UNIVERSITI SAINS MALAYSIA

Peperiksaan Semester Kedua
Sidang Akademik 2007/2008

April 2008

EEM 351 – REKABENTUK MEKATRONIK II

Masa: 3 jam

Sila pastikan bahawa kertas peperiksaan ini mengandungi ENAM BELAS muka surat dan TIGA muka surat LAMPIRAN yang bercetak sebelum anda memulakan peperiksaan ini.

Kertas soalan ini mengandungi ENAM soalan.

Jawab LIMA soalan.

Mulakan jawapan anda untuk setiap soalan pada muka surat yang baru.

Agihan markah bagi setiap soalan diberikan di sudut sebelah kanan soalan berkenaan.

Jawab semua soalan dalam bahasa Malaysia atau bahasa Inggeris atau kombinasi kedua-duanya.

...2/-

1. (a) Terangkan lima-langkah dalam kaedah penjanaan konsep
Describe the five-step concept generation method

(40%)

(b) Bincang kenyataan-kenyataan di bawah:
Discuss the following statements:

"Satu kumpulan dengan ahlinya bekerja bersendirian untuk satu tempoh masa akan menjana konsep yang lebih banyak dan lebih baik berbanding dengan orang yang sama bekerja bersama dalam tempoh masa masa yang sama"

"*A set of people working alone for a period of time will generate more and better concepts than the same people working together for the same time period*"

"Terdapat sebab praktikal untuk mengadakan sesi menjana konsep secara berkumpulan"

"*There is a practical reason for holding group concept generation sessions*"

(30%)

(c) Terangkan tiga (3) teknik yang digunakan untuk merangsangkan akal (berfikir) bagi penjanaan konsep.

Describe three (3) techniques which are used to stimulate thinking for generating concepts.

(30%)

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2. (a) Merujuk kepada rekabentuk-rekabentuk robot bergerak dalam Rajah 1, hasilkan matrik konsep kiraan mata dengan lima (5) kriteria pemilihan.

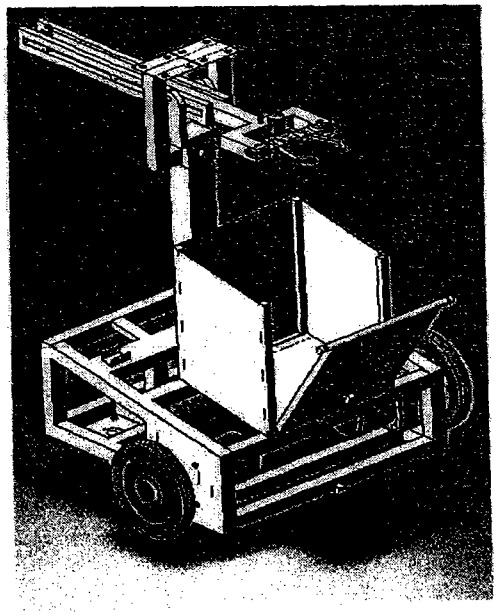
Referring to the following designs of mobile robot in Figure 1, generate a complete concept scoring matrix with five (5) selection criteria.

(50%)

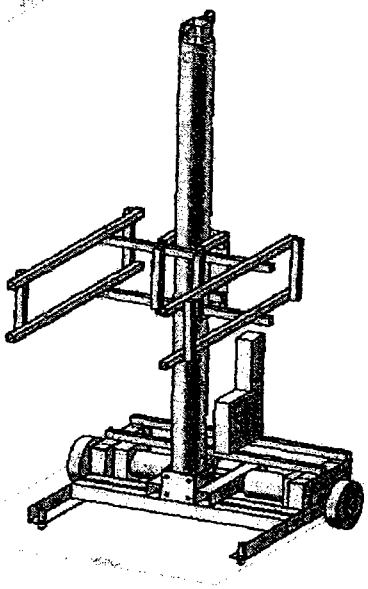
(b) Terangkan punca yang mungkin menyebabkan pasukan pembangunan menggunakan kaedah pemilihan konsep untuk bersetuju dengan satu konsep tetapi berkesudahan dengan kegagalan komersial.

Explain the possible cause of a development team uses the concept selection method to agree on a concept that then results in commercial failure.

