Step #	1B	2B	3B	4B	Reverse
	1	1	0	0	1	
	2	1	0	0	0	
	3	1	1	0	0	
	4	0	1	0	0	
	5	0	1	1	0	
	6	0	0	1	0	
	7	0	0	1	1	
	8	0	0	0	1	

Jadual S5/ Table Q5

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RUJUKAN I

FIGURE 2-3: PIC16F876A/877A REGISTER FILE MAP

Bank 0	File Address	Bank 1	File Address	Bank 2	File Address	Bank 3	File Address
Indirect addr.(*)	00h	Indirect addr.(*)	80h	Indirect addr.(*)	100h	Indirect addr.(*)	180h
TMR0	01h	OPTION_REG	81h	TMR0	101h	OPTION_REG	181h
PCL	02h	PCL	82h	PCL	102h	PCL	182h
STATUS	03h	STATUS	83h	STATUS	103h	STATUS	183h
FSR	04h	FSR	84h	FSR	104h	FSR	184h
PORTA	05h	TRISA	85h		105h		185h
PORTB	06h	TRISB	86h	PORTB	106h	TRISB	186h
PORTC	07h	TRISC	87h		107h		187h
PORTD(1)	08h	TRISD(1)	88h		108h		188h
PORTE(1)	09h	TRISE(1)	89h		109h		189h
PCLATH	0Ah	PCLATH	8Ah	PCLATH	10Ah	PCLATH	18Ah
INTCON	0Bh	INTCON	8Bh	INTCON	10Bh	INTCON	18Bh
PIR1	0Ch	PIE1	8Ch	EEDATA	10Ch	EECON1	18Ch
PIR2	0Dh	PIE2	8Dh	EEADR	10Dh	EECON2	18Dh
TMR1L	0Eh	PCON	8Eh	EEDATH	10Eh	Reserved(2)	18Eh
TMR1H	0Fh		8Fh	EEADRH	10Fh	Reserved(2)	18Fh
T1CON	10h		90h		110h		190h
TMR2	11h	SSPCON2	91h		111h		191h
T2CON	12h	PR2	92h		112h		192h
SSPBUF	13h	SSPADD	93h		113h		193h
SSPCON	14h	SSPSTAT	94h		114h		194h
CCPR1L	15h		95h		115h		195h
CCPR1H	16h		96h		116h		196h
CCP1CON	17h		97h	General Purpose Register 16 Bytes	117h	General Purpose Register 16 Bytes	197h
RCSTA	18h	TXSTA	98h		118h		198h
TXREG	19h	SPBRG	99h		119h		199h
RCREG	1Ah		9Ah		11Ah		19Ah
CCPR2L	1Bh		9Bh		11Bh		19Bh
CCPR2H	1Ch	CMCON	9Ch		11Ch		19Ch
CCP2CON	1Dh	CVRCON	9Dh		11Dh		19Dh
ADRESH	1Eh	ADRESL	9Eh		11Eh		19Eh
ADCON0	1Fh	ADCON1	9Fh		11Fh		19Fh
General Purpose Register 96 Bytes	20h	General Purpose Register 80 Bytes	A0h	General Purpose Register 80 Bytes	120h	General Purpose Register 80 Bytes	1A0h
	7Fh	accesses 70h-7Fh	EFh F0h FFh	accesses 70h-7Fh	16Fh 170h 17Fh	accesses 70h - 7Fh	1EFh 1F0h 1FFh

☐ Unimplemented data memory locations, read as '0'.
* Not a physical register.

Note 1: These registers are not implemented on the PIC16F876A.
2: These registers are reserved; maintain these registers clear.

