SINGAPORE POLYTECHNIC

ELECTRONICS & COMMUNICATION ENGINEERING DEPARTMENT

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MINE AVOIDANCE VEHICLE

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CONTENTS

Project Group No. 53

We are a team of four electronic students, who are interested in MAV. We felt that taking part in SRG (Singapore Robotics Games) is a very challenging and knowledgeable third year project. We wanted something different and this is what drives us to take up the project. After confirmation, we started the project around May of 1997 and expected completion date would be before the start of the 1st 1998 term. The SRG competition will be held at around May 1997. We hope to do Singapore Polytechnic proud in the Robotics Battlefield category in 1998's SRG.

The project members in alphabetical order are

1. Chew Chuen Hee (Group Leader)
2. Lee Chin Kwang
3. Lim Siong Boon
4. Pang Sze Hsin

ACKNOWLEDGMENT

We would like to extend our gratitude and thanks to our supervisor, Mr Toh Ser Khoon for guiding us and always searching for opportunities for us and also Mr Nandakumar for the valuable advises which he gave us. We would also like to thank our helpful lab technician, Miss Amanda Tan for all the help and allowing us to work in her lab. Last but not least, Miss Tan from 6805 microcontroller lab. We had bothered her at the initial stage of our project and had given her much trouble. We wish to thank her for all the advice regarding 6805 (chip programmer & EVM board).

Finally, we wish to express our gratitude to all those who made our project possible and fellow friends in the SRG team especially Jim from the micromouse team.

INTRODUCTION

Mine Avoidance Vehicle (MAV) is one of the many competitions in the Singapore Robotics Games (SRG). The 1st MAR (MAR was renamed MAV after November 1997) competition was successfully launched in 1994 and it attracted several participants. This is the third MAV competition and the advancement of technology used in the robots is growing at a tremendous rate therefore fierce competition is expected.

The objective of MAV competition is to design a mobile robot that is fully autonomous according to specifications (see Appendix) and to negotiate an arena of 5 x 5m in the shortest time without triggering the mines.

We began on the 1st of June 1997, without much knowledge on robotics. We started allocating the job and drawing out a schedule for our project. We started the project with basic knowledge and understanding of electronics and learned a lot about automation, sensors, motors and control circuitry as we progress. Our supervisor gave us suggestions and help us a lot during the course of our project. Although we faced a lot of problem in our project but each problem provided us an opportunity to learn something new.

This report will cover the technical aspect as well as the overall system description of the MAV project. It explains the hardware, software, the features of the MAV, how to troubleshoot faults, the strategy and other important notes that enable any person who reads the report to understand and operate the robot. The chassis design will also be illustrated and there will be a section containing list of components, products and cost used in MAV. Lastly the conclusion will contain the proposals and suggestions for future development and improvement of the project.

RULES
&
REGULATIONS

MINE AVOIDANCE VEHICLE COMPETITION

1 OBJECTIVES

Design a mobile robot that can navigate through a minefield and obstacles to reach the predetermined destination in the shortest possible time.

2 HOW THE GAME IS RUN

1. A maximum competition time of 3 minutes is allocated to each round.

2. Each robot will commence from its respective mid-span "START" position and try to cross the predetermined destination [i.e. 'Finishing Line'] on the opposite side of the arena in the shortest possible run time. In doing so, it has to navigate through a maze of mines and obstacles while observing the rules and regulations.

   To make the game more interesting, the Finishing Line is confined to a 1.5m wide goal-post marked with two tennis balls.

3. The first robot, together with all parts of its body, that crosses the Finishing Line will emerge as the winner of the round. In the process, the goal-post markers [tennis balls] must not be moved or disturbed.

   All robots must stop once the winner for that round is determined or when the competition time 3 minutes is up; whichever is earlier.

   For the Final Round, after the winner has emerged; the game can continue for other entries to vie for the remaining top positions i.e. first and second runner-up.

4. A robot is not allowed to continue with the race if it violates any one of the following conditions:

   iv. ventures completely beyond the arena boundary

v. triggers a mine

vi. hits any goal-post markers i.e. moves the tennis ball

vii. stalls in the arena for more than 30 seconds

viii. manual assistance or intervention is needed for whatsoever reasons

Obstacles are considered as part of the maze. As such, no penalty will be imposed if they are moved or disturbed by a robot.

5. In each round, a maximum of four competing robots may enter the arena. Once inside the arena, a robot is permitted to push other opponent robots either out of the arena or towards a mine and/or obstacles. If a robot violates any of the conditions mentioned in 4 above, it will not be allowed to continue with the race.

3 <u>ENTRY TO HIGHER COMPETITION LEVEL</u>

1. There will be a maximum of 32 entries in the Qualifying Rounds; eight in the Semi-final Round and four in the Final Round.

2. During the Qualifying and Semi-final rounds, if no robot manages to complete a successful run; then no representation from that group is allowed to advance to the next level of competition.

3. In the Final round, entries will vie for the position either as Champion; first runner-up or second runner-up. If no robot manages to complete a successful run after the competition time has elapsed; a short break of 3 minutes is permitted before a rematch.

4. During the rematch, if no outright winner emerges again, then all the finalist will retire and each be will awarded a consolation prize.

4 RULES AND REGULATIONS

1. Entries

Line-up of robot for competition	:	By drawing lots
Targeted destination of robot	:	'Goal-post' located on opposite side of arena
Max. Competition time	:	3 minutes

2. Inspection of Robot

30 minutes before the competition commences, all participants must submit their entries for inspection by a panel of judges. After which all robots must be displayed on a designated table for public viewing.

3. Disqualification

After an entry has been submitted for inspection, no alterations, changes and/or modifications to their mechanical design, power supply and/or electronic circuitry are permitted before and/or during the competition without any permission from the judges. Failure to observe this ruling will subject the participant with disqualification.

No participants is permitted to step inside the arena other than to retrieve robots that has stalled or when human intervention is required.

5 SPECIFICATIONS

1. Specifications of Robot

Min. Dimensions : 300mm [Length] x 300mm [Width] x height [No restriction]

Weight	:	Not more than 10kg
Power supply	:	Autonomous

No retroreflective tape or coating on the robot's body.

2. Specifications of Competitions Arena

Area	:	5m x 5m [Lined with non-reflective black tapes (~50mmwidth)]
Floor and Light	:	Lighting and floor as per condition of designated competition hall.
'START'	:	The mid-span marking on each side of arena.
No. of Mines	:	Minimum 12 mines per round.
Finishing Line	:	'Goal-post' marked with two tennis balls 1.5m apart.
Obstacles	:	Five circular BLACK plastic containers [minimum ∅ 0.5m] randomly positioned. Four wooden blocks of approx. 1m x 0.5m x 0.5m are placed diagonally at all four corners as shown in Figure 1.
Entries per round	:	Maximum 4 entries

Distance between mines/obstacles : Minimum 0.4m

3. Specifications of Mines

Dimension :	Approx. ∅ 300mm x 200mm [height excludes light indicator
Metallic Casing :	Coated in black. Base affixed with 25mm Scotch-lite Relective Tape.
Accessories :	Built-in Lamp & Alarm system powered by battery
Activation :	When mine is disturbed, the lamp & alarm system will activate.

4. General Tolerances

General tolerance of ± 2% is permitted for all dimensions unless otherwise specified.

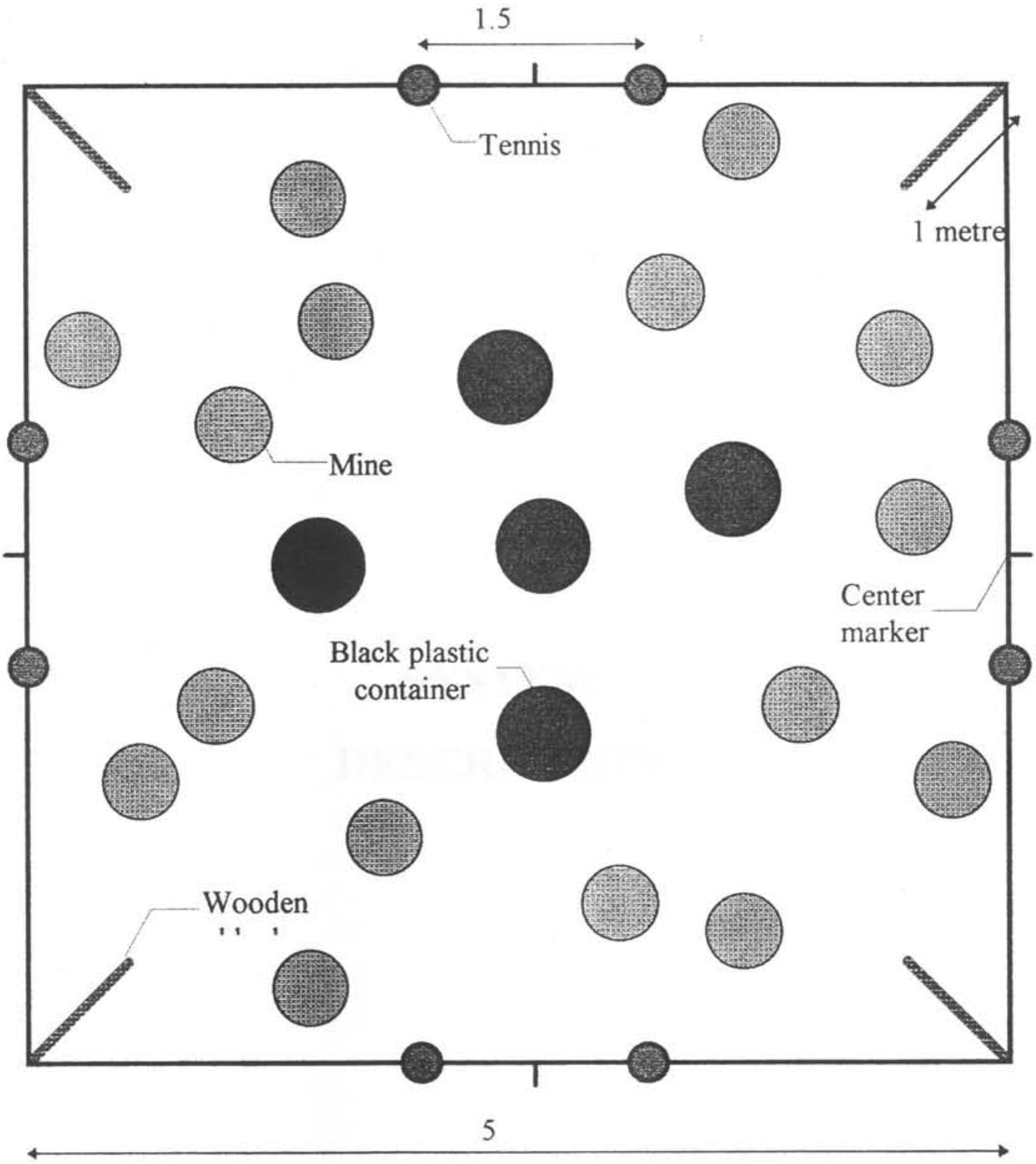


Figure 1 Competition Arena

Figure 2 Cross section of a mine

SYSTEM DESCRIPTION

3.1 SYSTEM OVERVIEW (HARDWARE)

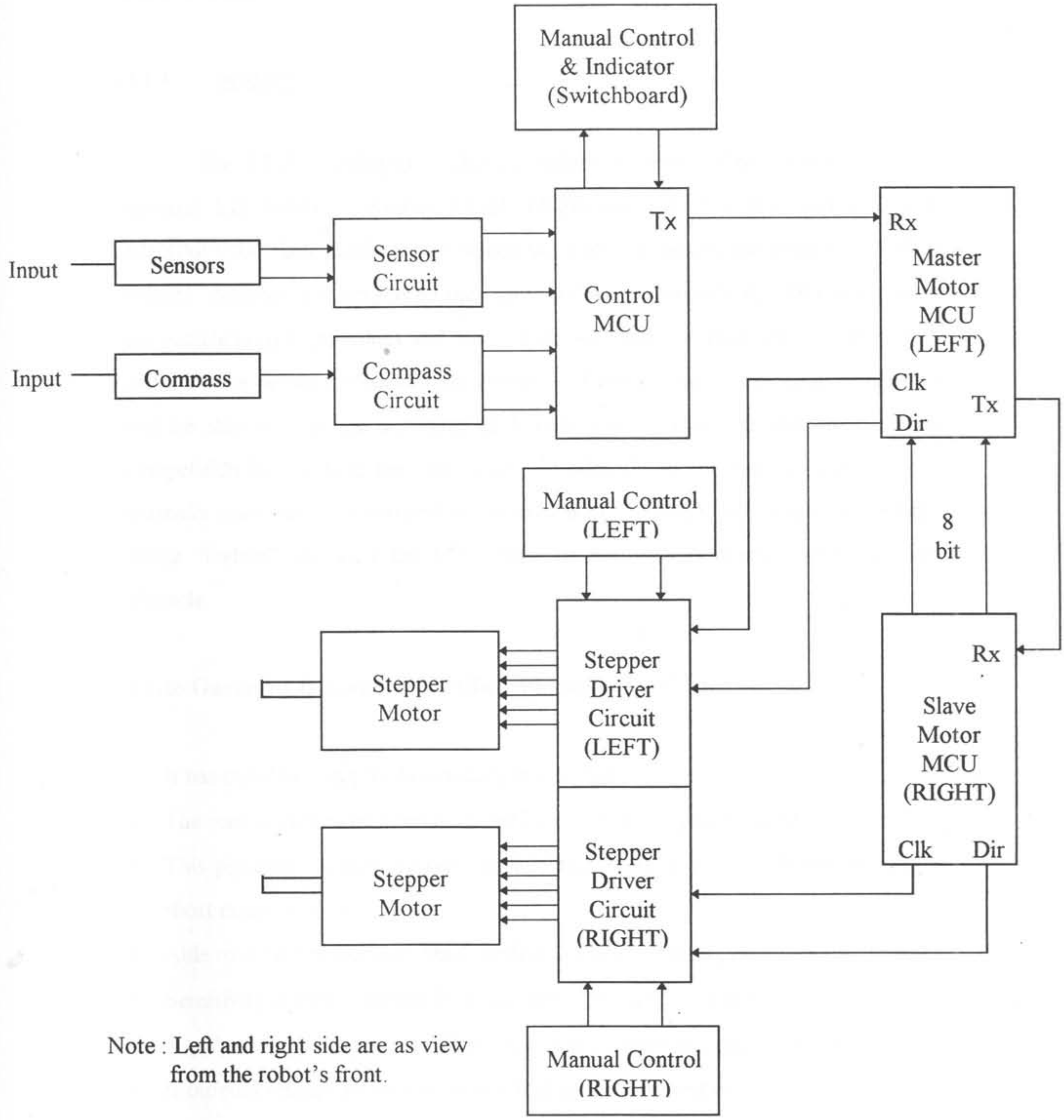


Figure 2 System block diagram

The MAV can be broken into several blocks as shown in Figure 3. Each block performs a unique function and they depend on each other so that the MAV can do its job. The MAV block diagram is used in the report to describe its individual task.

3.1.1 Sensors

The MAV employed 5 diffuse reflective photoelectric switches (Carlo Gavazzi EO 1804), 2 Banner S30SP6FF200 fixed field sensor and 4 Banner S30SP6FF400 fixed field sensors which were able to detect the presence of black objects. Sensors are considered the input module for the vehicle. The objective of the vehicle is to avoid mines and black obstacles thus it is vital that we use reliable and accurate sensors. Sensors are the eyes of the vehicle therefore good sensors will be able to help us negotiate each mine with confidence and complete the competition by reaching the other end. In addition to the sensors, there are 11 normally open switches situated at the crown of the MAV which act as "feelers". These "feelers" will alert the MAV when it comes into contact with the black obstacle.

Carlo Gavazzi ED18D4NPAS Diffuse Photoelectric Switch :

- It has metal housing for heavy-duty application.
- The sensor uses modulated infra-red light with horizontal sensing.
- This proximity sensor is useful in detecting long range — 0-40cm, as well as short range — 0-3cm.
- Able to detect object with black surface provided it is targeted perpendicularly.
- Sensitivity is easily adjustable by side-mounted potentiometer.
- Supply voltage ranges from 10V - 40V, max output current is 200mA.
- It outputs voltage levels that suits a transistor switching circuit.
- Operating temperature is -20 to +60 degree Celsius.
- Operating frequency (max) is 100 Hz for the DC type.

Banner S30SP6FF200 and S30SP6FF400 Fixed Field Sensor

- S30SP6FF200's range is 200mm non-adjustable.
- S30SP6FF400's range is 400mm non-adjustable.
- The sensor uses modulated infra-red light.
- Supply voltage ranges from 10V-30V.
- Output voltage is the same as that of the power supply.
- Both PNP and NPN output available
- Very stable sensing range regardless of object shape and colour.
- M30 barrel type mounting.

3.1.2 Sensor Circuit

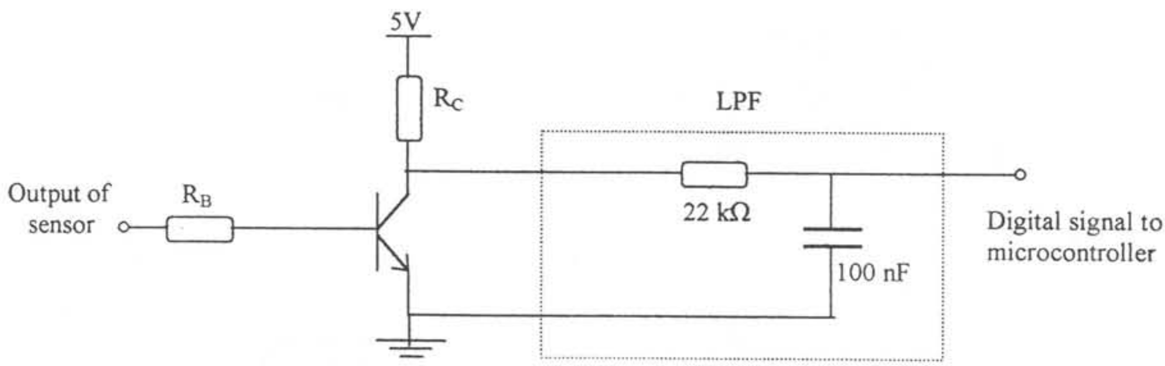


Figure 3 Sensor output to microcontroller I/O port interface

Although all the sensors that we used provide a digital output but all of them could not be fed directly into the I/O port of the microcontroller. For that purpose, we fed all the sensors' output into a transistor switch circuit and by working the transistor at its cutoff and saturation region, we were able to convert all the sensors' output into TTL digital output for the microcontroller. Depending on what sort of output voltage which the sensor is giving, we had to adjust the values of R_B and R_C to get a TTL output.

Sensor	R_B	R_C
Carlo Gavazzi ED18D4NPAS	330Ω	10KΩ
Banner S30SP6FF200	22kΩ	10kΩ

Banner S30SP6FF400	$22k\Omega$	$10k\Omega$

Table Sensor and its corresponding R_B and R_C values

After every interface circuit, a Low Pass Filter was added to filter off the noise introduced into the circuit by the motors. The noise will occur whenever the stepper motor rotates at low speed or stationary. It could severely degrade the signal and cause erratic in readings. The value of R and C was calculated based on the formula **Frequency = $1/(2\pi RC)$**.