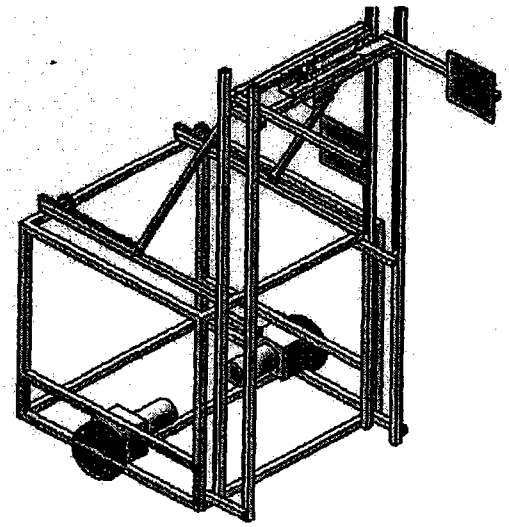
(20%)



Konsep A



Konsep B



Konsep C

Rajah 1
Figure 1

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(c) Terangkan perbezaan-perbezaan antara Rajah blok dengan pin RA4 dan Rajah blok bagi pin RB0 hingga RB3 berkaitan dengan input dan output digital dari dan kepada mikropengawal seperti ditunjukkan dalam Rajah 2 dan Rajah 3. Tunjukkan sambungan-sambungan luaran yang diperlukan untuk penggunaan digital input dan output.

Explain the differences between the following block Diagram for pin RA4 and block Diagram for pins RB0 through RB3 regarding digital input and output to and from microcontroller as shown in Figure 2 and Figure 3 respectively. Show the external connections required for using digital inputs and outputs.

(30%)

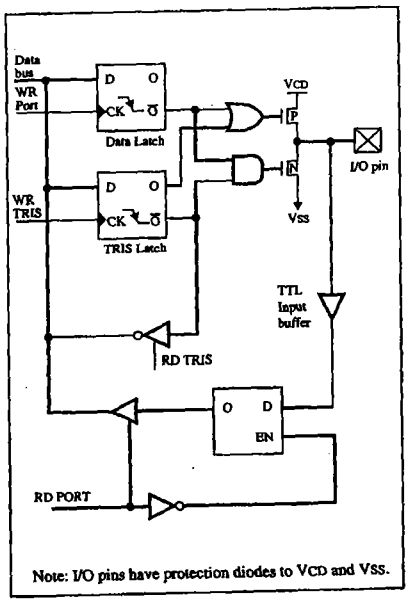

Figure 2: Block diagram for pins RA0 through RA3

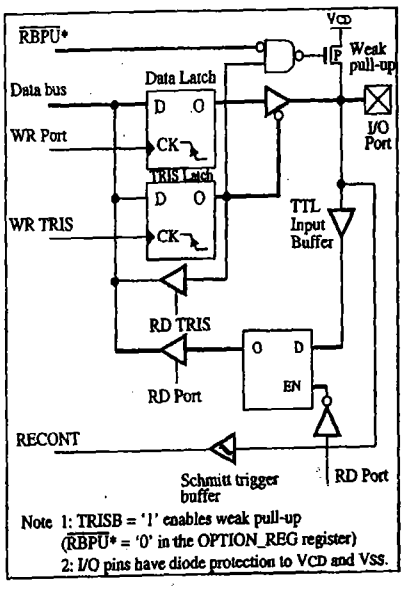

Figure 3: Block diagram for pins RB0 through RB3

3. (a) Anda membangunkan robot bergerak berautonomi yang dikawal oleh mikropengawal.

You are developing an autonomous mobile robot controlled by a microcontroller.

(i) Lukiskan rajah skematik sekiranya dua (2) unit motor DC tanpa berus dibekalkan kepada anda.

Draw the schematic diagram if two (2) units of Brushless DC motors are provided to you.

Diberikan pin-pin bagi pemacu motor tanpa berus:
Given the pins for brushless motor driver:

Pin	Description	Activation
8	Alarm output	Open collector
7	Encoder output	Open collector
6	CW/CCW	
5	Run/Brake	Active low
4	Start/Stop	Active high
3	GND	GND
2	External speed, PWM or analog voltage (0-5V)	Analog
1	5V (from driver for external variable)	5V

(ii) Tulis kod di dalam PICBasic Pro bagi menjalankan robot tersebut dalam garis lurus. Terangkan prosedur yang diperlukan untuk mencapai objektif ini.