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RUJUKAN II

PIC16F87XA

TABLE 15-2: PIC16F87XA INSTRUCTION SET

Mnemonic. Operands		Description	Cycles	14-Bit Opcode MSb	LSb	Status Affected	Notes
BYTE-ORIENTED FILE REGISTER OPERATIONS							
ADDWF	f, d	Add W and f	1	00 0111 dfff ffff		C,DC,Z	1,2
ANDWF	f, d	AND W with f	1	00 0101 dfff ffff		Z	1,2
CLRF	f	Clear f	1	00 0001 lfff ffff		Z	2
CLRW	-	Clear W	1	00 0001 0xxx xxxx		Z	
COMF	f, d	Complement f	1	00 1001 dfff ffff		Z	1,2
DECF	f, d	Decrement f	1	00 0011 dfff ffff		Z	1,2
DECFSZ	f, d	Decrement f, Skip if 0	1(2)	00 1011 dfff ffff			1,2,3
INCF	f, d	Increment f	1	00 1010 dfff ffff		Z	1,2
INCFSZ	f, d	Increment f, Skip if 0	1(2)	00 1111 dfff ffff			1,2,3
IORWF	f, d	Inclusive OR W with f	1	00 0100 dfff ffff		Z	1,2
MOVF	f, d	Move f	1	00 1000 dfff ffff		Z	1,2
MOVWF	f	Move W to f	1	00 0000 lfff ffff			
NOP	-	No Operation	1	00 0000 0xx0 0000			
RLF	f, d	Rotate Left f through Carry	1	00 1101 dfff ffff		C	1,2
RRF	f, d	Rotate Right f through Carry	1	00 1100 dfff ffff		C	1,2
SUBWF	f, d	Subtract W from f	1	00 0010 dfff ffff		C,DC,Z	1,2
SWAPF	f, d	Swap nibbles in f	1	00 1110 dfff ffff			1,2
XORWF	f, d	Exclusive OR W with f	1	00 0110 dfff ffff		Z	1,2
BIT-ORIENTED FILE REGISTER OPERATIONS							
BCF	f, b	Bit Clear f	1	01 00bb bfff ffff			1,2
BSF	f, b	Bit Set f	1	01 01bb bfff ffff			1,2
BTFSC	f, b	Bit Test f, Skip if Clear	1 (2)	01 10bb bfff ffff			3
BTFSS	f, b	Bit Test f, Skip if Set	1 (2)	01 11bb bfff ffff			3
LITERAL AND CONTROL OPERATIONS							
ADDLW	k	Add Literal and W	1	11 111x kkkk kkkk		C,DC,Z	
ANDLW	k	AND Literal with W	1	11 1001 kkkk kkkk		Z	
CALL	k	Call Subroutine	2	10 0kkk kkkk kkkk			
CLRWDT	-	Clear Watchdog Timer	1	00 0000 0110 0100		TO,PD	
GOTO	k	Go to Address	2	10 1kkk kkkk kkkk			
IORLW	k	Inclusive OR Literal with W	1	11 1000 kkkk kkkk		Z	
MOVLW	k	Move Literal to W	1	11 00xx kkkk kkkk			
RETFIE	-	Return from Interrupt	2	00 0000 0000 1001			
RETLW	k	Return with Literal in W	2	11 01xx kkkk kkkk			
RETURN	-	Return from Subroutine	2	00 0000 0000 1000			
SLEEP	-	Go into Standby mode	1	00 0000 0110 0011		$\overline{TO}$,PD	
SUBLW	k	Subtract W from Literal	1	11 110x kkkk kkkk		C,DC,Z	
XORLW	k	Exclusive OR Literal with W	1	11 1010 kkkk kkkk		Z	

Note 1: When an I/O register is modified as a function of itself (e.g., `MOVF PORTB, 1`), the value used will be that value present on the pins themselves. For example, if the data latch is '1' for a pin configured as input and is driven low by an external device, the data will be written back with a '0'.

2: If this instruction is executed on the TMR0 register (and where applicable, d = 1), the prescaler will be cleared if assigned to the Timer0 module.

3: If Program Counter (PC) is modified, or a conditional test is true, the instruction requires two cycles. The second cycle is executed as a NOP.

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RUJUKAN III

Reference for MikroC functions:

Functions	Using C Function samples
Initialize LCD to PORTD	Lcd_Init(&PORTD);
Clear LCD	Lcd_Cmd(Lcd_CLEAR)
Read ADC conversion at AN0	Adc_Read(0)

Convert floating value to String	Unsigned float ABC; //variable ABC as float
	Char CBA[13]; //variable CBA with 13 character long
	ABC = 123.456;
	FloatToStr(ABC, CBA); //CBA = "123.456" (string format)

Show text in LCD screen	Lcd_Out(2,1, "Hello"); // Show text "Hello" at Line 2 column 1
Configure Analog inputs with Vref using Internal Vref +5V.	ADCON1 = 0x80;
Initialize PWM Freq.	Pwm_Init(unsigned long freq)
PWM Change Duty Cycle to 75%	DutyCycle = 75/100 * 255 = 191 Pwm_Change_Duty(191);
Enable PMW	Pwm_Start();
Receive Usart data	int a = Usart_Read();
Transmit Usart data	int a = 100; Usart_Write(a);

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RUJUKAN IV

Special Function Registers

INTCON REGISTER (ADDRESS 0Bh, 8Bh, 10Bh, 18Bh)

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-x
GIE	PEIE	TMR0IE	INTE	RBIE	TMR0IF	INTF	RBIF
bit 7							bit 0

bit 7 **GIE:** Global Interrupt Enable bit
1 = Enables all unmasked interrupts
0 = Disables all interrupts
bit 6 **PEIE**: Peripheral Interrupt Enable bit
1 = Enables all unmasked peripheral interrupts
0 = Disables all peripheral interrupts
bit 5 **TMR0IE**: TMR0 Overflow Interrupt Enable bit
1 = Enables the TMR0 interrupt
0 = Disables the TMR0 interrupt
bit 4 **INTE**: RB0/INT External Interrupt Enable bit
1 = Enables the RB0/INT external interrupt
0 = Disables the RB0/INT external interrupt
bit 3 **RBIE**: RB Port Change Interrupt Enable bit
1 = Enables the RB port change interrupt
0 = Disables the RB port change interrupt
bit 2 **TMR0IF**: TMR0 Overflow Interrupt Flag bit
1 = TMR0 register has overflowed (must be cleared in software)
0 = TMR0 register did not overflow
bit 1 **INTF**: RB0/INT External Interrupt Flag bit
1 = The RB0/INT external interrupt occurred (must be cleared in software)
0 = The RB0/INT external interrupt did not occur
bit 0 **RBIF**: RB Port Change Interrupt Flag bit
1 = At least one of the RB7:RB4 pins changed state; a mismatch condition will continue to set
the bit. Reading PORTB will end the mismatch condition and allow the bit to be cleared
(must be cleared in software).
0 = None of the RB7:RB4 pins have changed state