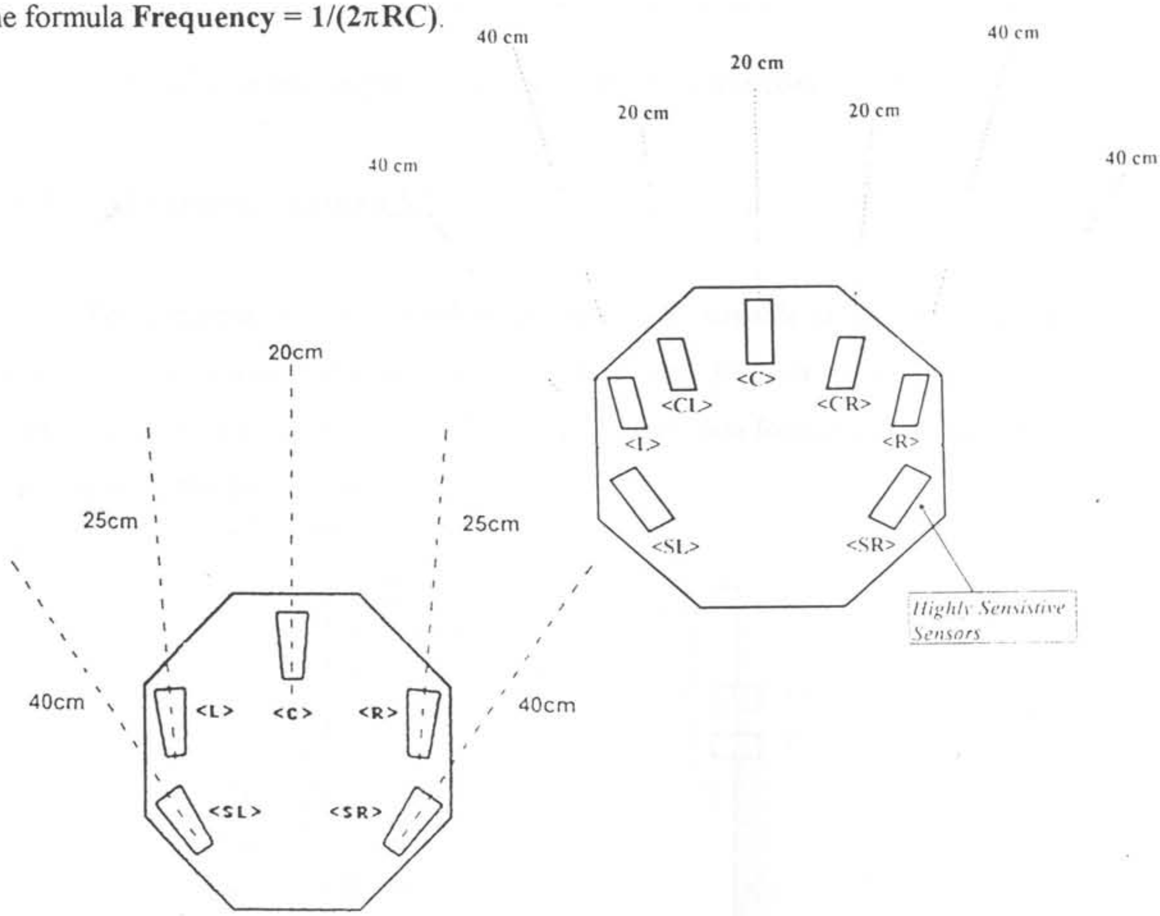


Figure 4 Sensor layout on the MAV

Sensor Position	Microcontroller Port
Centre	Port C 1
Right	Port C 0
Left	Port C 2
Base Right	Port B 2

Base Left	Port B 3
Top Centre	Port C 5
Top Centre Right	Port C 4
Top Centre Left	Port C 6
Top Right	Port C 3
Top Left	Port C 7
Top Side Right	Port B 0
Top Side Left	Port B 1

Table 1 Sensor output to microcontroller I/O port connections

3.1.3 The Digital Compass V2X

The compass is an independent device that is capable of getting reading through the x, y-axis. Pin programmability allows the user to configure the compass according to their specific needs. The output data format can be switched between BCD and binary mode.

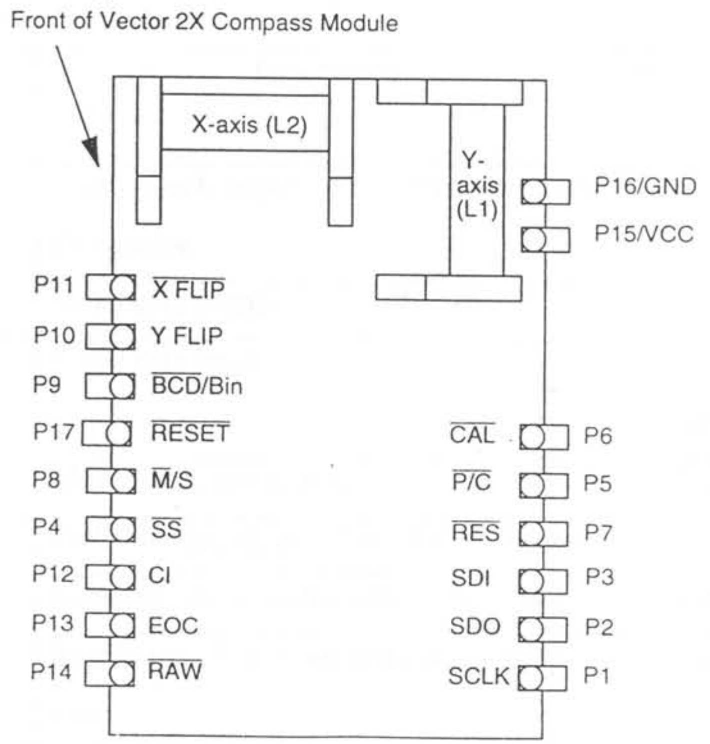


Figure 5 Vector 2X PCB layout

The X-Flip & Y-Flip

If the compass is to be place in an inverted position, the X-Flip and the Y-Flip enable you to configure the compass to get the actual reading. Therefore these pins are left inactivated. The X-Flip is connected to Vcc while the Y-Flip is connected to ground.

The Resolution Pin

The resolution pin is normally grounded unless higher resolution output is required for more counts at areas with weaker magnetic field strength.

The Reset Pin

In an event where the V2X enters into an unknown state, it may be necessary to reset the processor. The reset pulse must be low for at least 10 milliseconds.

Pin	Name	Description	Input/Output
P1	SCLK	Serial clock input; data valid on rising clock edge	Input/Output
P2	SDO	Serial data output	Output
P3	SDI	Serial data input	Not connected
P4	!SS	Slave select; active low	Input
P5	!(P/C)	Poll/Continuous; active when CAL is low	Input
P6	!CAL	Calibrate select; active when CAL is low	Input
P7	!RES	Resolution; low resolution when RES is low	Input
P8	!M/S	Master/Slave select; master mode when M/S is low	Input

P9	!BCD/Bin	BCD/Binary select; BCD when BCD/Bin is low	Input
P10	Y Flip	Flip Y-axis direction. Low is normal direction	Input
P11	!X Flip	Flip X-axis direction. High is normal direction	Input
P12	CI	Calibrate indicator signal; active high	Output
P13	EOC	End of conversion signal; conversion complete on the rising edge of EOC.	Output
P14	!RAW	Raw data mode select pin; active low	Input
P15	VCC	5 volt power input	Input
P16	GND	Power supply return	Input
P17	!RESET	Reset pin; active low	Input

Figure 6 Vector 2X pin labeling

3.1.4 Compass Circuit

We used the Vector 2X in its master mode therefore M/S is connected to ground. In master mode, the Vector generates its own clock (SCLK), which can be an output to clock the host system. One can use the master mode to load data into devices such as serial-to-parallel shift registers without a host processor. The serial data output (SDO) is never tri-stated in Master mode. The V2X can either polled once or sampled continuously.

The V2X is an integrated circuit therefore most pins has got its own internal pull-up resistors which allow unused pins to be left open. An external reset switch is provided to reset the V2X externally whenever the robot starts.

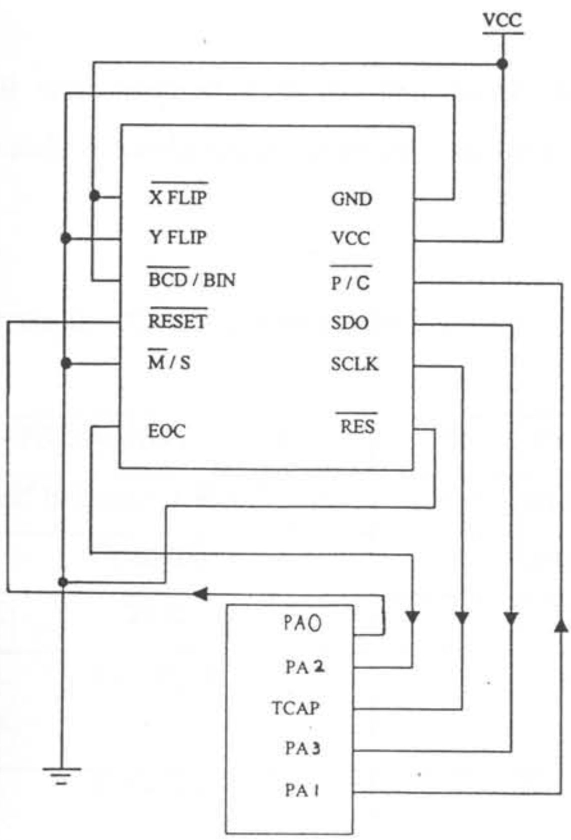


Figure 7 Vector 2X configuration diagram

3.1.5 Stepper Motor

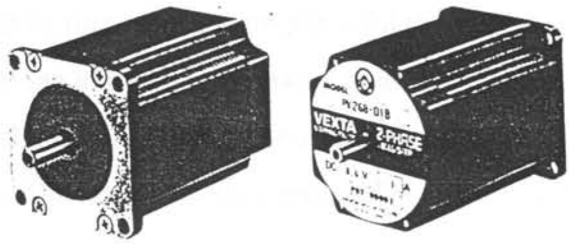


Figure 8 PK268-01B stepper motor

Stepper motors are motors which rotate at constant angle cause by an excitation of input pulse signals. As stepper motors can be directly controlled by the digital signal, feedback control is not necessary and therefore the control circuitry is very simple.

PK268-01B was favoured over the PK266-01B for this year's MAV because it offers nearly twice the torque of PK266-01B at only a small amount of cost increment.

The stepper motor we have chosen is Vexta PK268-01B.

	PK268-01B (Present)	PK266-01B (Previous)
Accuracy	0.9° half-step, 1.8° full-step	0.9° half-step, 1.8° full-step
Control	Open loop	Open loop
Price	$112	$102
Max. Torque	13.5 kgcm	9 kgcm
Max. Current	1 Ampere	1 Ampere
Resistance per phase	8.4 Ω	7.4 Ω

Table 2 Comparison of PK268-01B against PK266-01B

The performance of a stepper motor is determine by its holding torque — the greater the holding torque, the more powerful the motor is. However care must be taken to prevent the motor from working at a high torque region where it might cause the wheels of the MAV to spin loosely before the whole vehicle moves off. We assumed the coefficient of friction between the floor and the MAV's wheel to be 0.5

3.1.6 Stepper Motor Driver

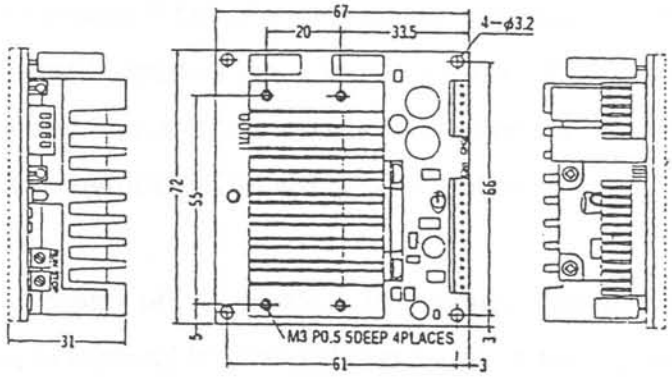


Figure 9 Vexta CSD2120-P stepper motor driver

For this year's MAV we choose to use the Vexta's card motor driver CSD2120-P instead of the L297/L298 driver although there are significant speed increment shown by this driver over the previous group's robot through extensive ground rewiring to minimize electromagnetic interference. However the CSD2120-P provides us with greater control over the span of speed which our robot is to travel and smoother motor operation.

	CSD2120-P	L297/L298
Weight	approx. 150g/motor	approx. 50g/2 motor
Max. No load speed	>4kHz Half-step	2kHz Half-step
Price	$154/motor	approx. $15/2 motor

Reliability	Good	Poor
Ease of use	Average	Very easy

Table 3 Comparison of Vexta CSD2120-P driver to L297/L298 driver

3.1.7 Microcontroller

In our project, we used three of Motorola's MC68HC705C8 microcontroller. The 6805 series is a single chip microcontroller. It consists of the CPU, memory and I/O all in one IC chip.

The CPU can process 8 bits of data at a time. There are five registers in the CPU which are affected by most of the instructions. The CPU runs on an internal clock which is generated from a 4MHz crystal oscillator circuit. The memory of the 6805 consist of 7744 bytes of EPROM and up to 304 bytes of RAM.

The I/O consists of 4 parallel I/O ports, Serial Communication Interface(SCI), Serial Peripheral Interface(SPI) and a 16 bit timer system.

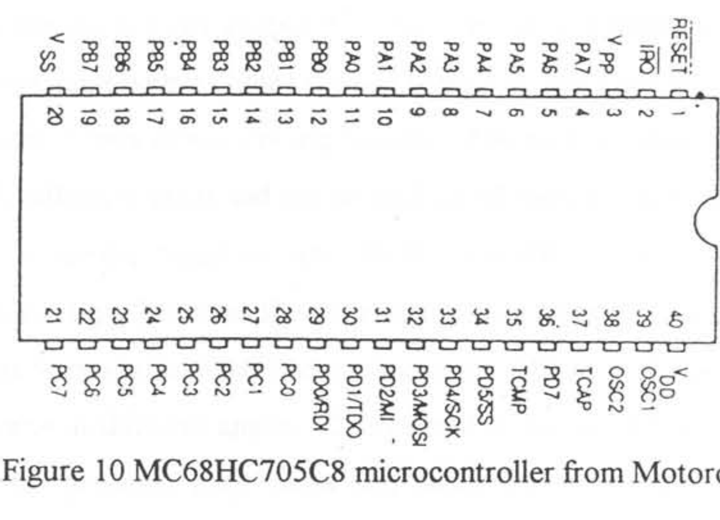


Figure 10 MC68HC705C8 microcontroller from Motorola

3.1.8 Manual Control & Indicator

The Manual Control and Indicator unit consists of DIP switches and LEDs. They were used for generating TTL logic levels for the microcontroller to adjust the top speed of the MAV, switching the program mode and partial control of the motor driver. As for the LEDs, they are for the microcontrollers to reflect their status so that the programmers can track their program flow.

3.2 Program Description

There are 3 microcontrollers in the MAV. One is used to control the action of the robot and does all the processing and thinking. This microcontroller is known as the control MCU. The other 2 microcontrollers are used to control the 2 stepper motors by generating rotating direction command and clock pulses for them. The master motor MCU receive commands from the control MCU and executes the command by sending instructions to its slave motor MCU to obtain the desired clock pulses for the stepper motors.

3.2.1 Control MCU

The sensors of the MAV are used for path finding and object tracing. The path finding sensors are used to check for available paths for the MAV to move on. The object tracing sensors enable the MAV to move around the object without coming into contact with it. Since the MAV need to avoid objects with and without reflective tape, 2 sets of sensors are needed. The first set specialized in avoiding mines (with reflective tape) and the second for obstacles (without reflective tape). Sensors for detecting mines are less sensitive but the sensing range do not differ much when the light beam hit the mine at different angles. Sensors for detecting obstacles are very sensitive but the sensing range differs a lot when the light beam hit the obstacle at different angles. Therefore it is not possible to use only one set of sensors for avoiding both mines and obstacles. The sensors for mines are mounted at the lower deck of the MAV targeted at the reflective tape. Sensors for obstacles are mounted on the upper deck which is clear of mines. (Refer to page 14 for the sensor layout)

When the path finding sensors sense a mine or obstacle, the program will execute different avoidance routine depending on which sensor is triggered. For example, if the lower deck left sensor is triggered, the program will assume that a mine is on the left of the MAV and do the appropriate avoidance routine. After the avoidance routine is executed, an alignment routine will be called upon to realign the MAV — pointing it in the direction of the tennis balls.