Write the code in PICBasic Pro in order to move the robot in straight line. Explain the procedure required to achieve this objective.

(60%)

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(b) Terangkan kaedah yang sesuai untuk merekabentuk satu sistem berdasarkan mikropengawal

Describe a proper method to design a microcontroller-based system

(40%)

4. Soalan ini akan merangkumi bab berkenaan Isu-Isu Penyatupaduan sistem mekatronik.

This question will cover topics on Mechatronic System Integration Issues.

(a) Andaikan yang anda akan membina sendiri satu pemacu H-bridge untuk mengawal motor DC
Say, you are to build your own H-bridge driver to control your DC motor.

(i) Apabila motor berhenti, terdapat sisa-sisa medan magnet dalam wayar dan apabila medan menghilang, arus akan mengalir pada arah asalnya ia mengalir. Apakah nama fenomena ini?

When the motor is stopped, there is still some magnetic field in the wires and when the field collapses, the current will flow in the direction of initial current was flowing. What is the name of this phenomenon?

(15%)

(ii) Syorkan kaedah untuk melindungi pemacu dan litar kawalan daripada rosak disebabkan oleh voltan sambaran yang besar. Nyatakan peranti yang sesuai dengan aplikasi robot mobil bagi menangani masalah ini.

Suggest method to protect your driver and control circuit from damage as a result of large voltage spikes. Name the device that is suitable for your mobile robot application to overcome this problem.

(15%)

(iii) Bagaimana peranti tersebut dipasangkan dan apakah spesifikasi bagi memilih peranti tersebut?

How is the device installed and on what basis/specification has this device been chosen?

(15%)

(b) Anda akan menggerakkan halaju dan kedudukan motor dengan kaedah pemberian denyut PWM dari pengawal mikro ke peranti pensuisan.

You are to actuate the motor speed and position by means of giving PWM (pulse-width-modulation) pulse from the microcontroller to the switching device such as MOSFET.

(i) Bincangkan bagaimanakah anda melindungi MOSFET daripada bebanan pensuisan voltan dan arus yang tinggi, yang juga sekaligus dapat mengurangkan kehilangan kuasa. Gunakan lakaran bagi membantu penerangan anda.

Discuss how would you protect your MOSFET from switching stresses of high voltage and current which will in turn minimize the power losses. Use diagram sketches to explain.

(15%)

(ii) Bagaimanakah mengklipkan voltage daripada sumber dan gat MOSFET supaya ciri-ciri keselamatan dapat disertakan dalam litar pemacu anda? Gunakan gambarajah/lakaran bagi membantu penerangan anda.

How to clip the voltage from the source and gate of the MOSFET so as to provide another safety feature of your driver circuit? Use diagram sketches to explain.

(15%)

(c) Sebuah sistem pemacu perlu dipilih untuk rekabentuk robot mobil anda.
A drive system need to be chosen for your mobile robot design.

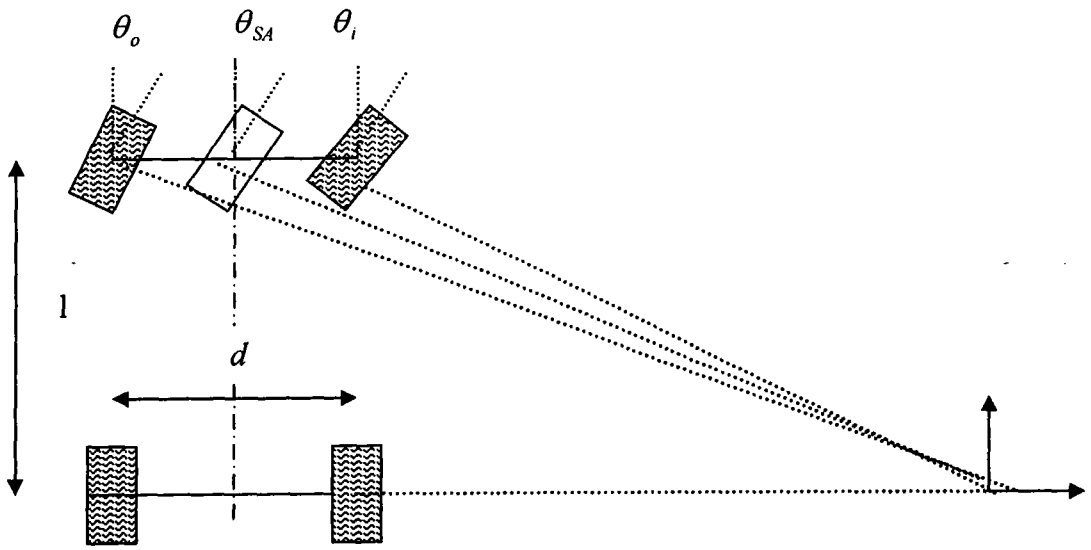
(i) Apakah nama sistem 'steering' yang ditunjukkan dalam Rajah 1.
What is the name of the steering system shown in the Figure 1.