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RUJUKAN V

OPTION_REG REGISTER (ADDRESS 81h, 181h)

R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1	R/W-1
$\overline{\text{RBPU}}$	INTEDG	T0CS	T0SE	PSA	PS2	PS1	PS0
bit 7							bit 0

RBPU: PORTB Pull-up Enable bit
1 = PORTB pull-ups are disabled
0 = PORTB pull-ups are enabled by individual port latch values
bit 6 **INTEDG**: Interrupt Edge Select bit
1 = Interrupt on rising edge of RB0/INT pin
0 = Interrupt on falling edge of RB0/INT pin
bit 5 **T0CS**: TMR0 Clock Source Select bit
1 = Transition on RA4/T0CKI pin
0 = Internal instruction cycle clock (CLKO)
bit 4 **T0SE**: TMR0 Source Edge Select bit
1 = Increment on high-to-low transition on RA4/T0CKI pin
0 = Increment on low-to-high transition on RA4/T0CKI pin
bit 3 **PSA**: Prescaler Assignment bit
1 = Prescaler is assigned to the WDT
0 = Prescaler is assigned to the Timer0 module
PS2:PS0: Prescaler Rate Select bits

Bit Value	TMR0 Rate	WDT Rate
000	1 : 2	1 : 1
001	1 : 4	1 : 2
010	1 : 8	1 : 4
011	1 : 16	1 : 8
100	1 : 32	1 : 16
101	1 : 64	1 : 32
110	1 : 128	1 : 64
111	1 : 256	1 : 128

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RUJUKAN VI

REGISTER 11-2: ADCON1 REGISTER (ADDRESS 9Fh)

R/W-0	R/W-0	U-0	U-0	R/W-0	R/W-0	R/W-0	R/W-0
ADFM	ADCS2	—	—	PCFG3	PCFG2	PCFG1	PCFG0
bit 7							bit 0

bit 7 **ADFM:** A/D Result Format Select bit
1 = Right justified. Six (6) Most Significant bits of ADRESH are read as '0'.
0 = Left justified. Six (6) Least Significant bits of ADRESL are read as '0'.

bit 6 **ADCS2:** A/D Conversion Clock Select bit (ADCON1 bits in shaded area are in bold)

ADCON1 <ADCS2>	ADCON0 <ADCS1:ADCS0>	Clock Conversion
0	00	Fosc/2
0	01	Fosc/8
0	10	Fosc/32
0	11	FRC (clock derived from the internal A/D RC oscillator)
1	00	Fosc/4
1	01	Fosc/16
1	10	Fosc/64
1	11	FRC (clock derived from the internal A/D RC oscillator)

bit 5-4 **Unimplemented:** Read as '0'

bit 3-0 **PCFG3:PCFG0:** A/D Port Configuration Control bits

PCFG <3:0>	AN7	AN6	AN5	AN4	AN3	AN2	AN1	AN0	VREF+	VREF-	C/R
0000	A	A	A	A	A	A	A	A	VDD	VSS	8/0
0001	A	A	A	A	VREF-	A	A	A	AN3	VSS	7/1
0010	D	D	D	A	A	A	A	A	VDD	VSS	5/0
0011	D	D	D	A	VREF-	A	A	A	AN3	VSS	4/1
0100	D	D	D	D	A	D	A	A	VDD	VSS	3/0
0101	D	D	D	D	VREF+	D	A	A	AN3	VSS	2/1
011x	D	D	D	D	D	D	D	D	—	—	0/0
1000	A	A	A	A	VREF-	VREF-	A	A	AN3	AN2	6/2
1001	D	D	A	A	A	A	A	A	VDD	VSS	6/0
1010	D	D	A	A	VREF-	A	A	A	AN3	VSS	5/1
1011	D	D	A	A	VREF+	VREF-	A	A	AN3	AN2	4/2
1100	D	D	D	A	VREF-	VREF-	A	A	AN3	AN2	3/2
1101	D	D	D	D	VREF-	VREF-	A	A	AN3	AN2	2/2
1110	D	D	D	D	D	D	D	A	VDD	VSS	1/0
1111	D	D	D	D	VREF+	VREF-	D	A	AN3	AN2	1/2

A = Analog input D = Digital I/O
C/R = # of analog input channels/# of A/D voltage references