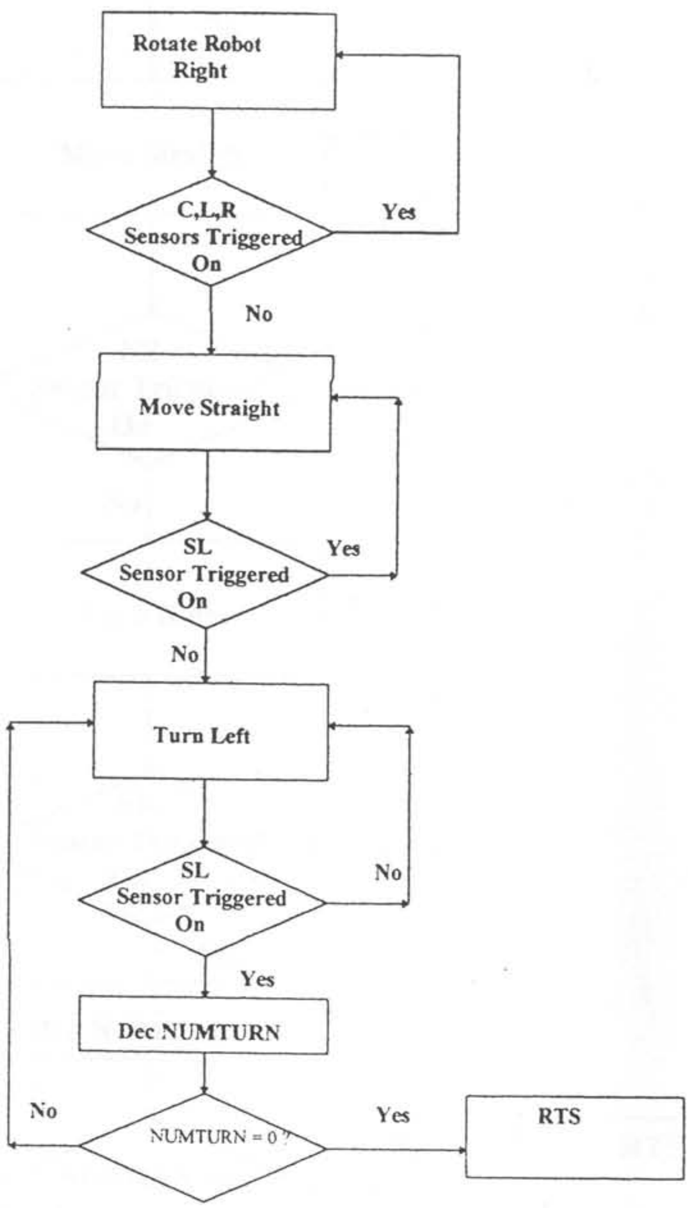


Figure 11 Mineleft flowchart

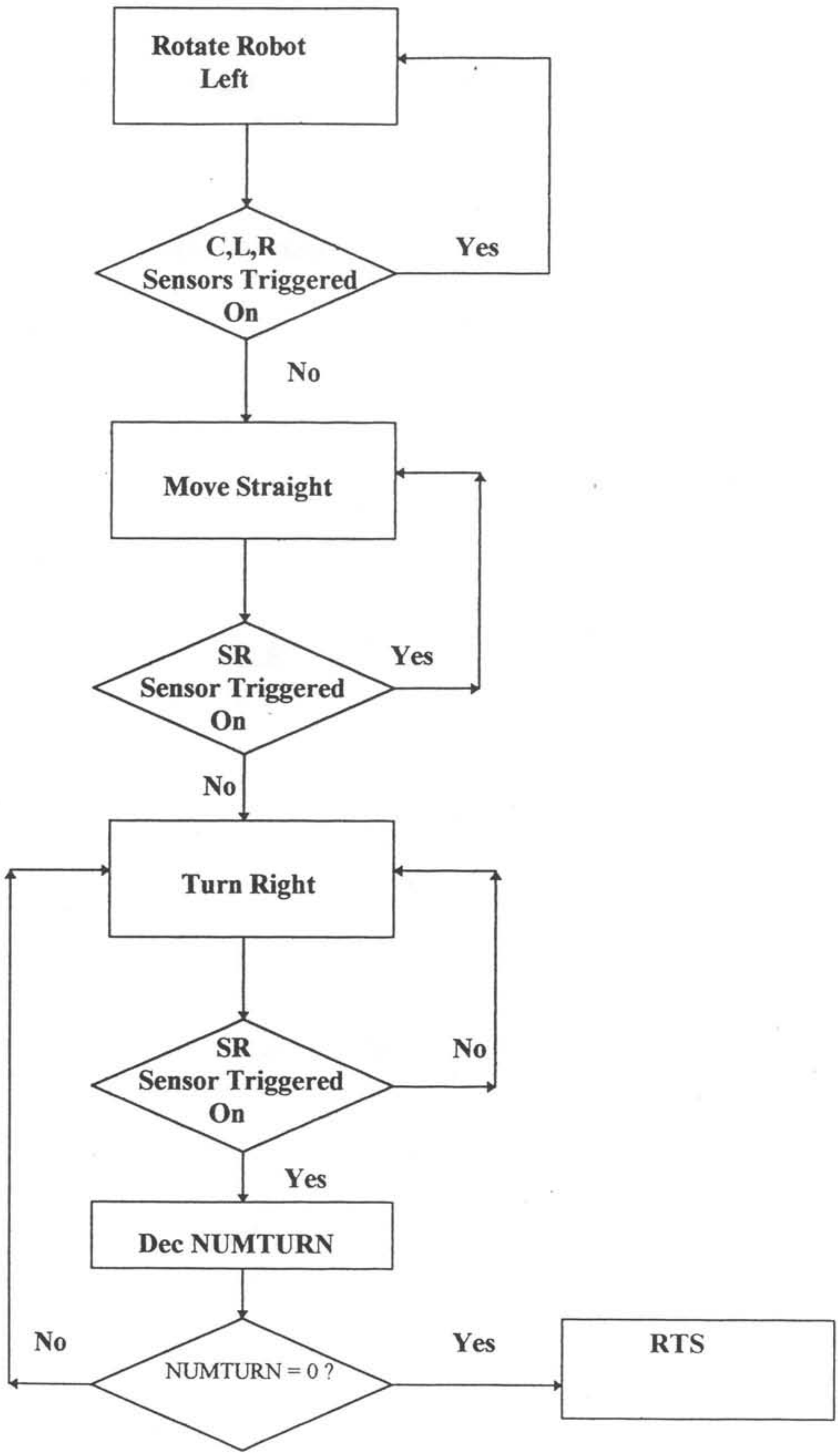


Figure 12 Mineright flowchart

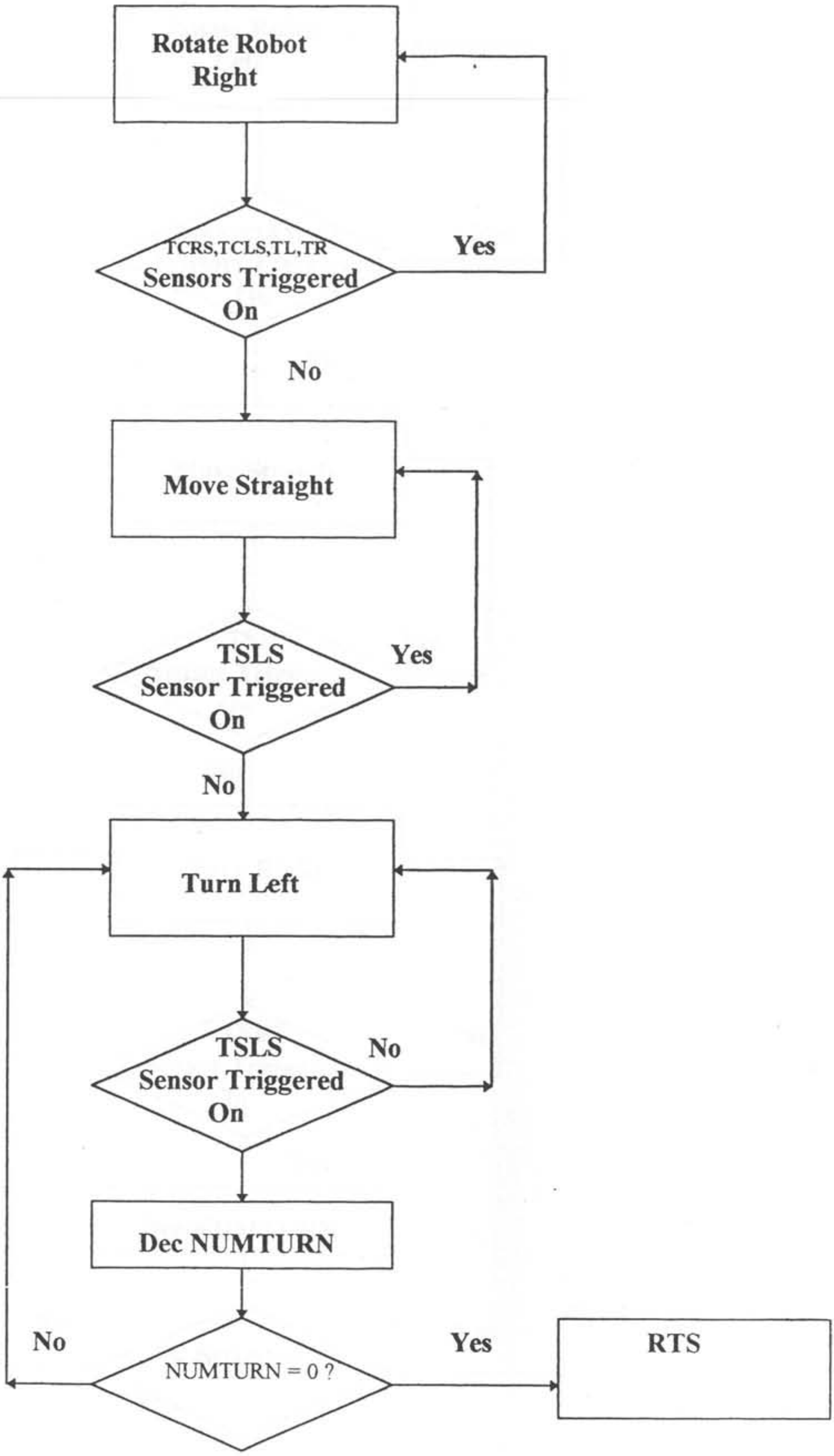


Figure 13 Binleft flowchart

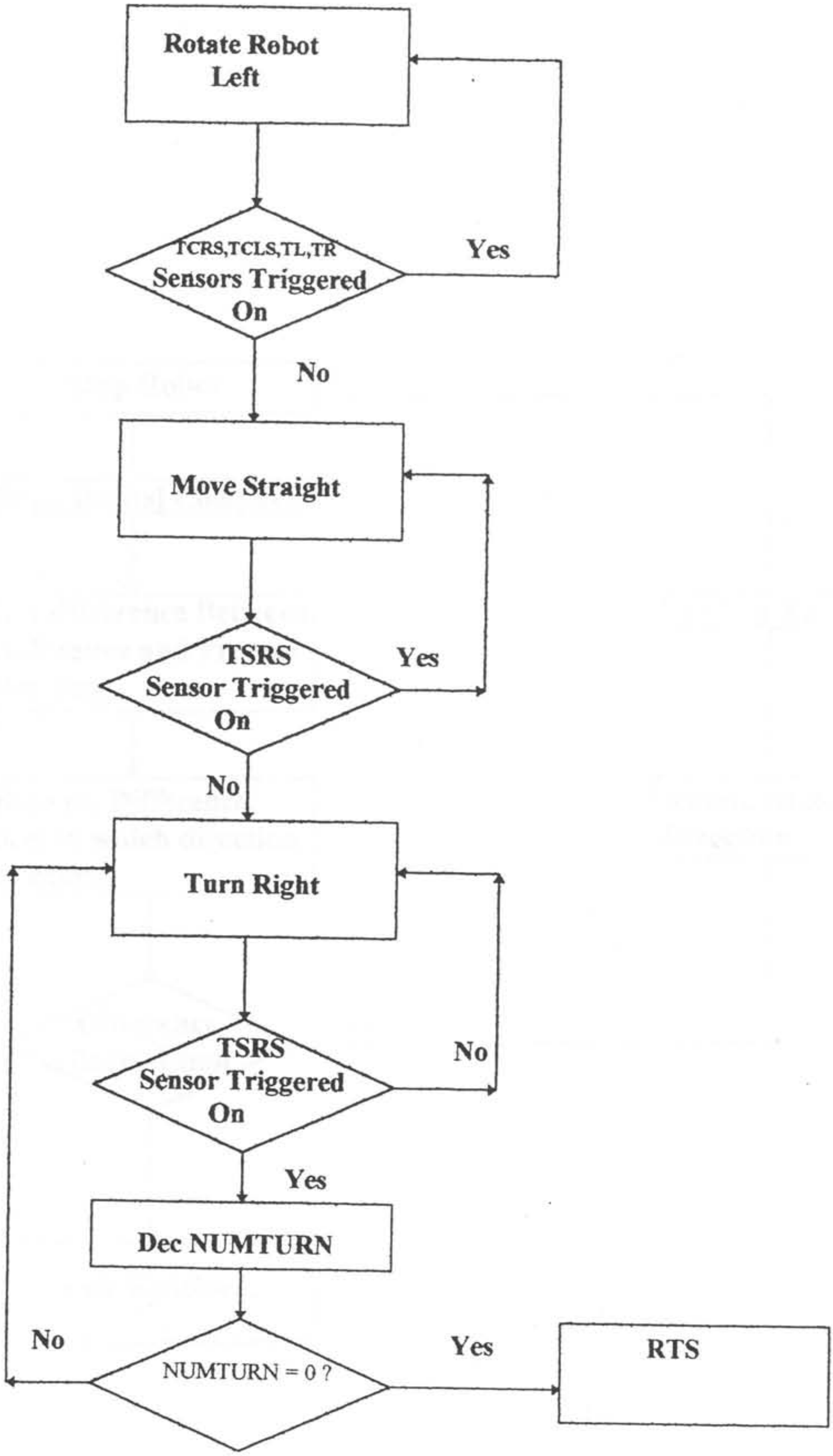


Figure 14 Binright flowchart

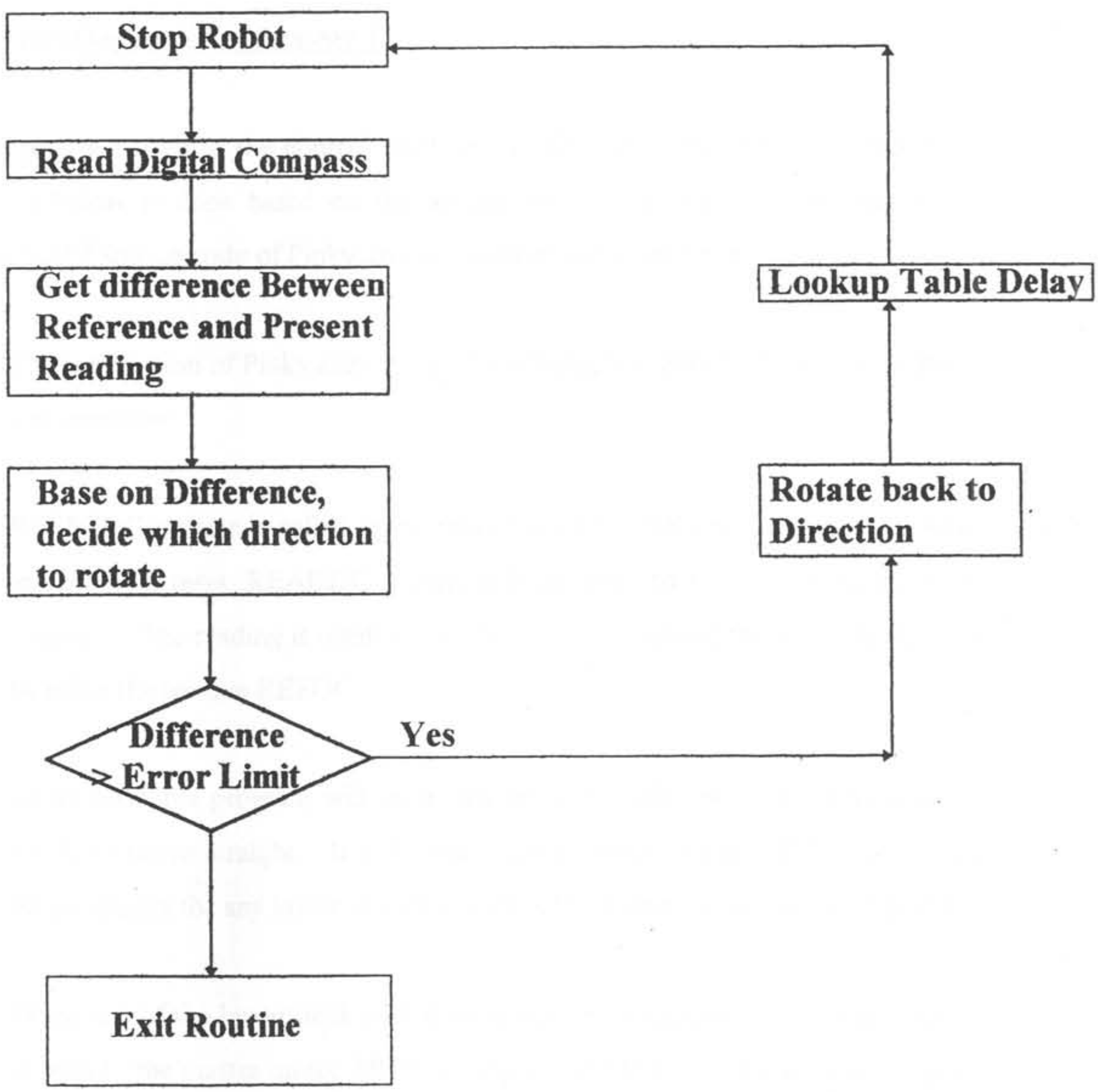


Figure 15 Alignment flowchart

3.2.1.1 Strategies

Algorithm of Strategy 1 — Avoiding the Mines and Obstacles

In strategy 1, the MAV will trying to avoid the mine or obstacles by maneuvering very close to their perimeter and stop at the far side. It will then realign itself towards the direction of goal using the Vector 2X Digital Compass.

Program Description of Strategy 1

The program used in the control MCU is PINKY.asm. The program description shown below is done based on the assumption that no other robots are in the minefield. Source code of Pinky.asm is available in the appendix.

1. The top portion of Pinky.asm are all the initialization and configuration of ports and variables.

2. RESETDC routine is called up to reset the Vector 2X Digital compass. After the compass reset, READDC routine will be called to take a reading from the compass. The reading is used as the reference throughout the whole navigation by using the routine REFDC.

3. At START, the program will set its maximum straight speed and command the MAV to move straight. It will then enter a waiting loop, CHECKSENSOR, which checks for any lower or upper deck path finding sensors being triggered.

4. When any of the lower deck path finding sensors is triggered, a stop instruction is send to the master motor MCU to stop the MAV's movement. The program will then poll to find out which sensor is triggered.

5. If R sensor is triggered — a mine is encountered on the right of the MAV, MINERIGHT routine will be called to carry out the mine avoidance action for right side.

6. If L sensor is triggered — a mine is encountered on the left of the MAV, MINELEFT routine will be called to carry out the mine avoidance action for the left side.

7. When C sensor is triggered, the program will decide whether to call MINELEFT or MINERIGHT based on previous routine call. This will be described in Strategy 2. The following will show how the robot avoid a mine using MINELEFT routine. MINERIGHT routine is just the mirror image of MINELEFT as instead of using SL sensor to trace the mine, MINERIGHT routine uses SR sensors to trace the mine.

8. When the upper deck path finding sensors is triggered, the speed of the MAV will be reduced and it will continue to move straight until the bumper switches is triggered. The purpose of the switches is to ensure that the MAV always avoid the obstacles at a close proximity to the obstacle so that the sensing is reliable.

9. If TR or TCR sensor is triggered , BINRIGHT routine is called to avoid the obstacles assuming the obstacle is at the right side of the robot.

10. If TL or TCL sensor is triggered on, BINLEFT routine is called to avoid the obstacles assuming the obstacle is at the left side of the MAV.

11. The BINRIGHT and BINLEFT routine is similar to the MINERIGHT and MINELEFT routine. For BINRIGHT and BINLEFT routine, TSRS and TSLS sensors are used for tracing around the obstacles.

12. After all avoidance routine, COMPASSALIGN routine will be call to align the MAV back to the direction of the goal. Alignment of the MAV is based on a

set of delay timings with the resolution of 1 degree. The angular difference between the reference heading and the present heading provided the correct delay for the MAV to rotate. Source code for the calculation of delay timings is available in the appendix.

<u>Algorithm of Strategy 2 — Determining the MAV's Path of Travel</u>

For homing purpose, the C sensors will have higher priority than the rest of the path finding sensors. This is due to the fact that when this sensor is triggered, the MAV will be at almost the center of the mine or obstacle. The program will decide based on previous avoidance routine called whether the robot should move left or right in order to have higher possibility of entering the goal pole. Initially, a memory location named OFFSET is initialized with a value 50_{16}. When MINERIGHT is called, OFFSET will increment by 1. When MINELEFT is called, OFFSET will decrement by 1. The program must keep the contents of OFFSET at 50_{16}. If previously there is more MINERIGHT, then when the C sensor is triggered, MINELEFT will be called and vice versa.

3.2.2 Algorithm For Digital Compass

Since V2X is a synchronous serial port communication device, reading has to be done by synchronising with the V2X's clock. The module is operating in master mode, therefore we have to look out for the rising edge of the clock before we take in the logic. Below shows how reading is done.

- Pulse P/C of V2X for continuous reading
- Awaits for EOC to be clear
- Look out for rising edge of the clock
- Read in logic at every rising edge
- Store first 8 bits in REF location (MSB)
- Store second 8 bits in REF+1 location (LSB)
- Check for invalid data

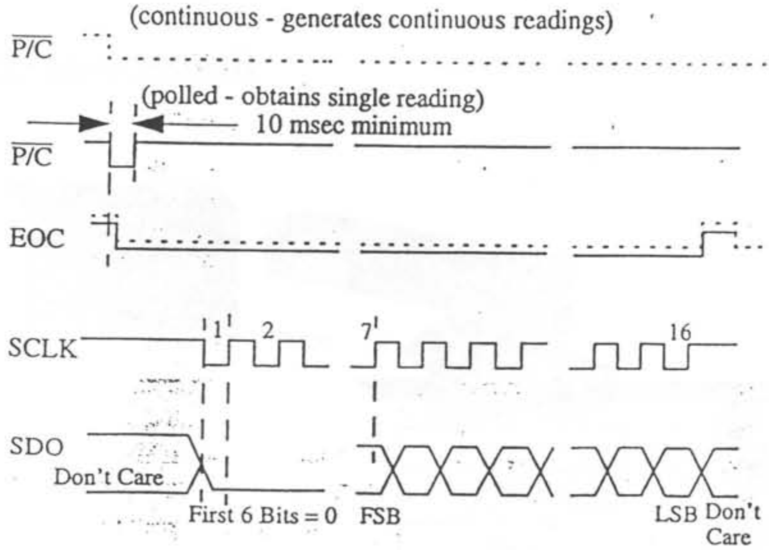


Figure 16 Data clock timing diagram (Master mode 16-bit data format)

3.2.3 Motor Control Software

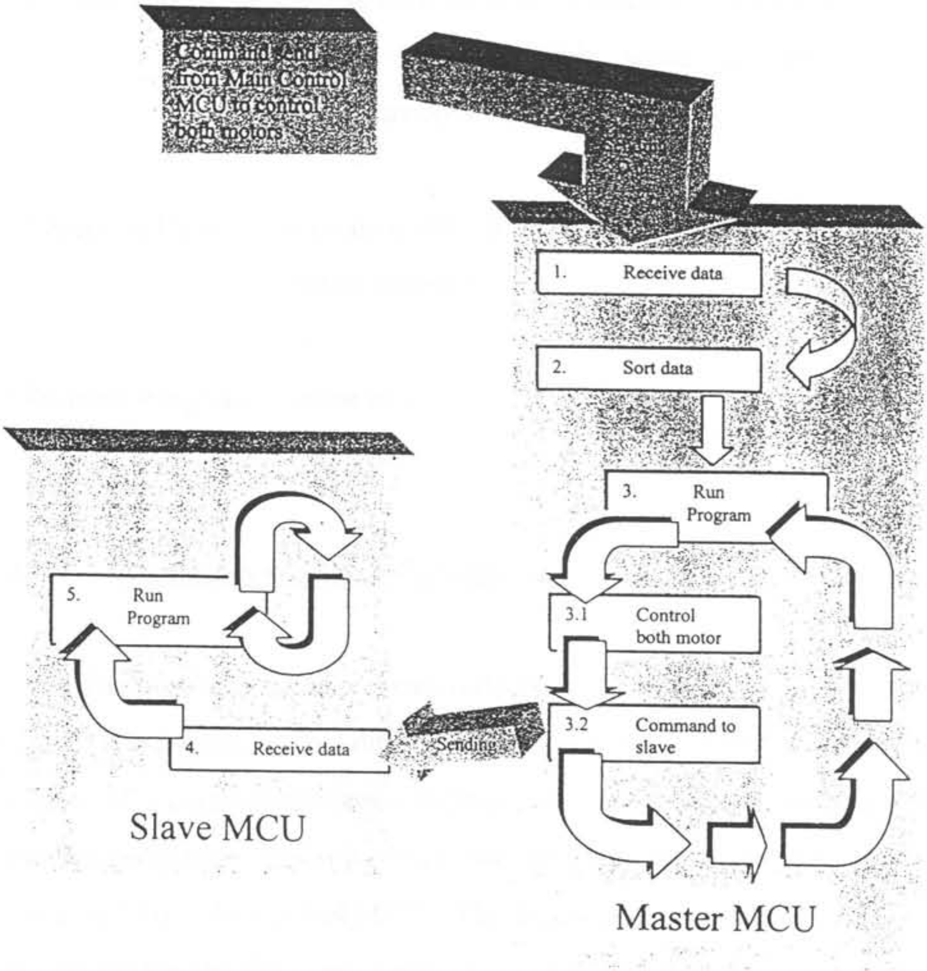


Figure 17 Motor control structure

1 Receiving Data : to obtain all data from CONTROL MCU and store them for processing.

2 Sorting Data : to convert the command from MAIN MCU to useful data (use for controlling motors).

3 Running Program : to run a motor according to the control variables.

3.1 Controlling Both Motor : to interpret useful data and convert them to control variable for both sides of the motor. (the target speed & the motor direction).

3.2 Command to Slave : to convert control variable to a byte and send the data to slave through serial communication of the microcontroller.

4 Receiving Data : to receive data from master and convert the data back to control variable.

5 Running Program : same as 3.

3.2.3.1 Algorithm of Motor Control

The flow chart shown above reflects the main program run but it is closer to the slave's program. The difference between the master and the slave is the presence of a control calculation section and communication sorting section in the Master's program. Without these two sections the slave cannot use the data transmitted from the Control MCU. The data will instead go to the Master where it will convert the raw data into usable form for the slave.