(ii) Bincangkan sistem pemacu yang ditunjukkan.
Discuss the drive system shown.

(iii) Tunjukkan pertalian antara pengasingan roda melintang dan sisi dengan sudut yang dibelokkan terhasil dari roda dalam dan roda luar.

Show the relationship between the longitudinal and lateral wheel separation with the angle turned produced by inner and outer wheel.

(25%)



Rajah 1
Figure 1

5. Soalan ini merangkumi bab berkenaan isu-isu pemodelan dan simulasi sistem pemacu robot mobil.

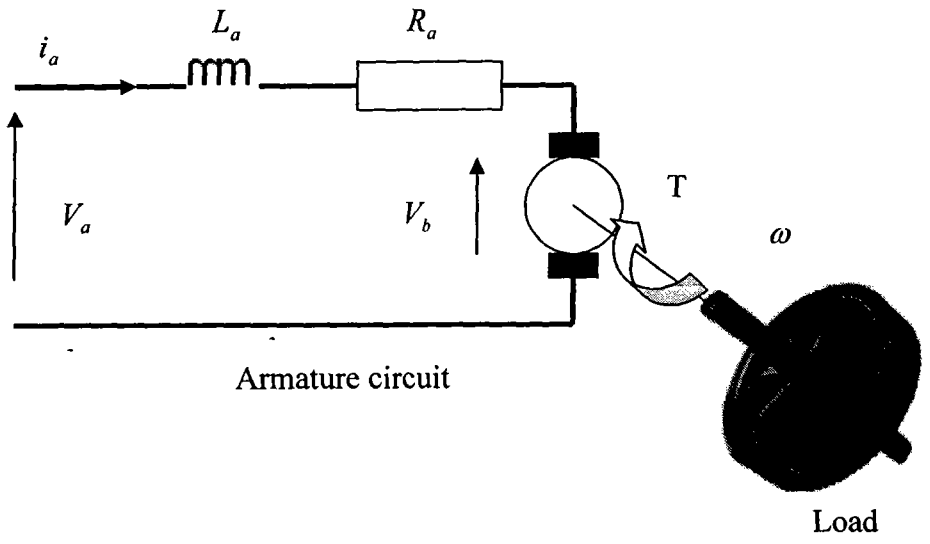
This question covers topics on the modeling and simulation issues of mobile robot's drive system.

(a) Bincangkan apakah yang dimaksudkan oleh ketaklelurusan. Gunakan gambarajah bagi membantu penerangan anda.

Discuss what is meant by nonlinearity. Use diagrams if you like to help in your explaination.

(10%)

(b) Sebuah model dinamik motor DC seperti yang ditunjukkan dalam Rajah 2 diamati.
A dynamic model of DC motor as shown in Figure 2 is studied.



Rajah 2
Figure 2

(i) Terbitkan persamaan kebezaan yang mengaitkan voltan masukan ke motor servo DC dengan halaju sudut keluaran. Andaikan motor tersebut dikawal-angker, dengan rintangan dan kearuhan berada dalam siri dengan beban.

Derive the differential equations relating the input voltage to a d.c. servo motor and the output angular velocity, assuming that the motor is armature controlled, having both resistance and inductance, in series with the load.
(30%)

(ii) Nyatakan persamaan yang diterbitkan dalam jelmaan Laplace.
Express the derived differential equation above in Laplace domain.