Variables

Useful Data

SLOWER? : want to slow down motor? left or right(for curve)

WHICHPROFILE? : to select optimize or delicated profile

DIFF_RATE : level rate difference by command(for curve)

STOPMOTORNOW : command to stop motor immediately

MAXSPEED : maximum speed allowed

Serial Communication

COMMAND : to store command from main MCU

COMMAND_rint : to store command from main MCU

SCI_INT : to tell if interrupt is activate & store no. of command

SCI_INT_rint : to tell if interrupt is activate & store no. of command

SCI_FLOW : to control the flow for SORTCOMMAND

PRE_SDATA : to save up previous data send for checking

Control Variables

MAXLEVEL1 : control maximum speed

MAXLEVEL2 : control maximum speed

DIRCHSTATUS : to indicate change of direction

Non control variables

LEVEL2 : for displaying current level

CYCLE1

Supporting Variables

DIRSTATUS : to store new/current motor direction status

*DIRSTATUS : (msb) right direction (lsb)left direction

REVERSEBRAKE : to indicate reverse braking action

TEMPA : protect ACC

TEMPX : protect X

TEMP1 : cannot be use for holding value for long

TEMP2 : cannot be use for holding value for long

Concept of the Controllevel routine

The purpose of the Controllevel routine is to change the content of the Control variable with the help of useful data & present status by means of calculation. The outcome will be the speed & direction of the motors. This is also the necessary data needed to control a motor. Therefore the function of Controllevel is to produce speed (maxlevel1, maxlevel2 which is left and right respectively) and dirstatus — 8 bit variable for controlling both motors' direction.

To control the motor, maxlevel1, maxlevel2 and dirstatus has to be change accordingly. In our case, calculation is use to change the 3 variables (2 speed & 2 direction). The following example shown below is a very crude representation of how a MAV maneuver is carried out.

In this turn we will keep speed difference with reference to the maximum speed (right motor).

The calculation will be:

Right motor speed = Maximum speed allowed

Left motor speed = Current Right speed - Speed difference to maintain

Knowing that the direction is forward:

Right motor direction = forward

Left motor direction = forward

Now the 4 basic information is calculated for both motor. The left motor information will then be sent to slave for processing.

Given these basic data, the Master and Slave MCU will alter the right and left motor's speed respectively. This is done by the ACC_CHANGE routine, which work in terms of the requirements shown above.

After the turning is done maybe a straight is to be executed

The calculation will be:

Right motor speed = Left motor speed = (Current Left speed + Current Right speed) ÷ 2

Knowing that the direction is forward:

Right motor direction = forward

Left motor direction = forward

Now the 4 basic information is calculated for both motor. The left motor information will then be sent to the slave for processing again. Then a straight motor run is executed.

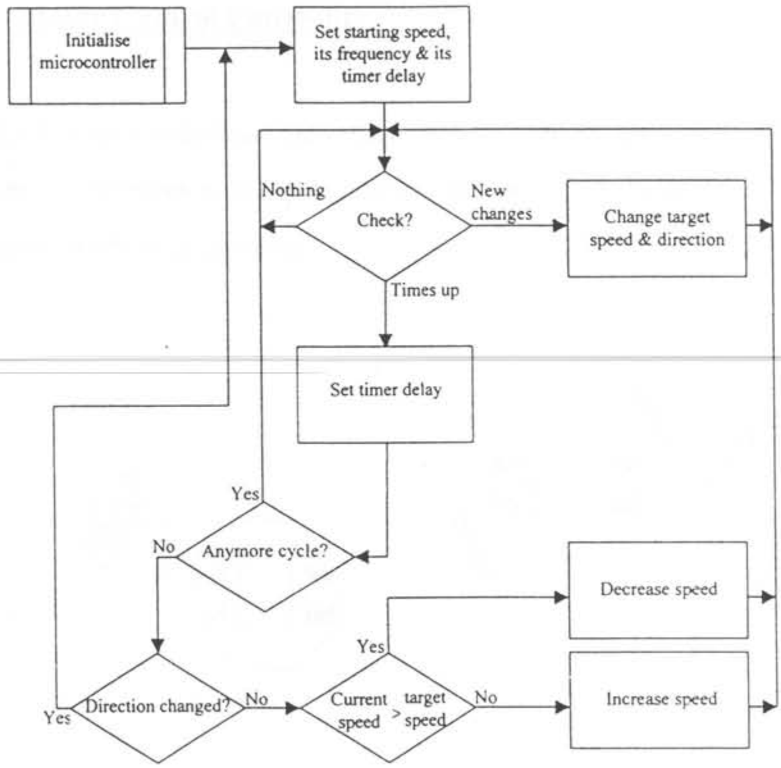


Figure 18 Speed control flowchart

3.2.3.2 Motor Acceleration Profile

The profile is represented by two look up tables. The two tables consist of the frequency or speed of the motor and the duration of the speed. Using decrement method (reduce code) a speed constant (level-1) had to be loaded (Refer to Appendix for the derivation of the acceleration profile used). Using this speed constant (level-1) the corresponding frequency (100Hz or 9C4 in the

CYCLEDELAY look up table) and cycle (4 in the CYCLE look up table) had to be loaded. Frequency is use for the timer while CYCLE is use to count the number of times the timer has to count the delay. A count of 2 is needed to sustain a particular frequency for one period. After the timer has counted one round of a particular value in the CYCLEDELAY look up table, the logic of the clock pin will toggle to an opposite one. When the count has ended the speed constant decrements and the corresponding frequency and cycle process is repeated. After the speed constant is reduced to 0, the acceleration is finish because 0 represents maximum speed.

3.2.3.3 Motor Control Capability

MAV's movements are governed by two stepper motors and the aim of this motor control program is to fully control the two motors and give the MAV as wide range of motion as possible.

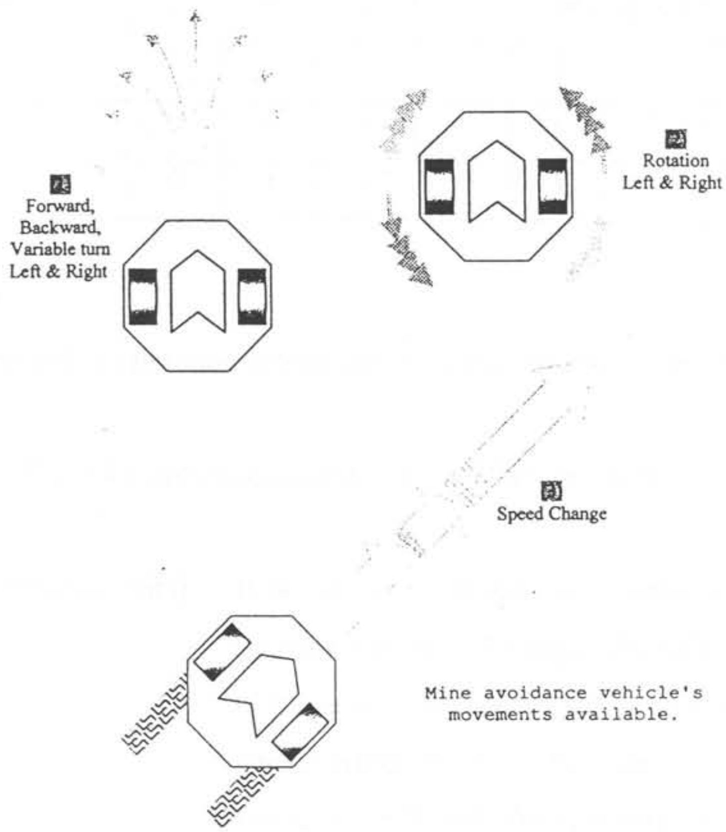


Figure 19 MAV's available movements

The forms of motion available for the MAV shown above is exclusive to vehicles that has got adjacent mounted driving mechanism eg. tank. There are no separate control devices for determining the direction of the MAV instead this is done by varying the speed of the two stepper motors.

3.2.3.4 Motor Controlling Commands

Movement	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Forward	0	x	0	0	0	0	0	0
Forward Turn Left	0	0	Rate of forward left turn					
Forward Turn Right	0	1	Rate of forward right turn					
Backward	1	1	x	0	0	0	0	0
Backward Turn Left	1	1	0	Rate of backward left turn				
Backward Turn Right	1	1	1	Rate of backward right turn				
Speed Control	1	0	@	Maxspeed Rate				
Stop	1	1	x	1	1	1	1	1
Rotate Left	0	0	1	1	1	1	1	1
Rotate Right	0	1	1	1	1	1	1	1

x — don't care

@ — "0" for normal acceleration profile and "1" for a slower acceleration profile

Table 4 Control commands for MAV's movements

Forward rate of turn (6 bits) : It is the rate that the MAV turns while still in forward motion. The larger the rate, the smaller is the turn radius. For a rate of zero, the MAV will interpret it as no turn and move straight forward. Although the data requires 7 bits but only 6 bits is use for the transmission because there are not enough bits. The Control MCU divides the rate by 2 before transmitting to the

Master MCU. Upon reception, the Master MCU will multiply it by 2 to obtain the original data.

Backward rate of turn (5 bits) : It is the rate the vehicle turns while still in backward (7 bits) motion. The larger the rate the smaller is the turn radius. For a rate of zero, the vehicle will interpret it as no turn or move straight backward. The actual rate of turn for backward = (5 bit data) × 4 = 7 bits. (Note that the resolution of backward rate is 5 bits because of the limitation in our 8 bits data. Also note that sending and receiving data should be minimize during run because of the time delay it cause.)

Maxspeed Rate : It is the rate of reduction of the vehicle's speed. The larger it is, the slower it goes. The speed reduction is done by moving back the look up table through a predetermined number of steps. The value (number of steps) is sent by Control MCU in a six bit format but due to bit constraints, the value has to be divided by 2 before transmission. When the Master MCU has received all 5 bits, it will convert the data to 6 bit format by multiplying it by 2.

CHASSIS DESIGN

4.1 Chassis Planning

The decision which we must make when designing can be divided into functional judgments and visual judgments.

4.1.1 Components of MAV

The following are rough estimation of which items are to be place inside the chassis :

- 2 ball transfer
- 1 digital compass
- 2 main wheels
- 5 veroboards
- 2 stepper motor
- 2 motor mount
- 13 push button
- 3 toggle switch
- 11 sensors

The size of every items were measured to decide their placement in the chassis. The compass had to be placed at a position higher than the motor to reduce the interference caused by the magnetic field of the motor. The ball transfer must be placed at a position whereby the weight of the chassis were equally shared.

4.1.2 Functional Judgment

The most important consideration when designing a chassis is that it should perform its intended job correctly and a careful analysis of what the vehicle has to do will provided many starting points for the design.

The following points were considered for the functional judgment :

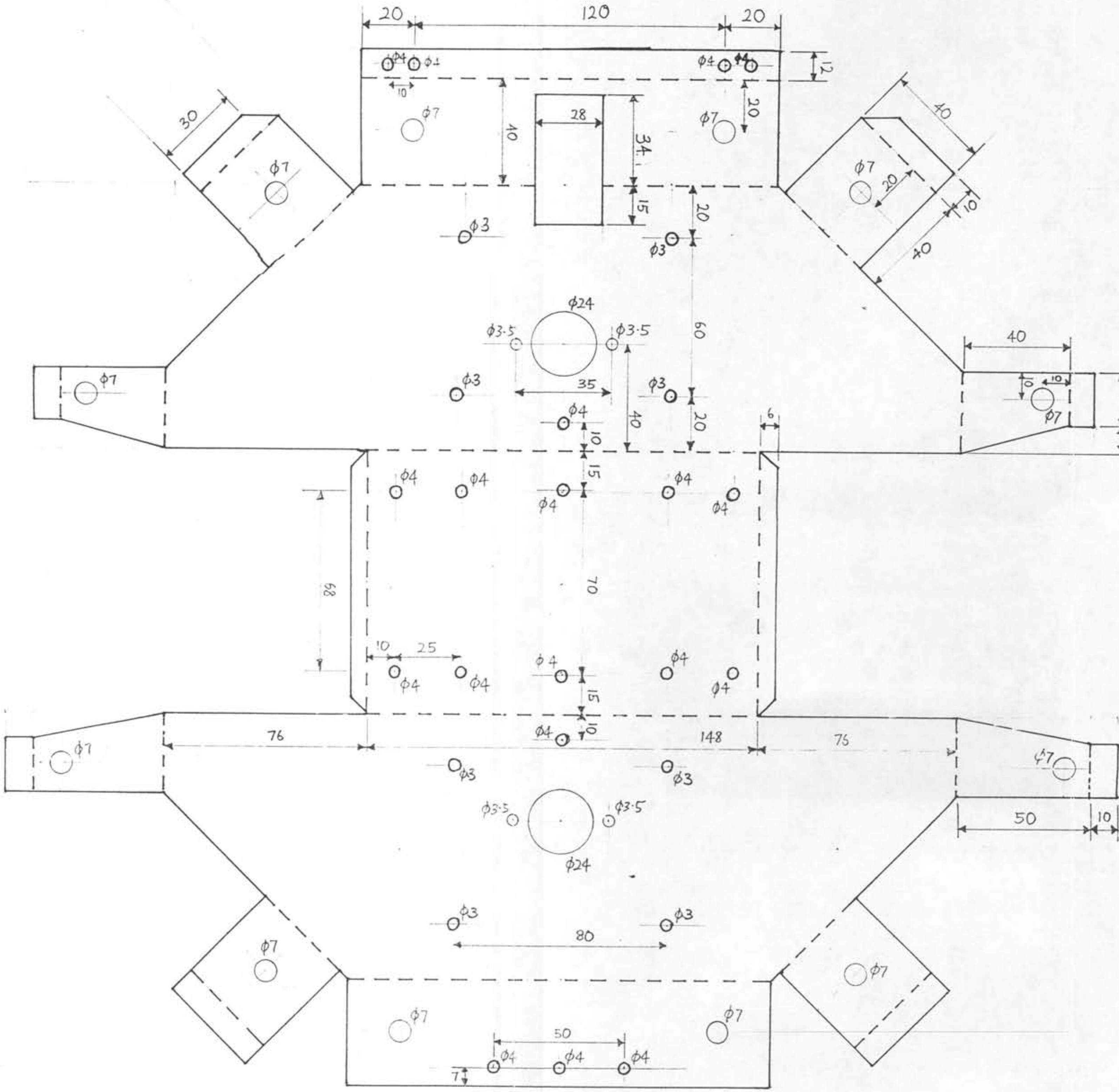
Weight	: Maximum of 5kg
Size	: Minimum of 30cm by 30cm
Strength	: Must be able to withstand the impact caused by collision with opponent robot or mines
Material	: Must be corrosion resistant
Construction	: Sheet metal bending, jointing is preferred
Cost	: Maximum of $50 per chassis
Durability	: Must be able to last for at least 5 years
Safety	: No sharp edge and corners

4.1.3 Visual Judgments

The following points were considered for visual judgment :

Appearance	: Must be presentable
Finish	: Either spray paint or normal finish
Environment	: Air-conditioned

FIONT

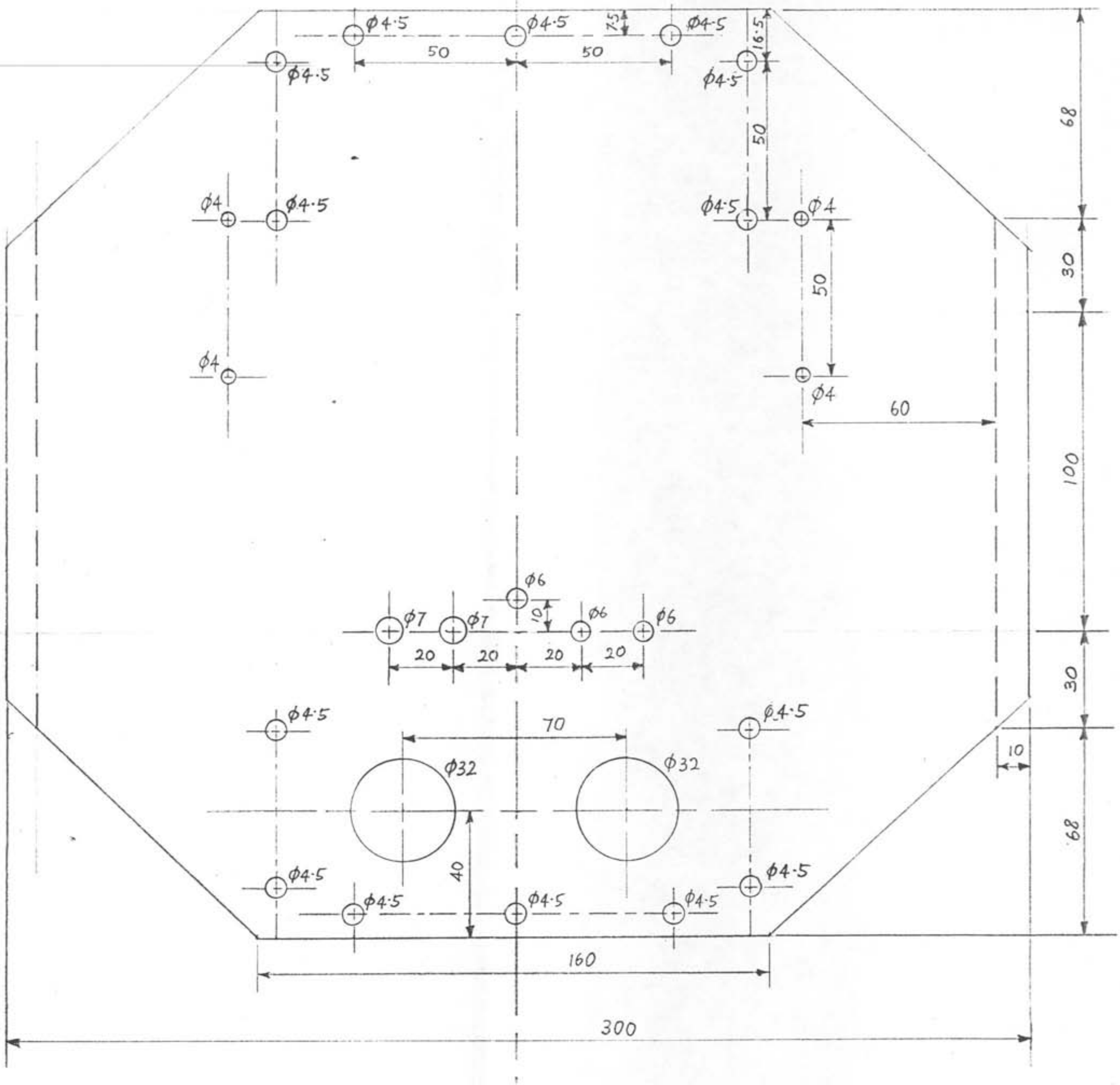


BACK

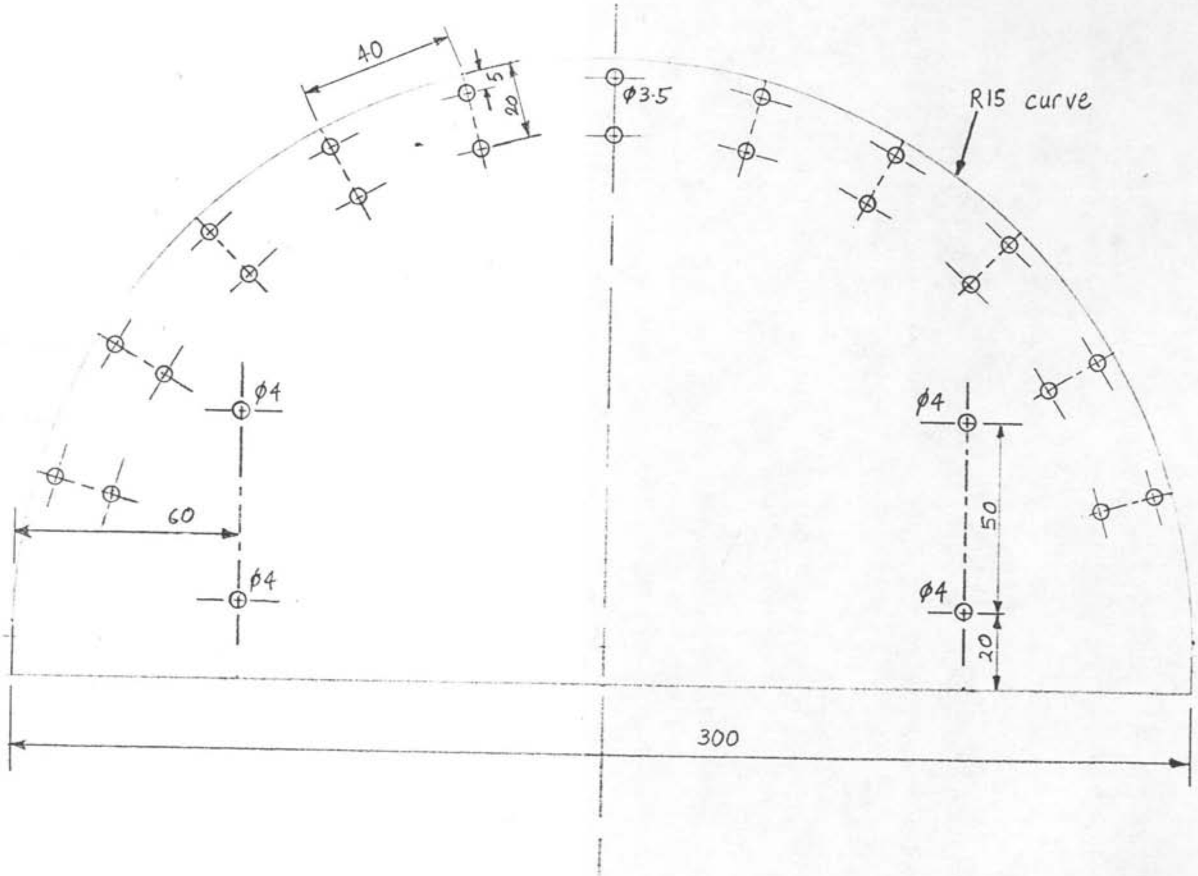
BASE

SCALE 1:2

TOP COVER SCALE 1:2

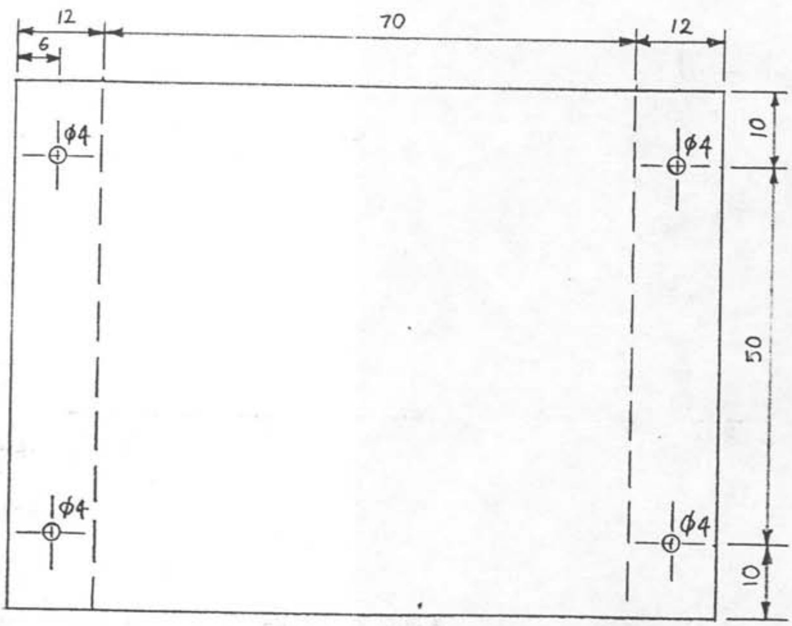


CROWN SCALE 1:2

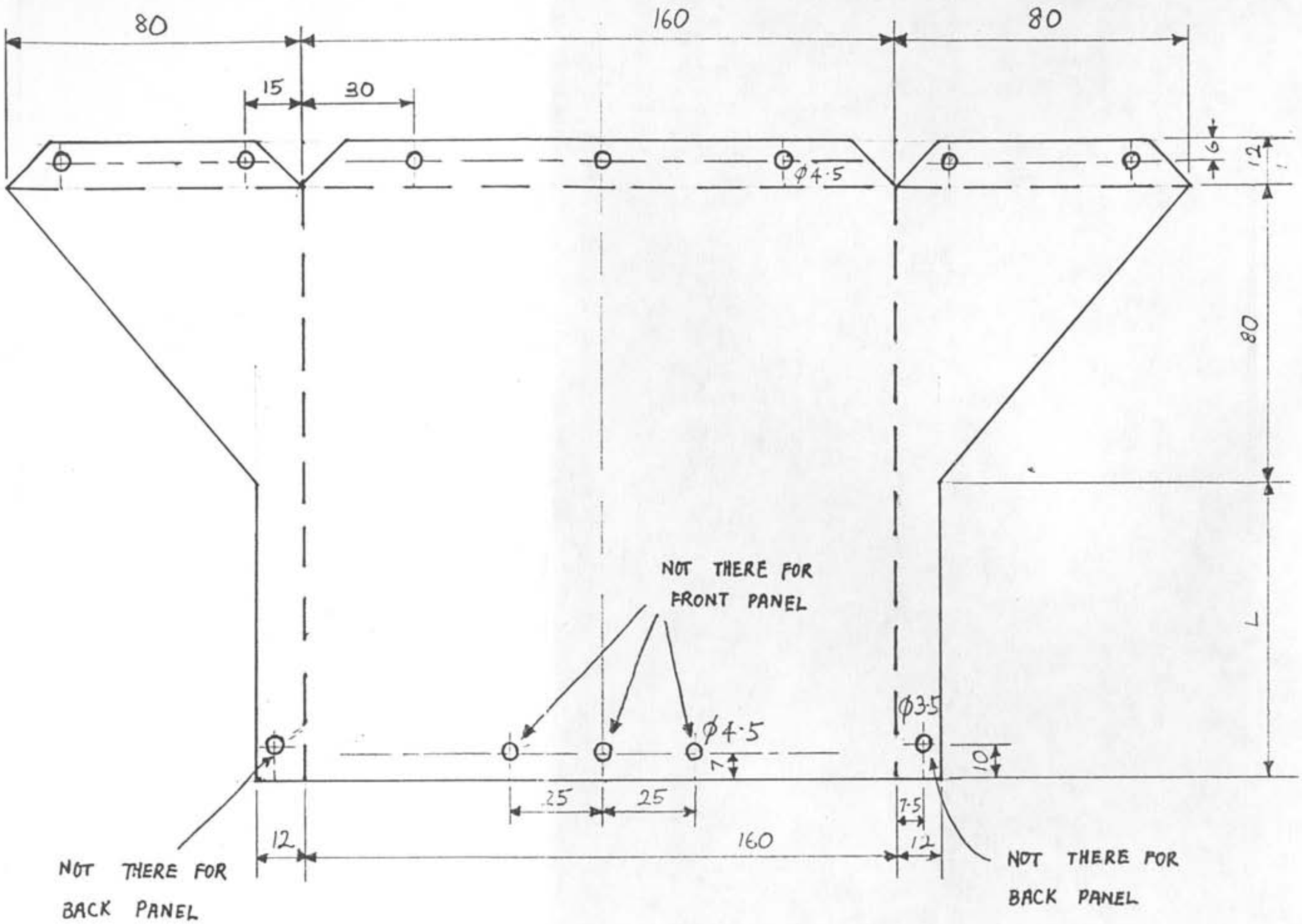


CROWN SUPPORT SCALE 1:1

×2



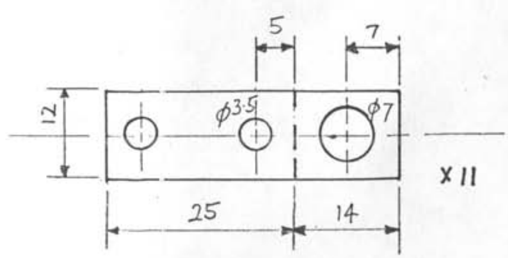
FRONT & BACK PANEL   SCALE 1:2

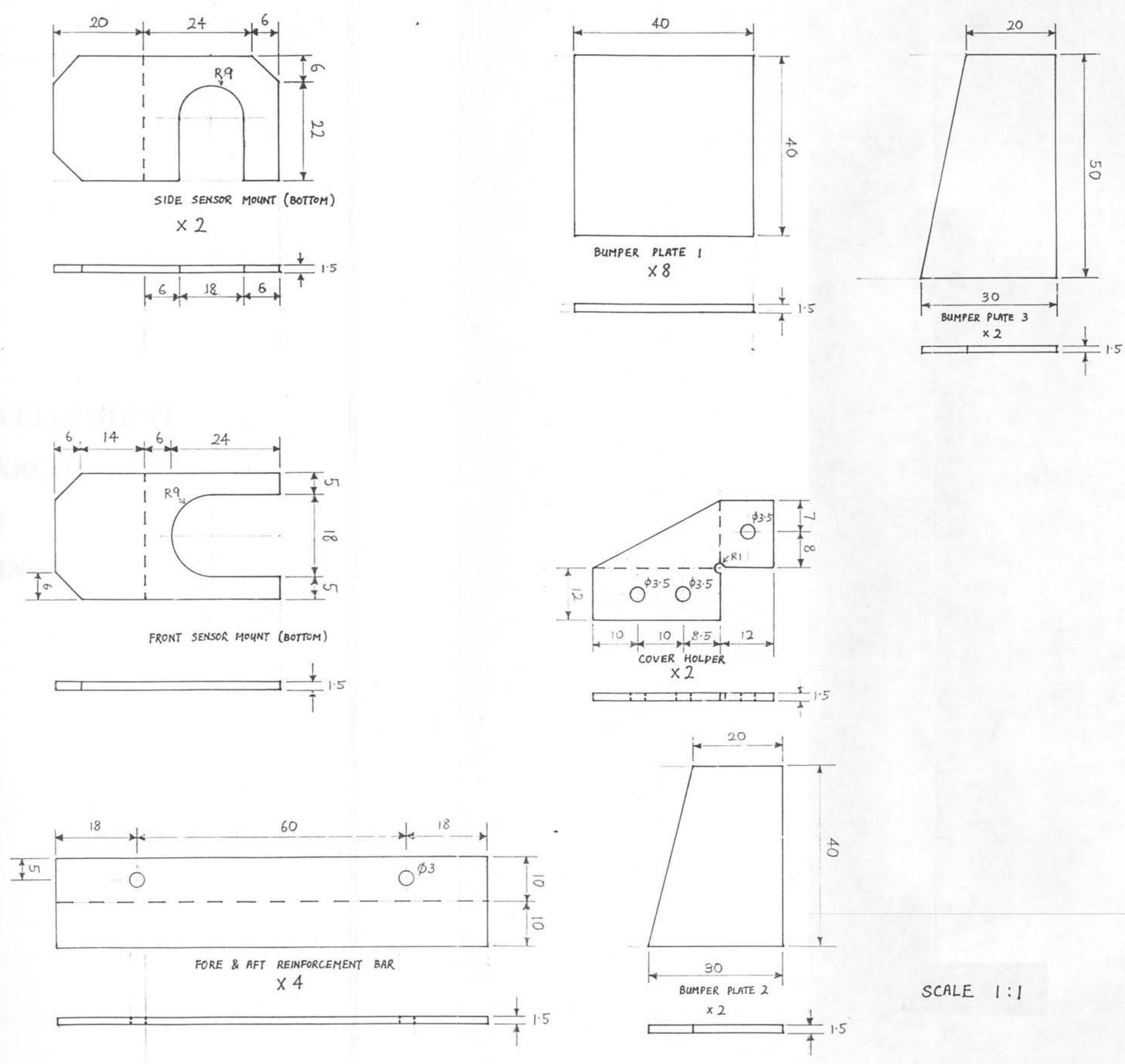


L = 85   FRONT PANEL

L = 80   BACK PANEL

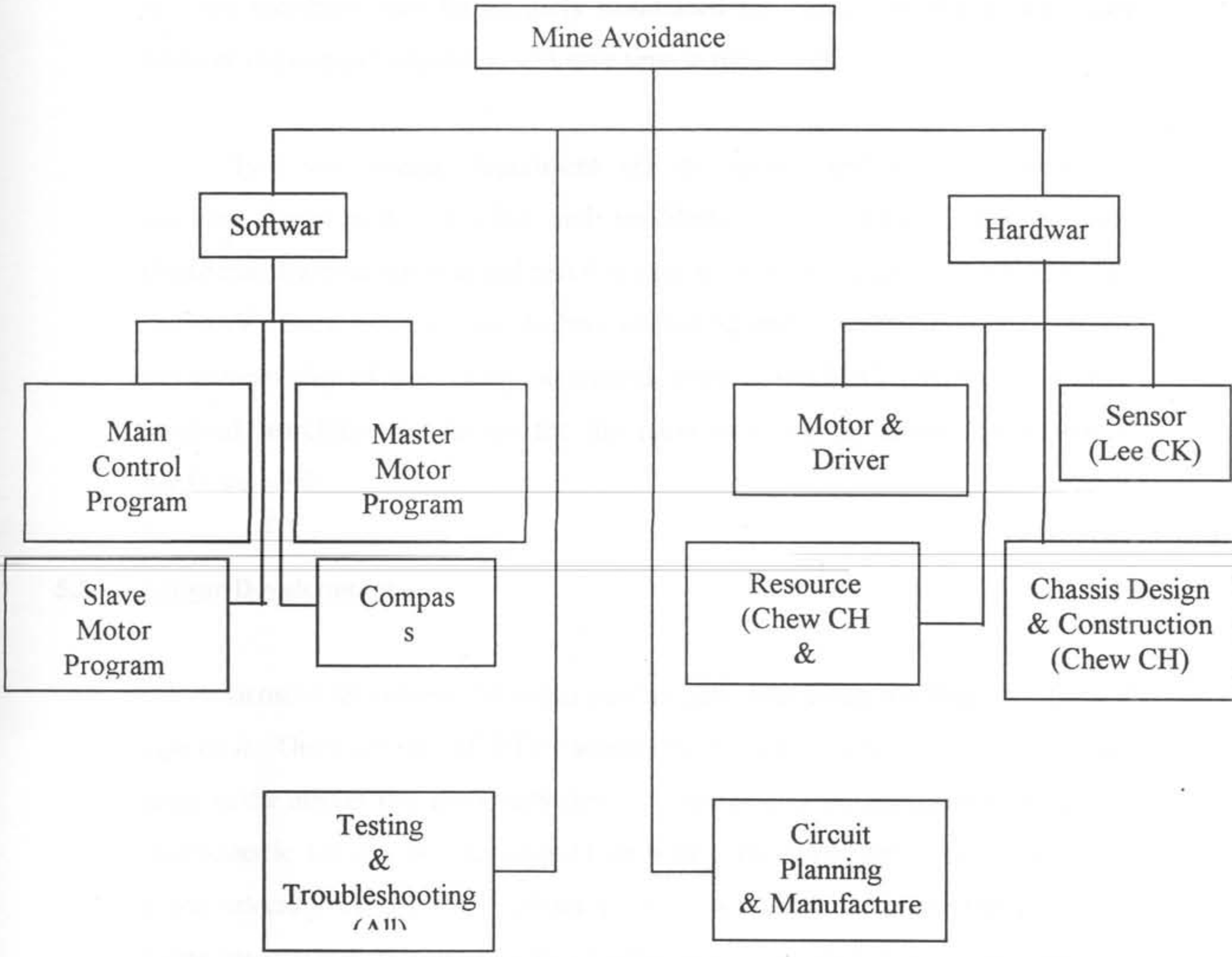
SWITCH HOLDER.   SCALE 1:1




SIDE SENSOR MOUNT (BOTTOM)
X 2
BUMPER PLATE 1
X 8
BUMPER PLATE 3
X 2
FRONT SENSOR MOUNT (BOTTOM)
COVER HOLDER
X 2
FORE & AFT REINFORCEMENT BAR
X 4
BUMPER PLATE 2
X 2
SCALE 1:1

PROJECT DEVELOPMENT
RESEARCH
&
FINDINGS

5.1 MAV Work Structure



Chew CH : Chew Chuen Hee
Lee CK : Lee Chin Kwang
Lim SB : Lim Siong Boon
Pang SH : Pang Sze Hsin

Figure 20 Components of the MAV work structure

The MAV work breakdown structure above shows the components which make up the MAV. Each person is responsible for their own portion/portions' workability, compatibility and smooth workflow. Compatibility is a very important issue in this project because without it, the program in the three microcontroller will not work, the circuit will not be efficient, the motor will not move, the chassis cannot house all the components and there would not be MAV. Communication between members must be properly maintained to gain compatibility, especially between the two programmers, and save time in the process.

Two very special department are the testing and troubleshooting and resource department. Testing and troubleshooting is shown as a separate department by itself but in actual fact it is present in every component that makes up the MAV. Each member must do his own testing and troubleshooting to maintain the serviceability of their component/components in the MAV. As for resource, it involved searching the market for the parts available to satisfy the members' hardware needs.

5.2 Sensor Development

Sensors for sensing the mines can be easily found because there is reflective tape on it. There are a lot of diffuse sensors available at a reasonable size, price and range in the market that can satisfy this requirement and one major manufacturer of photoelectric sensors is Yamatake-Honeywell. However one must be cautious about selecting the type of medium used for sensing in a photoelectric sensor. There are currently two major type of light used in photoelectric sensing and they are visible red light and infra-red. There are certain cases where visible red light may not perform as well as infra-red but this condition varies from one manufacturer to another.

Sensors for sensing black obstacle are harder to come by and cost more than normal photoelectric sensors. Normal photoelectric sensors can only detect black object without any drop in performance provided that its light beam is perpendicular to the object's surface. When the light beam hits the surface at an angle then its performance drops rapidly thereby rendering it useless. There are however some very expensive techniques offered by companies like Pepperl + Fuchs, Yamatake-Honeywell and AE Motion Controls but these methods require much better processing power which our MC68HC705C8 microcontroller does not possess. To employ such techniques, we must switch to PLC (Programmable Logic Controller) or processors that are much better than the microcontroller which we are using currently but there is one cheap method that involves discrete ultrasonic sensors. When using ultrasonic sensors there is always a danger of picking up stray echo due to the close proximity if the mines and obstacle and from neighbouring ultrasonic sensors. There are some photoelectric sensors offer by Wenglor of Germany and Banner of USA that can detect black objects but each has its weak points with respect to our project circumstances.

Sensor	Characteristic	Reason/s for not using	Seller
*HN55PA	• 10V-30V DC • Infra-red • 0.5m adjustable • Background suppression • PNP with adjustable NO and NC • Able to detect black with acceptable performance drop	• Odd shape causing difficulty in mounting • Very expensive for a photoelectric sensor • Slow delivery	Sentronics Automation & Marketing
*UJ1000-30GM-E-V1 Ultrasonic	• 10V-30V DC • Able to detect any hard object • 0.1m-1m adjustable • Output is stable even in high vibration environment	• Big and heavy • Cannot see as much of the obstacle as a photoelectric sensor that can detect black objects • Danger of	Pepperl+Fuchs

	• Fairly direct sound beam pattern	hearing stray echo signal	
*FE7C series photoelectric sensors	• 10V-30V DC • Good light beam directivity • Infra-red • Adjustable range • Steady output	• Not up to requirements for sensing black objects but good for sensing mine	TDS Technology (S) Pte Ltd

* Sensors in this table was not selected for use due to our project circumstances but do not exclude them for consideration in future MAV.

Table 5 Sensors not chosen for black obstacle sensing

List of sensors rejected by previous group :

- Infra-red (Omron)
- Ultrasonic Parking Sensor (Velleman sold by Sinta at Sim Lim Tower)
- Integral Amplifier and Infra-red (RS component)

5.3 Compass Development

Compass development was categorized under software because writing a program that could get the reading from the Vector 2X is a must. We had to design a program so as to verify that the readings that we obtained from the compass were not erratic. Bit manipulation and detection of the rising edge was very important in compass development. Researching the compass module also made us understand some of the things that were not taught in the syllabus. We gained precious knowledge about the limitations of the EVM board, the process involved in downloading a program to the MC68HC705C8 microcontroller and some of the tips to debugging a program.

The compass reading was being output from the SDO pin serially. Thus we need to take them in bit by bit and store them in a memory before the data could be processed. This was where bit manipulation and detection of the rising edge came in.

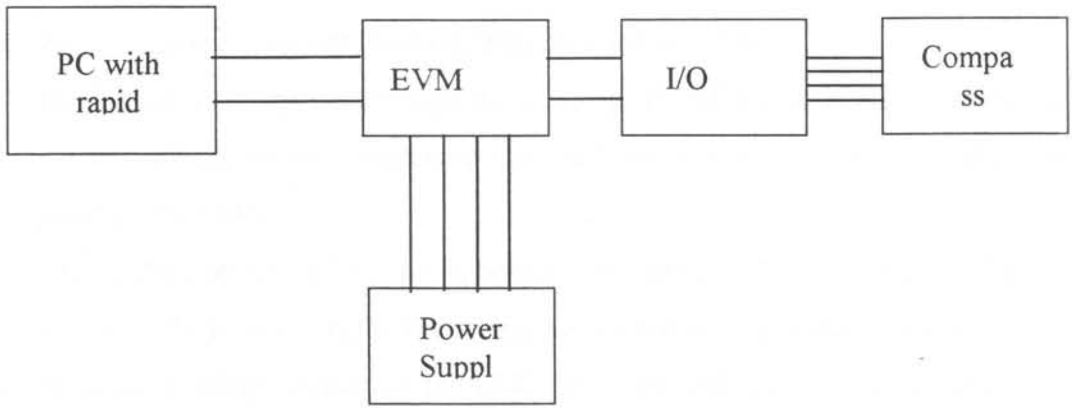


Figure 21 EVM setup for compass development

We hooked up the EVM board with the digital compass to simulate the program and for debugging purposes. The EVM board is a board that contains a 6805 chip and it's main purpose is to simulate the program before program is actually burned into the EPROM of the 6805.

A simple I/O board is build by us because we could not loan in out. The purpose of the I/O board is to tell us what is going on in the program by displaying the status through ports that are connected to LED packs. In this way, we got to see every step of the program and makes debugging of program easier. The 4 wires from the I/O board are TCAP for detecting rising edge and 3 pin from any of the 6805 ports.