(10%)

(c) Dalam satu projek, anda diarah untuk menggunakan motor DC yang bergear sebagai salah satu penggerak yang dipasakkan pada robot mobil yang direkacipta anda. Yang melegakan adalah, anda hanya perlu mengambil kira sistem gear sahaja dan bukan motor. Seperti yang ditunjukkan dalam Rajah 3, dua gear yang berlainan nisbah akan digunakan. Satu gear (gear kecil) akan dipasang pada aci motor dan satu lagi (gear besar) pada roda aci. Sila rujuk pada Rajah 3. Dua gear dipadankan dengan elok supaya tiada ruang untuk berlakunya 'backlash'. Jadual 1 menunjukkan maklumat tentang dua gear ini.

In one project, you are instructed to use a geared DC motor which will be used as one of the actuators of your designed mobile robot. Fortunately, you are only concerned with the gear system and not the motor. As shown in Figure 3, two gears of different ratio are used. One gear will be attached to the shaft of the motor and the other one will be attached to the shaft of the wheel. Please refer to Figure 3. The two gears are properly meshed such that there will be no space for backlash to occur. Table 1 shows information about the two gears.

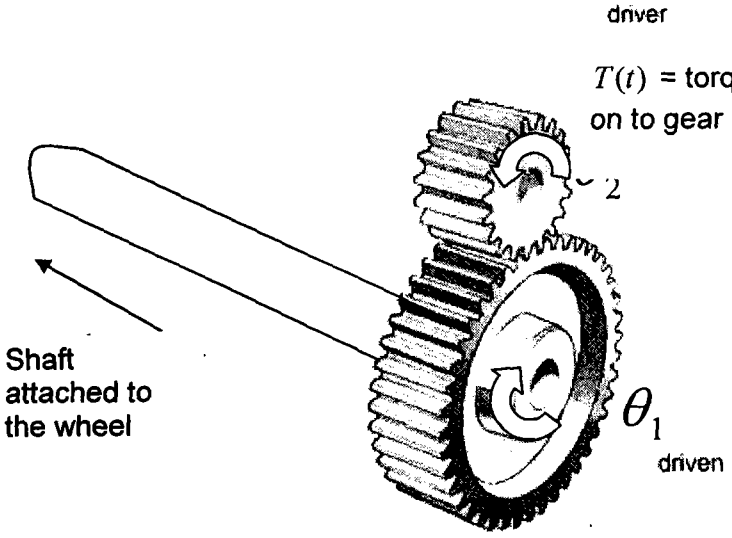
Jadual 1
Table 1

Gears information	**Dimensions (cm)**
Pitch radii of the plastic gear 2:	0.5
Pitch radii of the plastic gear 1:	1.5
Tooth face widths	0.2

(i) Cari gerakan persamaan bagi sistem ini sekiranya, gear yang kecil ini mempunyai daya kilas sebanyak $T \sin \omega t$ diaplikasikan padanya dan ω adalah frekuensi dalam unit rad/s.

Find the equation of motion of this system if the smaller gear has a torque $T \sin \omega t$ applied to it, where ω is the frequency in rad/s, of the excitation torque.

(50%)



Rajah 3
Figure 3

6. Soalan ini merangkumi bab berkenaan rekabentuk pengawal digital dalam pembangunan robot mobil.

This question covers topics on digital controller design in mobile robot development.

(a) Bincangkan secara ringkas kesan terhasil oleh setiap parameter pengawal digital PID (K_p, K_I, K_D) pada sambutan sistem.

Discuss briefly the effects of each term of a digital PID (K_p, K_I, K_D) controller on the response of a system. (20%)

(b) Sebuah sistem kawalan robot mobil dikaji dari aspek kestabilan. Di bawah adalah rangkap pindah bagi sistem ini.

A control system of mobile robot is studied in terms of its stability. Below is the transfer function of the system.

$$G(z) = \frac{K(z+0.5)}{3(z-1)(z-0.333)}, \qquad \text{T=1 s}$$

(i) Lakarkan gambarajah bode (mengunakan penghampiran asimptot) untuk mengkaji kestabilan sistem melalui pengamatan pada jidar gandaan dan jidar fasa.

Plot the bode diagram (using asymptotic approximation) to study the system stability by observing the gain and phase margin. (60%)

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(ii) Sebuah op-amp dengan pekali boleh ubah dalam sebuah modul sistem kawalan telah diperuntukkan untuk meningkatkan masa sambutan sistem pemacu robot mobil supaya ia memecut lebih pantas. Sekiranya gandaan K dalam rangkap pindah di atas mewakili gandaan/pekali op-amp, tentukan nilai maksimum gandaan K yang boleh ditingkatkan sebelum sistem menjadi tidak stabil? Petua: jidar gandaan.