The power supply box that was loaned is not very reliable. Some of the output voltages 5V, 12V, -12V and 0V are not always present. This sometime causes the EVM board to malfunction. Normal error message like "EVM board not responding" will be shown on the screen of the PC whenever the EVM board does not get the necessary supply voltages.

Steps to get data :

1. Store all the serially clocked output from the compass.
2. Manipulate them in the registers
3. Store them in 2 memory location, high byte and low byte.
4. Display the readings out through the ports eg. PORTA and PORTB. There are 10 bits of information therefore we need more than 1 port to display the readings by LEDs.
5. The reading on the LED can only be seen after pressing the Master Reset button on the EVM board. This is something we learned during research stages.
6. Read the readings shown on the LED. Is it the real reading? Confirm this by comparing the result with the analog compass.
7. The next step should be polling the compass for a continuous reading. In this way when we shift the compass around, the LED should change too. Direction has changed and the output is always loaded into the ports. This shows that it is working.
8. Utilize the data. How do we want to process the data? Processing the reading, subtraction, addition is not an easy task. Creativity, originality and common sense play an important role.
9. We noticed that the compass outputs the data at slow rate. This pose a problem when accuracy and speed is of importance.
10. Avoid touching the coil of the Compass. It breaks easily.
11. Master reset the compass upon power up. Subsequent reading should be accurate.

5.4 Stepper Motor and Driver Development

Stepper motor has special features that allow user to control with ease due to the fact that it works with electromagnet rather than permanent magnets that are commonly found in DC motors. Each of these permanent magnets energized at a different time according to the frequency of the input clock causing the motor shaft to move a tiny bit at a time. However stepper motors are not as powerful as DC motor of equivalent size but its ease of control cannot be surpassed by DC motors. As for our application, we manage to find a stepper motor that suited us both in size and torque therefore we chose the Vexta PK268-01B stepper motor.

5.4.1 Features of a Stepper Motor

1. The rotation angle of the motor shaft is directly proportional to the number of input pulses and its angular velocity is directly proportional to the frequency of the input pulses.
2. The angle error per step is very small and non-accumulative.
3. Rapid response to starting, stopping and reversing.
4. Open loop control is sufficient due to the high accuracy of stepper motor.
5. Self-holding capability when there is no clock input eliminate the need for brakes.

5.4.2 Terms Regarding Stepper Motor

Torque Speed Curve

A plot of torque against speed(e.g. pulse per second). Every motor has got a different torque speed curve (curve comes together with every stepper motor).

Holding Torque

The maximum torque created by the angle displacement that can be externally applied to the shaft of the stepper motor which is energized at its rated voltage.

Step Angle

The nominal angle through which the shaft of a stepping motor turns in response to one pulse signal. It depends on the structure of the motor and the excitation mode (half-step/full-step).

Start-Stop Region

The region in which a stepping motor can start, stop or reverse in synchronism with the external pulse signal.

Maximum Starting Pulse Rate

The maximum frequency at which a stepping motor can start, stop or reverse in synchronism with the external pulse signal.

Pull-In Torque

The maximum torque at which an energized stepping motor will start and run in synchronism with the external pulse signal. It is developed when the motor starts in the start stop region.

Pull-Out Torque

The maximum torque that can be applied to the shaft of the stepping motor without loss of synchronism, even when there is a gradual increase in frequency.

With this terms in mind we can conclude that the speed and torque is very important in the selection of stepper motor. We need to find the torque that is to be applied to the shaft of the motor. We can then roughly determine the type of stepper motor that we need. To select one, we will have to look at the torque speed curve given in the motor specification. The torque speed curve will show the speed of the motor that will rotate with the amount of torque applied to it. The speed and torque is where we need to invest on.

5.4.3 <u>Steps of Selecting Stepper Motor</u>

1. Determine the vehicle's weight.
2. Find the maximum torque that can be applied to the vehicle.
3. Decide the speed of the vehicle.
4. Choose a stepper motor from motor catalog that satisfy the torque and speed requirement

5. Make sure that voltage and current of the stepper motor is within your supply capability.

Step 1:

The estimated mass of the robot is tabulated below.

Item	Unit Weight	Quantity	Total Weight
Battery	0.4kg	1	0.4kg
Stepper Motor	1kg	2	2kg
Motor Mount	0.11kg	2	0.22kg
Drive Wheel	0.1kg	2	0.2kg
Chassis	1kg	1	1kg
Miscellaneous	0.5kg	1	0.5kg
		Grand Total	4.32kg
		Weight to use	5kg

Step 2:

Estimated mass — 5 kg

Diameter of drive wheel (d) = 0.105m

Coefficient of friction (μ) $\approx$ 0.5

Acceleration of gravity (a) $\approx$ 9.8 ms^{-2}

Force to be acting on 1 drive wheel = (Mass $\times$ a) / No. of drive wheels

= (5 kg $\times$ 9.8) / 2

= 24.5N

Maximum possible torque on 1 drive wheel = μ $\times$ radius $\times$ 24.5N

= 0.5 $\times$ (0.105 / 2)m $\times$ 24.5N

= 0.643125Nm (6.5579kgcm)

The calculated maximum possible torque that can be applied on one drive wheel is usually lower than the practical values because the coefficient of friction is usually higher. Therefore a stepper motor of maximum torque that is twice that of the calculated value can usually be safely used. From the above value we can roughly said that two Vexta PK268-01B stepper motor is able to drive the robot satisfactorily.

Step 3:

Targeted Speed — $2ms^{-1}$

Vexta PK268-01B provides full-step and half-step operation. Full-step operation requires 200 clock pulse to complete one revolution while half-step operation requires 400 clock pulse to complete one revolution but half-step offers better speed vs torque characteristic therefore half-step operation is selected.

Diameter of wheel = 0.105m

Circumference of wheel = $\pi \times 0.105$m

= 0.329867m

One step of motor (Half-step) : 0.9°

One revolution $\equiv 360° \div 0.9^0 \equiv 400$ steps

Distance moved in one step = 0.329867m ÷ 400

= 0.8246675mm

Frequency of clock pulse required for $2ms^{-1}$ = (2m ÷ circumference of wheel) × 400

= (2m ÷ 0.329867m) × 400

= 2425Hz

After determining the speed required in Hz, we can go on to confirm whether the stepper motor can be used by checking the corresponding torque of the frequency on the speed vs torque curve. If the value still stays at or around the value of maximum torque that can be applied to one drive wheel then that motor can be used.

Step 4:

The torque speed curve of each motor in the catalog will clearly show the stepper motor operating region. Compare the values of the torque and speed on the curve of the catalog and there should be one that is within the specification.

Step 5:

Check that the maximum current of the motor is within acceptable value by dividing the capacity of the battery in Ampere Hour by the current value. The duration in hours must meet the user's requirement or else the motor cannot be used at all.

5.4.4 Driver Circuit

Most stepper motors will have its own compatible driver circuit that is specially built for it and it is usually very expensive. For the benefit of our study we decided to go on with the driver used by the previous group first before making any decision to change the driver. The previous group's MAV could only move at 700Hz because the two L298 were not properly cooled and the oscillator of L297 was very unstable. These made the driver very unreliable and performed poorly but after some extensive rewiring we were able to get the speed up to 2000Hz.

With the use of L297 and L298 chip the use of complicated logic to generate both full and half-step driving signals is avoided. Using these ICs, there is only four signals involved in direct control of the stepper motor that we need to control for all operation of the stepper motor.

Clock : Square wave in TTL level input and its frequency will control motor's speed.

Control Lo to activate inhibit chopping and Hi to activate phase chopping.

Direction : Controls the motor shaft's direction of rotation.

Half/Full : Hi to activate half-step and Lo to activate full-step.

Of the four signals mention above, only Half/Full was not controlled by the microcontroller because half-step was our permanent choice of operation.

The stepper motor is configure as half step(0.9°)control. The reasons are :

- Higher resolution.
- Higher torque
- Decrease the effect of resonance (no torque in certain frequency).

5.4.4.1 Vref

Vref is an implementation of chopper current control in the L297. When driver circuit is activated, the supplied current from the L298 to the stepper motor winding will rise, following the L/R time constant curve in Figure .

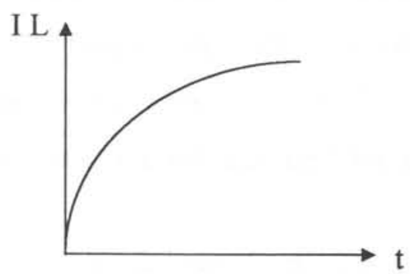


Figure 22 Waveform of winding current

The current will rise until the voltage across sense resistor (pin 1, 15 of L298) is equal to the reference voltage input (Vref). When this occur, the current in the winding drop to zero causing the voltage across the sensing resistor to reach 0V as shown in Figure .

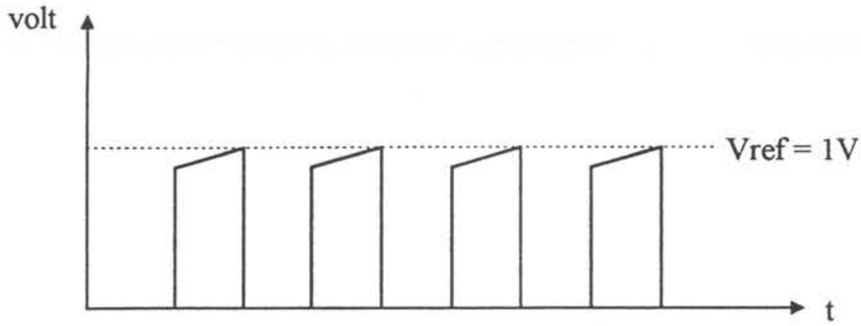


Figure 23 Voltage waveform across R sense.

More winding current means more motor torque so if Vref is less than 0.8 volts the torque will be less, this may cause motor to loss torque while accelerating and cruising.

5.4.4.2 Rewiring of L297 & L298

Rewiring the L297 and L298 circuit board involved repositioning the ground, 24V and 5V wires and addition of filters to attain oscillator stability. The whole idea was to avoid any potential difference in the ground of L297, L298, L6210 and the motors' ground. Whenever possible, we try to avoid bunching up the ground wires before returning to the battery to prevent loop buildup which can cause potential difference. The ground of the 24V and 5V was separated by connecting the 5V's ground to the voltage regulator and the 24V's ground to the battery's negative terminal.

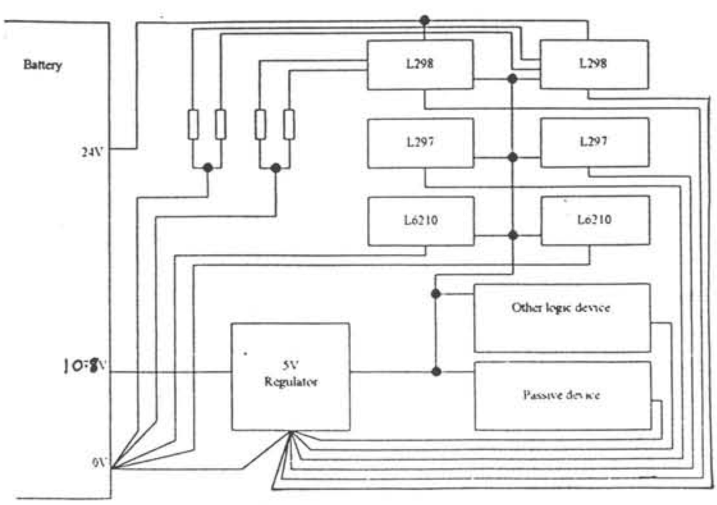


Figure 24 Concept of rewiring L297/L298

TROUBLESHOOTING

6.1 Troubleshooting List of L297/L298 Driver

Fault	Cause
Fuse Burnt	• Short circuit • Transistor in L298 is damage
Motor does not move	• Motor is damage • L297 and L298 not powered up • L297 not producing A, B, C, D, INH1 and INH2 for L298 • L298 did not receive A, B, C, D, INH1 or INH2 from L297 • Motor not connected properly • Battery weak • L297 not enabled
Motor does not accelerate properly	• Check whether oscillator waveform (L297 pin 16)is disturbed • Acceleration profile not suitable for MAV's weight • Wrong motor choice
MAV not turning properly	• Ball transfer not turning freely
MAV did not respond correctly to the program	• Check the output of sensor interface to microcontroller for spikes • Check power supply for stability • Sensor detected some other shiny object eg. floor
MAV skid to one side when stopped	• Both clock to the L297 was not removed at the same time
MAV did not aligned properly	• Delay not calculated properly • Compass damaged
Supply voltage drop rapidly when battery is connected	• Battery is not fully charged

6.2 Troubleshooting List of CSD2120-P Driver

Refer to CSD2120-P operating manual in Appendix

CALIBRATION
&
USER MANUAL

7.1 L297/L298 Stepper Motor Driver

The torque of the stepper motor can be controlled by the two L297 ICs. On this 20 pin IC, pin 15 or the Vref controls the torque of the motor. If more torque is required, the value of Vref can be made higher but not exceeding 1V.

The value of Vref is controllable by means of a potential divider. A 22K resistor in series with a 100K potentiometer forms the potential divider.

By using a screwdriver to adjust the value of the potentiometer will change the Vref and thus the torque of the motor. The Vref for both the left and right motor are set at a maximum of 1V.

7.2 CSD2120-P Stepper Motor Driver

Refer to CSD2120-P operating manual in Appendix

7.3 Sensor Sensitivity

All sensors used in the MAV can be easily adjusted by a potentiometer found on the body of the sensor.

7.4 Rapid Software

Each time when a source code is written and assembled, a S19 extension file will be generated. To test the workability of the program, the assembled file can be burned into the EPROM or downloaded to the EVM board. It is recommended to use the EVM board for testing as the designer can edit and try out programs in a more easily and convenient way without having to burn the program into the microcontroller EPROM over and over again. In this way, it will extend the lifespan and improve the reliability of the EPROM.

7.4.1 Installation of Rapid Software

The following procedures are used to install the rapid software.

Step 1 : Insert diskette into the 3.5 diskette drive

Step 2 : Create a directory first, etc. 6805 directory

MD 6805

Step 3 : Enter the following command at the DOS prompt :

Copy a:*.* c:\6805

Note : One installation diskette available

7.4.2 Simulation Using EVM and I/O Board

An EVM board (Evaluation Module) is a tool for designing, debugging and evaluating microcontroller based target system. It can provide all the essential microcontroller timing and I/O signals. By connecting to a microcomputer, an assembled program can be loaded into the EVM board through the serial cable. The program in the EVM board memory can be executed and the EVM will provide the control signals to the target system as the program runs. The I/O Board is connected to the EVM Board through a 40-pin connector. Each pin carries a microcontroller pin signal. From this connector, ports signals from the microcontroller are connected to LEDs and dip switches through buffers and resistors.

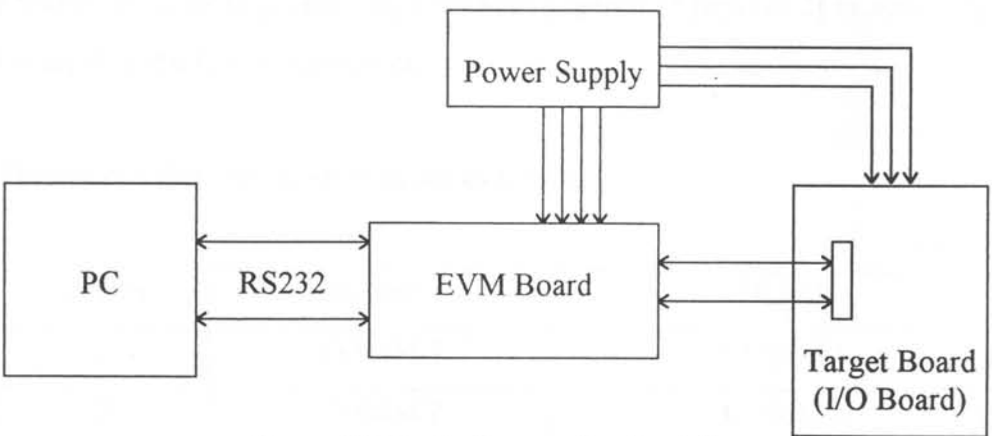


Figure 25 Block diagram for simulation unit

The supply voltages needed for the EVM Board are :

- one +5 volt
- one +12 volt
- one -12 volt
- one 14.5 volt

The supply voltages needed for the I/O Board are :

- one +5 volt
- one +12 volt
- one -12 volt

7.4.3 Compilation of MC68HC705C8 Programs

The program is first written by any text editor but must be saved with file extension ASM. It is then assembled using the assembler AS5.exe or activating the F4 key at the rapid text editor to generate a S19 file for downloading. If there is any error in the program, it will be highlighted at the top of the screen. After compilation, the S19 file can then be downloaded to the EVM for simulation..

7.4.4 Starting the EVM

EVM05 is a front end processor for Motorola M68HC05EVM emulator. It runs on an IBM PC or compatible using either COM1 or COM2 Port. To start EVM05 at the DOS prompt, type **EVM05 [option 1] [option 2]** or activating **F6** at the rapid text editor environment.

The options that may be entered are as follows :

Option	Meaning	Default
1	COMM 1	COMM 1
2	COMM 2	COMM 1
C	M68HC05Cx	M68HC05C

P	M68HC05Px	M68HC05C
H	M68HC05Hx	M68HC05C
T	M68HC05Tx	M68HC05C
M	M68HC05Mx	M68HC05C
#	Monochrome	Color

Table 5 Options of EVM05

At the EVM environment, there are eight primary windows and three secondary windows. The eight primary windows are :

The CPU window	This window shows the current values in the Accumulator, index register, Stack Pointer and Program Counter.
The Break window	Four user break points are shown with their current values. A value of XXXX means that the break point is not set.
The PORTS window	The current value of Port A through D and their respective data direction registers are shown in this window.
The CCR window	The current value of the CCR is shown in binary
The STACK/TIMER/SE-RIAL window	This window can be toggled between showing the current stack, the timer register values and the serial register values. The timer itself is shown as ** since it is free-running and continually changing.
The CODE F2 window	This window displays disassembled code at the current PC (highlighted in the second row)
The MEMORY F3 win-dow	This window displays the current values of 64 consecutive memory locations in both hexadecimal and printable ASCII. The window

	may also be set anywhere in memory from the DEBUG F1 window with the MD or SHOW commands.
The DEBUG F1 window	This is the main "command" window. All commands are entered here. To return to this window from the CODE or MEMORY window, hit F1.

Table 6 Eight primary windows

The three secondary windows are :

The VIEW F5 window	This window let you view any ASCII file on your disk. You are prompted for a filename and allowed to scroll the window. The primary reason for this window is to look at the code listing.
The LOG FILE window	This window let you create or append to an already existing file any ASCII text. It's main purpose is to use it as a note pad for changes to be made to your code. It will time and data stamp the file whenever it is opened.
The DUMB TERMINAL window	This is a really dumb terminal emulator. You enter it by typing the command TERMINAL in the debug window. You now have complete the direct access to the EVM. To leave your EVM05 software, you should enter the TERMINAL window and try communicating directly with the EVM board. This will tell you if the problem is with the board or the interfacing software.

Table 7 Three secondary windows

Hot Keys

Hitting these hot keys will perform the following instructions :

- F1 : Go to Debug window from Code or Memory windows
- F2 : Go to Code window from Debug window
- F3 : Go to Memory window from Debug window
- F4 : Toggles between Stack, Timer and Serial windows
- F5 : Bring up File viewing window
- F6 : Bring up Log file window
- F9 : Repeats last command entered into Debug window
- F10 : Shows help screen

7.4.5 EVM Debugging Commands

The followings are the commands you may enter in the DEBUG F1 window. Square brackets indicate an optional parameter. Note that 'add' is a valid address and may be replaced by a label in most instructions if a MAP file has been loaded.

ASM [add]	Virtually the same as that built into the EVM. If a map file has been loaded, a label may be used where appropriate.
BNB [add]	Sets a break point. n is the number 1, 2, 3 or 4. The address is a hexadecimal number or if a map file is loaded, a symbol. To remove a break point, do not specify an address.
B1 105	Sets break point 1 at address $105.
B2	Removes break point 2.
B3 loop1	Sets break point 1 at label loop1.
BF	Same as in EVM.
BULK	Same as in EVM.
CHCK	Same as in EVM.

CODE add	Shows disassembled code in the CODE F2 window starting at address add.
COPY	Same as in EVM.
EVAL n[op][n]	Does simple math. Entering just a number will show the hexadecimal, decimal, octal and binary equivalents. You may also enter +, -, *, /.
EXIT, QUIT	Returns to DOS.
G, GO, RUN [add]	Same as in EVM.
GOTIL add	This command automatically sets and removes break point in the EVM. You specify the end address. The go from address is the current PC.
LOAD	Loads the file specified into the EVM. You will be prompted for the filename. The file must be in S19 records.
LOADMAP	This command loads a symbol map. You will be prompted for the file name. The file extension is forced to .MAP for consistency. The map is either created by the IASM05 cross-assembler from P&E Microcomputer Systems or by the included program "MAKEMAP.EXE". In order to use MAKEMAP, first assemble your code with the MOTOROLA freeware assembler AS5.EXE. When assembled with the -S option, a symbol table and only this one may be used with MAKEMAP. At the DOS prompt, type **MAKEMAP filein fileout**
	Where filein is the symbol table and fileout is the file that will contain the MAP file. Note that IASM05 will quickly and automatically make compatible .MAP files. Loading a second map erases the first. Once a map is loaded, the symbols may be used as any other number.
LOADALL	This command is equivalent to both a LOAD and a

	LOADMAP.
MD, MEM add[n]	Similar to the EVM entering MM[add] or MEM[add] will cause prompts and let you change values of memory locations. If you also enter a value on the line, just that value will change with no further prompts. Several consecutive values may be given separated by spaced.
P[n]	Same as in EVM
PROG	Same as in EVM
SPEED	Same as in EVM
STEPTIL add	
SYMBOL sym add	This command adds a symbol to the symbol table. The symbol must be less than 16 characters long.
T, STEP, ST[n]	Same as EVM
TERMINAL	Enter DUMB TERMINAL mode. This mode is exited by hitting the < ESC > key.
WHEREIS sym WHEREIS add	This command will return the address of a symbol. If it is in the currently loaded map or will return the symbol at an address.

Table 8 List of commands in EVM05

7.4.6 <u>Downloading Program to EVM Broad</u>

The following steps are to be followed for downloading the S19 program.

Step 1 : Switch to DEBUG F1 window.

Step 2 : Type "LOAD FILENAME.S19" to download S19 file from PC to EVM.

Step 3 : Type "PCXXXX" to let program counter begin at XXXX.

Step 4 : Type "GO" to run the program.

7.5 Protel Software

From the beginning of designing the schematic drawing to the final development of the artwork for fabrication, it involves several tedious and complicated steps. The following section will provide guidance and procedures in using the PROTEL software.

7.5.1 Installation of Protel

STEP 1 : Insert diskette 1 to the 3.5 diskette drive.

STEP 2 : Create a directory first, etc. PROTEL directory at the DOS prompt.

MD PROTEL

STEP 3 : Enter the following commands at the DOS prompt :

Xcopy b: c:\PROTEL /s

STEP 4 : Repeat the previous step for the rest of the diskettes.

7.5.2 Usage of Protel

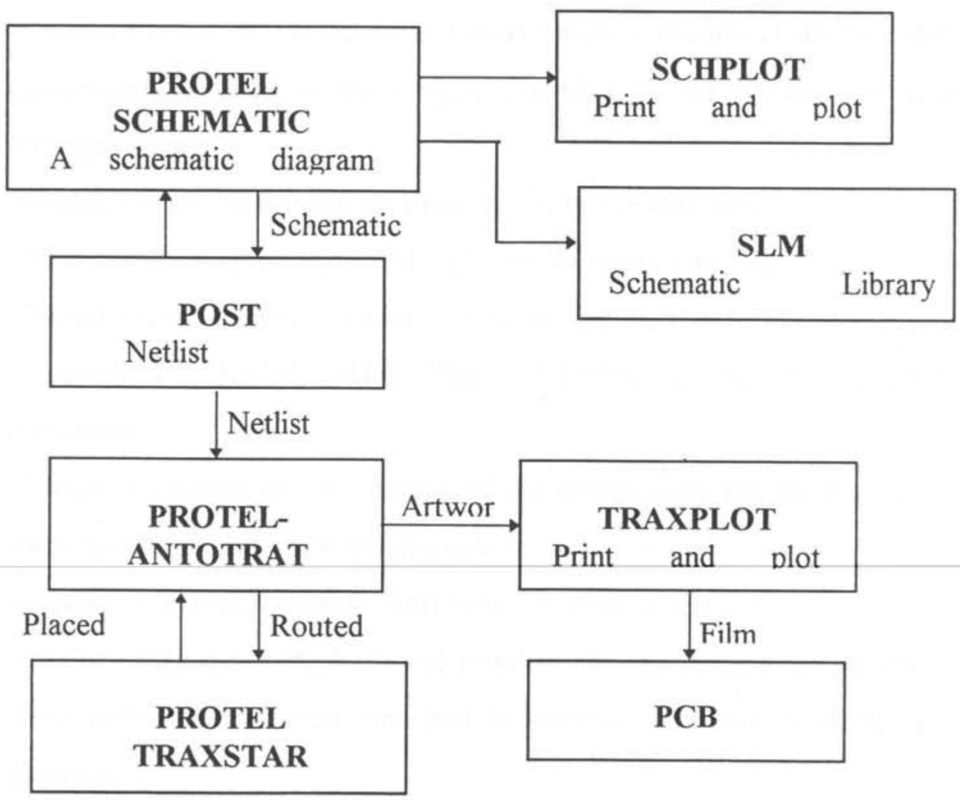


Figure 25 Overview of Protel

Steps For Converting Schematic Diagram To PCB Layout

1. Execute schedit.exe inside the directory <protel\schedit> at DOS prompt to run schedit program.
2. Complete drawing and editing the schematic diagram <Edit> <Component> to ensure that every component has appropriate package, eg. 4 PIN should have sip4 or fly4.
3. Save the diagram as filename XX.S01.
4. Execute post.exe at DOS prompt to convert the schedit file to other files, which are required for <Netlist> in traxedit program Schematic File Name > XX
   Output File Name > XX
   Files of XX.bom, XX.net, XX.rep, XX.wir will appeared in the directory.
5. Edit XX.rep at DOS prompt to check for any error in the schematic diagram, correct them in schedit program and repeat step 3 until there is no error before continuing.
6. Execute traxedit.exe at DOS prompt to run traxedit program.
   To begin, <Place> <Track> on the keepout layer as well as the board layer. Try to make the size of the board as big as possible enough to accumulate all the components. Cut it to appropriate size after all the components have been arranged properly.
7. <Netlist> <Get Nets> with filename of XX.net to load the nets.
8. <Netlist> <Auto-Placement> <Load Components From Netlist>.
9. <Netlist> <Show Nets> <Show All> to display the green connections among all components. <Netlist> <Hide Nets> <All Nets> if you find the connections distracting.
10. <Move> <Componen> to arrange all the components for the ease of manual-routing with the guidance of the green connections.
11. <Netlist> <Optimize Select> <All Nets> to arrange the nets.
12. <Netlist> <Route> <Manual> and select to the appropriate net so that you can route individual net from one pad to another, you will find this green net disappears.
13. <Move> <Break> or <Drag End> to change the placement of this track.

14. <Edit> <Track> and change the top layer to bottom layer or vice versa if you feel necessary.
15. Go to <Setup> and <Toggle Layer>. Turn off the bottom layer and then check the top layer connection for any shorting of tracks. Next, do the same for the other layer. Turn on the bottom layer and turn off the top layer and then do the check.
16. Check that the spacing between the components to ensure that they are accurate.
17. Save file as XX.pcb and plot.

7.5.2.1 Plotting of Schematic Diagram

Executing File : Schplot.exe

Printing File Extension : *.S01

Using the program, one is able to plot or print the schematic diagram on a piece of paper.

1. Loading the desired file to be printed
   >> File
      >> Load
2. Setting the output parameters
   >> Option
      >> Title block (On/Off)
      >> Border Plot (On/Off)
      >> Pin Numbers (On/Off)
3. Selecting the type of printer /Plotter used and determine the size of drawing
   >> Setup
      >> Plotter
      >> Printer
         >> Type (Ensure printer driver file - *.drv is present)
         >> Scale (Normal/Reduced drawing)

7.5.2.2 Creating PCB Layout

Executing file : Traxplot.exe

Printing File Extension : *.pcb

Using the program, one is able to plot or print the PCB layout on a piece of paper.

1. Loading the desired file to be printed.

   >> File

   >> Load

2. Setting the output parameters.

   >> Option

   >> Type of plot (Check Plot)

   Ensure that it is check plot.

3. Selecting the type of printer/plotter used and determine the size of drawing.

   >> Setup

   >> Check Plot (Toggle layer to be printed)

   >> Scale

When toggling the layers to be printed, ensure the keepout layer is always "ON" and the top overlay is "OFF". The scale can be set to 1:2 or 1:4, however ensure that scale is 1:1 for actual PCB plotting.

If the board is sent for outside fabrication, these are the necessary files to generate :

<Top Layer>

<Top Overlay>

<Top Solder Mask>

<Bottom Solder Mask>

<Drill Guide>

The Executing file is : Traxplot.exe

1. Under option <Setup>,

   >>Device : (Filename) need to be change to the directory where your XX.pcb is.

2. In order to generate the required postscript of the required layer, you need to go to <Options>, change the type of plot : <layer> to the required layer.

3. For generation of postscript file, go to <Postscript> and follow the instructions in it. The required extension filename will be generated. For example : Top layer postscript <XX.STL>.

All these files will be needed by the fabrication company.

Note : 1000 mil = 2.54 cm

All measurements in Protel program are in mils

CONCLUSION

Overall, the project was a success. We had met the basic requirement for the competition and added in certain features of our own. We also made it into the COMMEX.

Taking SRG as a project makes the project different from others. Other non-competitive projects and industrial projects had either finished or reached the final stage of their project and were waiting for COMMEX. For the SRG team, we could not afford to slack behind. We continued to upgrade and further improve the present situation so that we could have greater chance of winning.

After the submission of the report, our team got back to the project to see if there were any room for improvement. We hope to make the robot faster, smarter and much more reliable.

8.1 Recommendation for Future Development

1. Change the present MC68HC705C8 microcontroller to 80196 microcontroller from Intel which the micromouse is using. This microcontroller has been used by micromouse for quite some time and the whole circuit which they are using makes them very self-sufficient. Further more the code used by Intel is much better than those used by Motorola and the 80196 is four times faster than the MC68HC705C8.
2. Convert the MAV into a geared-drive instead of the present direct-drive.
3. Use DC motor for driving the MAV because it is much stronger than a stepper motor of the equivalent size.
4. Build a round chassis for the MAV because it is the most efficient shape for the competition.
5. Upgrade the sensing technique to image processing type that uses camera to effectively select the most efficient way to move through the competition arena.

MATERIAL COST ANALYSIS

The material cost analysis that is provided here are about the full sum of the MAV.

Item	Quantity	Source	Price
Vexta PK268-01B stepper motor	2	OM-matic (Singapore) Pte Ltd	$225.12
Vexta PAL2P-2 motor mount	2	OM-matic (Singapore) Pte Ltd	$40.00
Vexta CSD2120-P stepper motor driver	2	OM-matic (Singapore) Pte Ltd	$290.40
Carlo Gavazzi ED18D4NPAS diffuse photoelectric sensor	5	Farnell	$760.00
1/8 scale foam tyre	2	Elite Racing Models Pte Ltd	$20.00
1/8 scale rim	2	Elite Racing Models Pte Ltd	$18.00
Wheel to motor shaft adapter	2	Elite Racing Models Pte Ltd	$26.00
20VE 2/3A 600mAh Ni-Cad 24V battery pack	1	SAFT Singapore Pte Ltd	$100.00
Banner S30SP6FF200 fixed field sensor	2	AE Motion Controls Pte Ltd	$280.00
Banner S30SP6FF400 fixed field sensor	4	AE Motion Controls Pte Ltd	$560.00
1.5 mm x 4ft x 4ft aluminum sheet	1	Khiam Aik Hardware Pte Ltd	$35.00
Hinge	1	Variware	$1.00
Vector 2X Digital Compass	1	Bertda Services (Sea) Pte Ltd	$140.00
5045 ball transfer	2	Interroll (Asia) Pte Ltd	$63.40
Motorola MC68HC705C8CS microcontroller	3	Main Store (T924)	$75.00
Push Button Switch Normally Open Chassis Mount	13	Main Store (T924)	$5.59
Push Button Switch Normally Open PCB Mount	2	Main Store (T924)	$1.60
Toggle Switch	3	Main Store (T924)	$2.85
10 bit DIP switches	1	Main Store (T924)	$0.30

4 bit DIP switches	1	Main Store (T924)	$0.20
Item	**Quantity**	**Source**	**Price**
Veroboard	6	Main Store (T924)	$7.14
8 parallel resistor in package 10kΩ	4	Main Store (T924)	$1.72
22kΩ resistor	12	Main Store (T924)	$0.60
1kΩ resistor	4	Main Store (T924)	$0.15
4.7kΩ resistor	4	Main Store (T924)	$0.20
330Ω resistor	5	Main Store (T924)	$0.25
120kΩ resistor	8	Main Store (T924)	$0.40
18pF ceramic capacitor	2	Main Store (T924)	$0.10
10nF ceramic capacitor	1	Main Store (T924)	$0.05
35V 47μF electrolytic capacitor	3	Main Store (T924)	$0.21
100nF capacitor	16	Main Store (T924)	$0.80
50V 470μF electrolytic capacitor	1	Main Store (T924)	$0.30
4MHz crystal	1	Main Store (T924)	$0.80
BC109 NPN transistor	12	Main Store (T924)	$3.60
7805 voltage regulator	1	Main Store (T924)	$0.45
Heat Sink for voltage regulator	1	Main Store (T924)	$0.45
40 pin DIP IC socket	3	Main Store (T924)	$0.84
20 pin DIP IC socket	1	Main Store (T924)	$0.15
14 pin DIP IC socket	1	Main Store (T924)	$0.15
6 pin DIP IC socket	1	Main Store (T924)	$0.15
Fuse Holder	1	Main Store (T924)	$0.30
0.637A fuse	1	Main Store (T924)	$0.06
		Sub-Total	$2663.33

Miscellaneous Item

Molex Pin	4 mm lock nut
40 pin header socket	4 mm washer

Dual row 40 pin header socket	13A cable
Gold plated 90^0 single row header	Insulation tape
Gold plated single row straight header	Heat resistant double-sided tape
Rainbow wire	Masking tape
Cable tie	Aerosol spray paint
3 mm screw	1 inch copper stand
3 mm nut	1/2 inch copper stand
3 mm lock nut	Heat shrinkable tubing (small)
3 mm washer	AWG 26 single strand wire
4 mm screw	AWG 30 single strand wire
4 mm nut	

It is estimated that all the miscellaneous item would cost around $50.00 therefore the **total price** of the MAV is **$2713.33**

APPENDICES

APPENDIX 4

```
//Filename : Profile3.cpp
//This program calculates the necessary delay for the alignment of the MAV

#include <stdio.h>
#include <conio.h>
#include <math.h>

float delay(float time[],float speed[],float dis_per_deg,float angle,int maxsegment);
float areaunderpoints(float x1,float y1,float x2,float y2);


void main()
{
//1	float time[100]={0,0.035,0.15,0.19,0.2922,1};
//2	float time[100]={0,0.0415,0.1777,0.2254,0.5659,1};
  float time[]={0,0.0592,0.2542,0.3223,0.4923,1}; //Set 9.1
//Set 10 float
time[]={0,0.043,0.0604,0.0779,0.0962,0.1166,0.1355,0.1585,0.1835,0.2102,0.2901,0.335
4,0.3507,1};
//1	float speed[100]={0,0.165,0.659,0.825,1.122,1.122};
//2	float speed[100]={0,0.165,0.659,0.825,1.122,1.122};
  float speed[]={0,0.165,0.659,0.825,1.113,1.113};//Set 9.1 MAXSEGMENT=5
//Set 10 float
speed[]={0,0.16493,0.24740,0.32987,0.41233,0.49480,0.57727,0.65973,0.74220,0.82467,
0.98960,1.07207,1.09269,1.09269};//MAXSEGMENT=13
//1	float dis_per_deg=0.00161;
//2//3	float dis_per_deg=0.001623;
  float dis_per_deg=0.001745;//wheel to wheel distance is 20cm
			//taken at center of wheel's width

	float angle=1;
	float timetook;
  int maxsegment=5;
	int x;

	clrscr();
		timetook=delay(time,speed,dis_per_deg,angle,maxsegment);


//	printf("Please enter the number of points: ");
//	scanf("%d",&maxsegment);
//	maxsegment--;
//	for(x=maxsegment;x>=0;x--)
//	{
//		printf("\nPoint %d\tTIME  (in seconds): ",maxsegment-x);
//		scanf("%f",&time[maxsegment-x]);
```

```
//		printf("\tSPEED (in m/s)	: ");
//		scanf("%f",&speed[maxsegment-x]);
//	}
	printf("Please enter angle difference: ");
	scanf("%f",&angle);

	{
		clrscr();
		printf("\n");
		printf("\tANGLE\tDELAY\t\tRev\t\treminder\n");
		float y;
		int xyx=0;
		long int lsb1;
		long int lsb2;
	for(y=angle;y<=180;y+=angle,xyx++)
	{
		if(xyx>=10)
		{
		printf("\b \n");
		xyx=0;
		}
		timetook=delay(time,speed,dis_per_deg,y,maxsegment);

		lsb1=(long int)(timetook/0.000002);
		lsb2=lsb1%65535;
		lsb1=lsb1/65535;
		printf("$%ld,",lsb1);

	}
		printf("\b \n");
		getch();
	for(y=angle;y<=180;y+=angle,xyx++)
	{
		if(xyx>=10)
		{
		printf("\n");
		xyx=0;
		}
		timetook=delay(time,speed,dis_per_deg,y,maxsegment);

		lsb1=(long int)(timetook/0.000002);
		lsb2=lsb1%65535;
		lsb1=lsb1/65535;
		lsb2=lsb2>>8;
		printf("$%x,",lsb2);

	}
		printf("\n");
	getch();
```

```
	for(y=angle;y<=180;y+=angle,xyx++)
	{
		if(xyx>=10)
		{
		printf("\n");
		xyx=0;
		}
		timetook=delay(time,speed,dis_per_deg,y,maxsegment);

		lsb1=(long int)(timetook/0.000002);
		lsb2=lsb1%65535;
		lsb1=lsb1/65535;
		lsb2=lsb2 & 0x0ff;
		printf("$%x,",lsb2);

	}

	}
	getch();
}

float delay(float time[],float speed[],float dis_per_deg,float angle,int maxsegment)
{

	float distance_covered=0; //distance covered by that angle
	float timetaken=0;	//time taken by that distance
	float accum_distance=0;		//accumulated distance from calculation
	int segment=0;

	float aaa;
	float bbb;
	float ccc;
	float ddd;

	distance_covered=dis_per_deg*angle;

	for(segment=0;(accum_distance<distance_covered);segment++)
	{
		if(segment>=(maxsegment))
			segment--;

	accum_distance+=areaunderpoints(time[segment],speed[segment],time[segment+1]
,speed[segment+1]);
	}
	segment--;
	accum_distance-
=areaunderpoints(time[segment],speed[segment],time[segment+1],speed[segment+1]);
	distance_covered-=accum_distance;
```

```
                aaa=0.5*( (speed[segment+1]-speed[segment])/(time[segment+1]-
time[segment]) );
                bbb=speed[segment];
                ccc=-distance_covered;
                if(aaa==0)
                        ddd=distance_covered/bbb;
                else
                        ddd=( (-bbb+(sqrtl(bbb*bbb-4*aaa*ccc)))/(2*aaa) );

                timetaken=time[segment]+ddd;

                return  timetaken;

}

float areaunderpoints(float x1,float y1,float x2,float y2)
{
        float ans;
        ans=(float)( (0.5*(y2-y1)*(x2-x1))+(y1*(x2-x1)) );
        return ans;
}
```

APPENDIX 5

ACCELERATION PROFILE 9.1

This acceleration profile follows that of an exponential curve because it is more efficient than the linear acceleration. It assumes a 70% efficiency of the PK268-01B stepper motor and the compensated weight is 12kg (actual MAV weight is 5.5kg). The conversion factor for coverting kgcm to Nm is 98.06×10^{-3} (kgcm $\times$ 98.06×10^{-3} = Nm).

Torque value of motor = T_x

Acceleration = A_x

Time interval required to accelerate from one speed to another = t_x

T_1 = 8.946kgcm	T_2 = 8.169kgcm	T_3 = 7.777kgcm	T_4 = 5.446kgcm
0.8772Nm	0.8011Nm	0.7626Nm	0.534Nm

Radius of wheel (r) = 0.0525m

A_x = Force / mass

= $[(T_X / r) \times 2]$ / mass

$A_1 = 2.785ms^{-2}$	$A_2 = 2.54ms^{-2}$	$A_3 = 2.421ms^{-2}$	$A_4 = 1.695ms^{-2}$

t_x = speed change / A_x

t_1 = 0.0592s	t_2 = 0.195s	t_3 = 0.0681s	t_4 = 0.487s

A_1, speed interval = 50Hz, 3 levels (50Hz — 150Hz)

Duration per speed value = 0.0592 /3

= 0.0197s

A_2, speed interval = 25Hz, 24 levels (200Hz — 775Hz)

Duration per speed value = 0.195 / 24

= 0.008125s

A_3, speed interval = 25Hz, 8 levels (800Hz — 975Hz)

Duration per speed value = 0.0681 / 8

= 0.0085125s

A_4, speed interval = 25 Hz, 40 levels (1kHz — 1.975kHz)

Duration per speed value = 0.487 / 40

= 0.012175s

Top speed, 2kHz, has infinte interval time.