An operational amplifier (op-amp) with variable gain inside the control system module is intended to increase the response time of the drive system as to make the mobile robot accelerate faster. If the gain K in the transfer function represents the variable gain of the op-amp, determine what is the maximum gain K which can be increased before the system become unstable? Hint: gain margin.

(20%)

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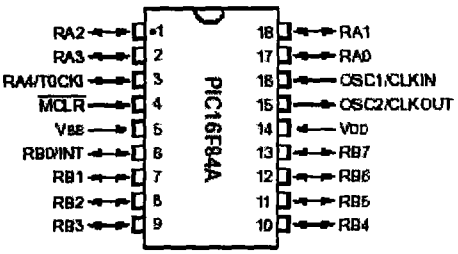

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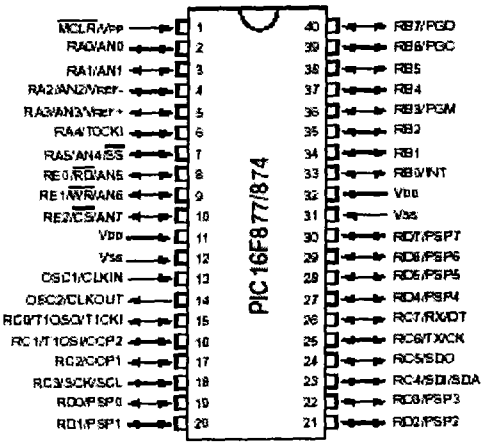

PIC16F877

Table 7.5 PicBasic Pro statement summary

Statement	Description
@ assembly statement	Insert one line of assembly language code
ADCIN channel, var	Read the on-chip analog to digital converter (if there is one)
ASM . . . ENDASM	Insert an assembly language code section consisting of one or more statements
BRANCH index, [label1{, label2, . . .}]	Computed goto that jumps to a label based on index
BRANCHL index, [label1{, label2, . . .}]	Branch to a label that can be outside of the current page of code memory (for PICs with more than 2 k of program ROM)
BUTTON pin, down_state, auto_repeat_delay, auto_repeat_rate, countdown_variable, action_state, label	Read the state of a pin and perform debounce (by use of a delay) and autorepeat (if used within a loop)
CALL assembly_label	Call an assembly language subroutine
CLEAR	Zero all variables
CLEARWDT	Clear the watch-dog timer
COUNT pin, period, var	Count the number of pulses occurring on a pin during a period
DATA {@ location,} constant1{, constant2. . . .}	Define initial contents of the on-chip EEPROM (same as the EEPROM statement)
DEBUG item1{, item2, . . .}	Asynchronous serial output to a pin at a fixed baud rate
DEBUGIN {timeout, label,} {item1{,{item2. . . .}]	Asynchronous serial input from a pin at a fixed baud rate
DISABLE	Disable ON INTERRUPT and ON DEBUG processing
DISABLE DEBUG	Disable ON DEBUG processing
DISABLE INTERRUPT	Disable ON INTERRUPT processing
DTMFOUT pin, {on_ms, off_ms,} {tone1{, tone2. . . .}]	Produce touch tones on a pin
{EEPROM {@ location,} constant1{, constant2. . . .}}	Define initial contents of on-chip EEPROM (same as the DATA statement)
ENABLE	Enable ON INTERRUPT and ON DEBUG processing
ENABLE DEBUG	Enable ON DEBUG processing
ENABLE INTERRUPT	Enable ON INTERRUPT processing
END	Stop execution and enter low power mode
FOR count = start TO end {STEP {-} inc} {body statements} NEXT {count}	Repeatedly execute statements as count goes from start to end in fixed increment
FREQOUT pin, on_ms, freq1{, freq2}	Produce up to two frequencies on a pin
GOSUB label	Call a PicBasic subroutine at the specified label
GOTO label	Continue execution at the specified label
HIGH pin	Make pin output high
HSERIN {parity_label,} {time_out, label,} [item1{, item2, . . .}]	Hardware asynchronous serial input (if there is a hardware serial port)
HSEROUT [item1{, item2, . . .}]	Hardware asynchronous serial output (if there is a hardware serial port)
I2CREAD data_pin, clock_pin, control,{ address,} [var1{, var2, . . .}]{, label}	Read bytes from an external I^2C serial EEPROM device
I2CWRITE data_pin, clock_pin, control,{ address,} [var1{, var2, . . .}]{, label}	Write bytes to an external I^2C serial EEPROM device
IF log_comp THEN label	Conditionally jump to a label

IF log_comp THEN
true_statements
ELSE
false_statements
ENDIF
	Conditional execution of statements

INPUT pin	Make pin an input
LCDIN {address,} [var1{, var2, . . .}]	Read RAM on a liquid crystal display (LCD)
LCDOUT item1{, item2, . . .}	Display characters on LCD
{LET} var = value	Assignment statement (assigns a value to a variable)

Statement	Description
LOOKDOWN value, {const1{, const2, . . .}}, var	Search constant table for a value
LOOKDOWN2 value, {test} {value1{, value2, . . .}}, var	Search constant/variable table for a value
LOOKUP index, {const1{, const2, . . .}}, var	Fetch constant value from a table
LOOKUP2 index, {value1{, value2, . . .}}, var	Fetch constant/variable value from a table
LOW pin	Make pin output low
NAP period	Power down processor for a selected period of time
ON DEBUG GOTO label	Execute PicBasic debug subroutine at label after every statement if debug is enabled
ON INTERRUPT GOTO label	Execute PicBasic subroutine at label when an interrupt is detected
OUTPUT pin	Make pin an output
PAUSE period	Delay a given number of milliseconds
PAUSEUS period	Delay a given number of microseconds
{PEEK address, var}	Read byte from a register
{POKE address, var}	Write byte to a register
POT pin, scale, var	Read resistance of a potentiometer, or other variable resistance device, connected to a pin with a series capacitor to ground
PULSIN pin, state, var	Measure the width of a pulse on a pin
PULSOUT pin, period	Generate a pulse on a pin
PWM pin, duty, cycles	Output a pulse width modulated (PWM) pulse train to pin
RANDOM var	Generate a pseudo-random number
RCTIME pin, state, var	Measure pulse width on a pin
READ address, var	Read a byte from on-chip EEPROM
READCODE address, var	Read a word from code memory
RESUME {label}	Continue execution after interrupt handling
RETURN	Continue execution at the statement following last executed GOSUB
REVERSE pin	Make output pin an input or an input pin an output
SERIN pin, mode,{ timeout, label,} {{qual1, qual2, . . .},}{ item1{, item2, . . .}}	Asynchronous serial input (Basic Stamp 1 style)
SERIN2 data_pin{\flow_pin}, mode, {parity_label,} {timeout, label,} {item1{, item2, . . .}}	Asynchronous serial input (Basic Stamp 2 style)
SEROUT pin, mode, { item1{, item2, . . .}}	Asynchronous serial output (Basic Stamp 1 style)
SEROUT2 data_pin{\flow_pin}, mode, {pace,} {timeout, label,} {item1{, item2, . . .}}	Asynchronous serial output (Basic Stamp 2 style)
SHIFTIN data_pin, clock_pin, mode, {var1{\bits1} {, var2{\bits2}, . . .}}	Synchronous serial input
SHIFTOUT data_pin, clock_pin, mode, {var1{\bits1} {, var2{\bits2}, . . .}}	Synchronous serial output
SLEEP period	Power down the processor for a given number of seconds
SOUND pin, {note1, duration1{, note2, duration2, . . .}}	Generate a tone or white noise on a specified pin
STOP	Stop program execution
SWAP var1, var2	Exchange the values of two variables
TOGGLE pin	Change the state of an output pin
WHILE logical_comp statements	Execute code while condition is true
WEND	
WRITE address, value	Write a byte to on-chip EEPROM
WRITECODE address, value	Write a word to code memory
XIN data_pin, zero_pin, {timeout, label,} {var1{, var2, . . .}}]	Receive data from an external X-10 type device
XOUT data_pin, zero_pin, {house_code1\key_code1{\repeat1}{, house_code2\key_code2{\repeat2, . . .}}	Send data to an external X-10 type device

PicBasic Pro commands