Speed (Hz)	No. of 2μs in 1/2 period	Hexadecimal	No. Of 1/2 period in the duration of speed value	Hexadecimal
50	5000	1388	2	2
100	2500	9C4	4	4
150	1667	683	6	6
200	1250	4E2	4	4
225	1111	457	4	4
250	1000	3E8	4	4
275	909	38D	4	4
300	833	341	4	4
325	769	301	6	6
350	714	2CA	6	6
375	667	29B	6	6
400	625	271	6	6
425	588	24C	6	6
450	556	22C	8	8

475	526	20E	8	8
500	500	1F4	8	8
525	476	1DC	8	8
550	455	1C7	8	8
575	435	1B3	10	A
600	417	1A1	10	A
625	400	190	10	A
650	385	181	10	A
675	370	172	10	A
700	357	165	12	C
725	345	159	12	C
750	333	14D	12	C
775	322	142	12	C
800	313	139	14	E
825	303	12F	14	E
850	294	126	14	E
875	286	11E	14	E
900	278	116	16	10
925	270	10E	16	10
950	263	107	16	10
975	256	100	16	10
1000	250	FA	24	18
1025	244	F4	24	18
1050	238	EE	26	1A
1075	233	E9	26	1A
1100	227	E3	26	1A
1125	222	DE	28	1C
1150	217	D9	28	1C
1175	213	D5	28	1C
1200	208	D0	30	1E
1225	204	CC	30	1E

1250	200	C8	30	1E
1275	196	C4	32	20
1300	192	C0	32	20
1325	189	BD	32	20
1350	185	B9	32	20
1375	182	B6	34	22
1400	179	B3	34	22
1425	175	AF	34	22
1450	172	AC	36	24
1475	169	A9	36	24
1500	167	A7	36	24
1525	164	A4	38	26
1550	161	A1	38	26
1575	159	9F	38	26
1600	156	9C	38	26
1625	154	9A	40	28
1650	152	98	40	28
1675	149	95	40	28
1700	147	93	42	2A
1725	145	91	42	2A
1750	143	8F	42	2A
1775	141	8D	44	2C
1800	139	8B	44	2C
1825	137	89	44	2C
1850	135	87	46	2E
1875	133	85	46	2E
1900	132	84	46	2E
1925	130	82	46	2E
1950	128	80	48	30
1975	127	7F	48	30
2000	125	7D	∞	∞

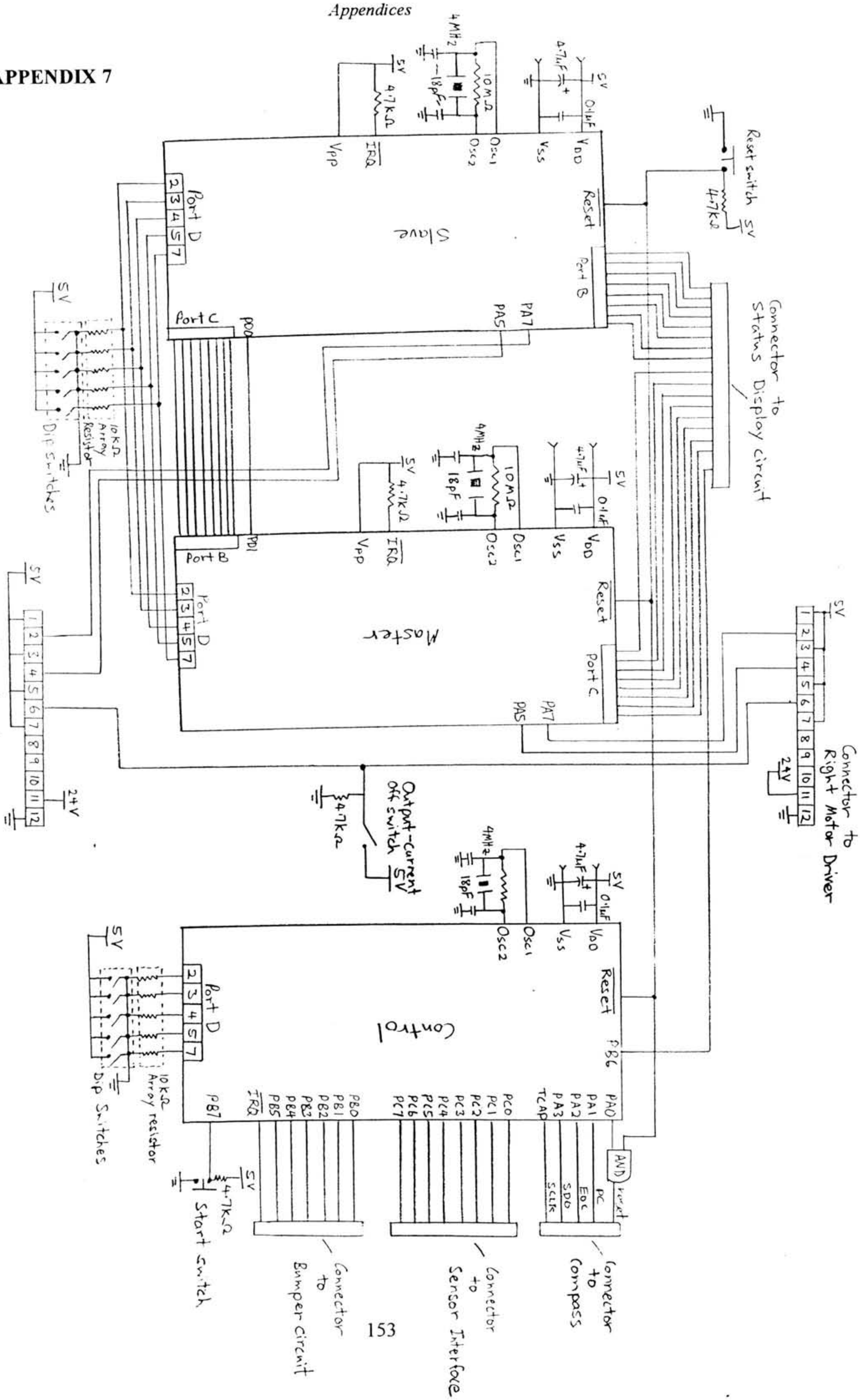
APPENDIX 6

ADDRESS LIST

AE Motion Controls Pte Ltd Blk 2, Loyang Lane, #03-03 S508913 Tel: 542 6882 Fax: 542 8987 Contact: Andy Loh T Y Pg: 9598 3043	Elite Racing Models (Pte) Ltd 150 Orchard Road #02-40/41 Orchard Plaza S238841 Tel: 732 5227 Fax: 733 8501
OM-matic (Singapore) Pte Ltd No. 15 Fan Yoong Road S629792 Tel: 266 1101/266 3377 Fax: 266 6323/265 0526 Contact: Desmond Tan Pg 9522 5343 H/P 9816 1721	Pepperl+Fuchs 18 Ayer Rajah Crescent P+F Building S139942 Tel: 779 9091 Ext 434 Fax: 778 1372 Contact: Randy Lim Pg 9311 3858
Sentronics Automation & Marketing Blk 3021, Ubi Avenue 2, #03-169, S408897 Tel: 744 8018 Fax: 7441929 Contact: David Teo Pg 9300 3490	TDS Technology (S) Pte Ltd 64 Sungei Kadut Loop S729493 (HOCEN Building, 3rd Storey) Tel: 366 1661 Fax: 362 1662 Contact: Ai Peng (internal) Paul Yeo (external) Pg 9588 4877 H/P 9682 2684
Variware #02-31 Holland Road Shopping Centre Tel: 468 1890	Interroll (Asia) Pte Ltd 11 Kian Teck Drive S628828 Tel: 266 6322 Fax: 266 6849 Contact: Teresa Bee

SAFT Singapore Pte Ltd
996 Bendemeer Road #05-02/04 Kallang
Basin Industrial Estate S339944
Tel: 296 8211 Fax: 298 4101
Contact: Wong Yeou Hock

APPENDIX 7


Slave
Master
Control
Connector to Status Display circuit
Connector to Left Motor Driver
Connector to Right Motor Driver
Connector to Bumper Circuit
Connector to Sensor Interface
Connector to Compass
Start switch
Reset switch
Output-current off switch
Dip Switches
10kΩ Array resistor
Port B
Port C
Port D
Reset
AND

APPENDIX 8

OPERATING MANUAL

Thank you for purchasing Oriental Motor products..
To obtain the best performance from your equipment, please read this manual thoroughly before use.

2-Phase Stepping Motor/Driver Package

CSK Series

CSK243-AP	CSK243-BP
CSK244-AP	CSK244-BP
CSK245-AP	CSK245-BP
CSK264-AP	CSK264-BP
CSK266-AP	CSK266-BP
CSK268-AP	CSK268-BP

ontents

Components

Package Model		Motor Model		Driver Model
Single shaft	Double Shaft	Single Shaft	Double Shaft	
CSK243-AP	CSK243-BP	PK243-01A	PK243-01B	CSD2109-P
CSK244-AP	CSK244-BP	PK244-01A	PK244-01B	CSD2112-P
CSK245-AP	CSK245-BP	PK245-01A	PK245-01B	
CSK264-AP	CSK264-BP	PK264-02A	PK264-02B	CSD2120-P
CSK266-AP	CSK266-BP	PK266-02A	PK266-02B	
CSK268-AP	CSK268-BP	PK268-02A	PK268-02B	

Tech The company
it can be usec
PK-268-01B

Accessories:

Connector Housing:	1-171822-2 (AMP)	1 piece
	171822-6 (AMP)	1 piece
Contact:	170204-2 (AMP)	20 pieces
Operating Manual		

Product Number Code

CSK268-AP

- CSK: Stepping Motor/Driver Package, **CSK** Series
- 2: 2-Phase
- 6: Installing Base Size — **4**: 42mm sq., **6**: 60mm sq.
- 8: Length of Motor Case
- A: Shaft Type — **A**: Single Shaft, **B**: Double Shaft
- P: Type of Signal Input/Output — **P**: Photocoupler Input Type

Before Use

1. Heat Generation
- To suppress heat generation, always keep the automatic-current-cutback (ACD) switch on (except when setting the current). If left the switch off or operated while off, the driver can be damaged under some conditions.
- Under some operating conditions, the motor and driver can generate intense heat. Use the product such that the temperature, when it is mounted in a unit does not exceed 100°C for the motor case and 85°C for the driver heat sink.
- Temperature can be lowered by improving operating conditions such as the operating current, current at motor standstill, speed, duty cycle, etc. The radiator of the driver should be installed on a thermally conductive metal plate or have forced cooling.

2. Motor/Driver Combinations
- Do not use the motor/driver assembly you have purchased in other combinations.

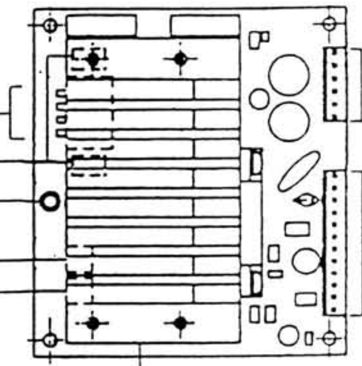
3. Handling the Motor
- Never disassemble the motor or loosen the screws. Once the motor has been disassembled or the installation screws loosened, performance drops markedly.
- The surface temperature of the motor and driver is extremely high while the power is turned on and immediately after the power is turned off, so be sure not to touch them.

4. Turning the Power On
- Repeatedly turning the power on and off repidly can damage the driver. Wait two to three minutes after turning the power supply off before turning it back on again. To temporarily free the motor output shaft, use the output-current-off function (described on page 5).

5. Switching the Power Supply Voltage
- When the voltage of the power supply changes, be sure to change the voltage switch setting to match the power supply. When settings do not match, damage or noise can result.

Name and Functions of Driver Part

Numbers in parentheses are page numbers of descriptions.



Function Switch (Page 7)

- **Automatic-Current-Cutback at Motror Stanstill** (ON/OFF)
  To suppress heat, the output current is automatically reduced when the motor stops. (Normally, this switch is kept at ON.)
- **Step Angle** (Full/Half)
  Switch the amount of movement per pulse between a full step of 1.8° and a half step of 0.9°.
- **Pulse Input Mode** (1-Pulse/2-Pulse)
  Select whenever to command by using one pulse and the direction of rotation or by using two different pulses for the two directions of rotation.
- **Power Supply Voltage** (24V/36V)
  Can be switched to match the power supply voltage being used. (When a 36V power supply is being used, the high speed characteristics are better than from the 24V characteristics.)

Current Check Terminal (Page 8)
The output current setting can be checked using a digital tester (voltage range).
Use this terminal when adjusting the output current.

Power Lamp
Lights when the power is turned on.

RUN Potentiometer (Page 8)
[RUN VR]
The output current while the motor is operating can be lowered to reduce the vibration or heat generation. (When shipping, this potentiometer is set to the rated current of the motor.)

STOP Potentiometer (Page 8)
[STOP VR]
The output current while the motor is stopped can be lowered to reduce heat generation. (When shipping, this potentiometer is set to about 40% of the rated current of the motor.)

Trminal for Motor Connection (Page 4)
Connect the Motor leads (connector).

Radiator

Terminal for Signal and Power Supply (Page 5)
[CN1]
Cinnect the signal and power supply leads (connector).

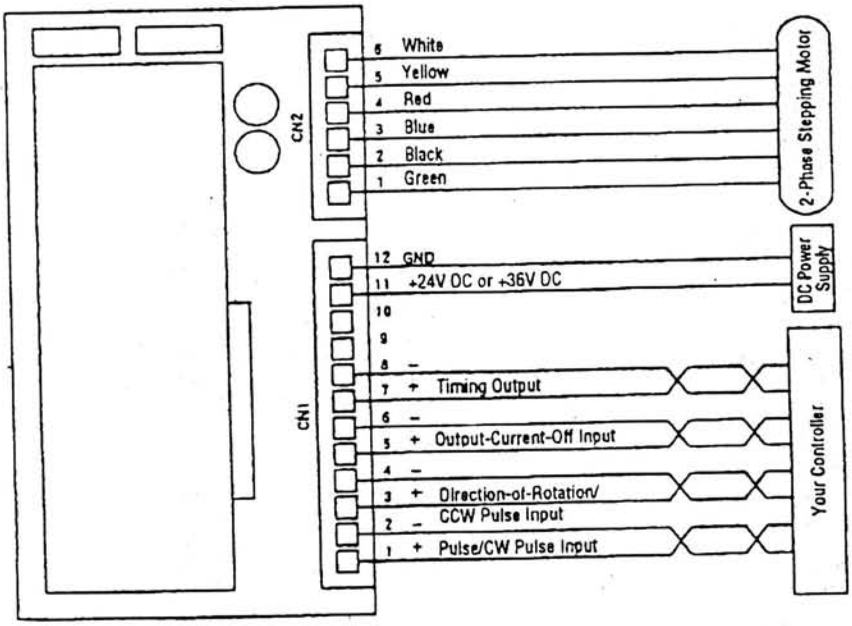
- **Pulse Input**
- **Direction-of-Rotation Input**
- **Output-Current-Off Input**
  Temporarily frees the motor shaft so it can be turned by hand. Use this when positioning manually.
- **Excitation-Timing Output**
  Output when the motor's excitation sequence is in its initial status (step 0).
  (Output every 4 pulses for full step and every 8 pulses for half step.)
  It can match the mechanical home position of the device with the excitation home position of the motor (step 0) to acheive more accurate home position detection.
- **Power Supply Input**

3

Attn: Amanda pp 955

FAX: 7721974

Connecting Diagram



Assembling the Connector

- The suitable wire size for the CN1 and CN2 connectors is AWG20 to AWG26.
  Use a wire rated at AWG20 to AWG22 for the power supply line.
- Use a dedicated assembling tool (AMP722560-1, etc.) when assembling the connectors.

Precaution on Connection

- Assemble the connectors firmly using a dedicated assembling tool. Always check the conductivity of the connector using a tester. Misassembling or miscontact will damage the motor and driver.
- Use twisted-pair wires for signal lines and keep them as short as possible.
- Signal lines should be kept away from power lines (power supply lines and motor lines). Do not bind the signal lines and power lines together.
- If electrical noise generated by the motor lead wires cause problems, try shielding the motor lead wires with conductive tape or wire mesh.

Before Turning On the Power

- Always check the connection of the power line (arranged GND, + left to right as seen facing the connector CN1).
- Is the connector properly and firmly connected?

■ Power and Signal Inputs

CN1 (For Input/Output Signal and Power Supply)

Pin No.	Name of Signals		Functions	Electrical Characteristics
1 IN	PULSE/CW + IN 5V	Pulse Input/CW Pulse Input	⋆ **At 1-Pulse Input Mode** *1 When a negative logic pulse is input to the - terminal, the motor rotates one step at rising edge of the pulse. ⋆ **At 2-Pulse Input Mode** *1 When a negative logic pulse is input to the - terminal, the motor rotates one step clockwise at rising edge of the pulse.	L: 0 ~ 0.5V H: 4 ~ 5V Pulse width: 5 μs min. Pulse Rise/Pulse Fall Time: 2 μs max. Pulse duty: 50% max. *2 Input Impedance: 220 Ω Input Current: 20mA max.
2 IN	PULSE/CW - IN clock			
3 IN	DIR./CCW + IN 5V	Direction-of-Rotation Input/CCW Pulse Input	⋆ **At 1-Pulse Input Mode** *1 Input direction-of-rotation signals to the - terminal. "L" level (photocoupler is on): CW "H" level (photocoupler is off): CCW ⋆ **At 2-Pulse Input Mode** *1 When a negative logic pulse is input to the - terminal, the motor rotates one step counterclockwise at rising edge of the pulse.	
4 IN	DIR./CCW - IN direction			
5 IN	H.OFF + IN 5V	Output-Current-Off Input	⋆ At "L" level (photocoupler is ON), current to the motor stops and the motor shaft can be rotated by hand.	L: 0 ~ 0.5V H: 4 ~ 5V Input Impedance: 220 Ω Input Current: 20mA max.
6 IN	H.OFF - IN SIGNAL			
7 OUT	TIMING + IN 5V	Excitation-Timing Output	⋆ A signal is output whenever the motor excitation sequence returns to step "0" in synchronization with the input pulse signal. (Output transistor is ON) ⋆ A signal is output every 4 pulses in full step mode and every 8 pulses in half step mode.	24V DC max. 10mA max. Photocoupler Open-Collector Output
8 OUT	TIMING - OUT synchronization signal			
NOT USE 9	NC	—	⋆ Connect no wires.	—
NOT USE 10	unused			
11 IN	+24V/36V IN	Power Supply Input	⋆ Connect + and GND wires of 24V DC or 36V DC.	24V DC or 36V DC ±10% 1.4A max. (CSD2109-P)*3 1.6A max. (CSD2112-P)*3 2.8A max. (CSD2120-P)*3
12 IN	GND out			

*1: A switch is used to select the pulse input mode. (See page 7)
*2: A pulse duty of 50% can handle up to about 10Kpps. When using the motor at faster speeds, shorten the pulse width (shorter the length of time the photocoupler is on).
*3: This varies with the voltage, motor type, opeating speed and load. Connect to a power supply that has a current capacity of at least the values listed in the above table or of at least 1.1 times the maximum input current in the range for speeds used (from 0pps to operating speed) from the speed-input characteristics of the catalog. when conditions are to be changed, be sure to reconsider the power supply capacity.

½ step max ~~rpm~~ freq. no load : more than 4 kHz

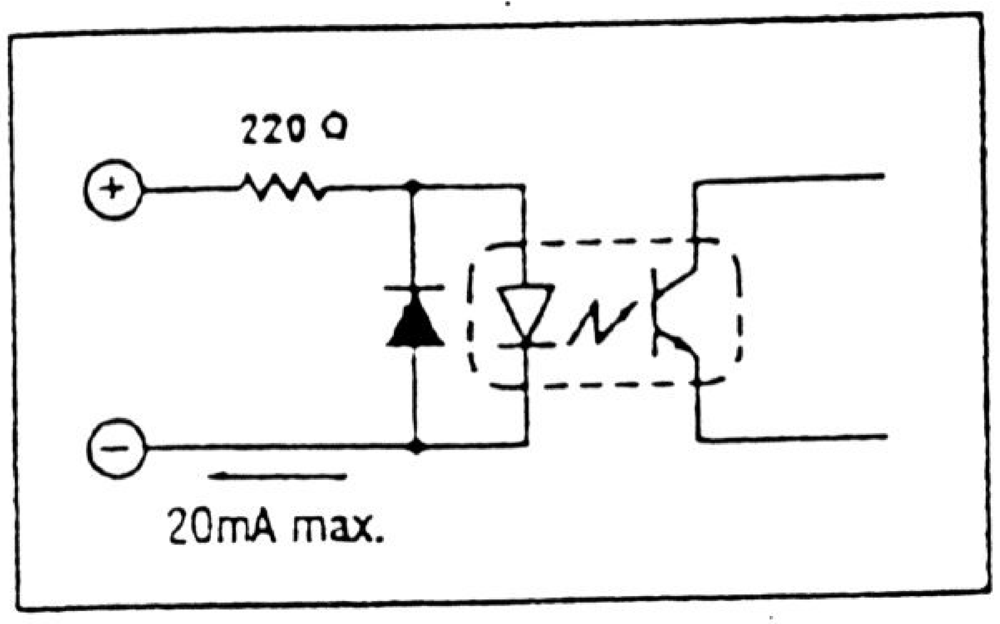
CN2 (For Motor)

Refer to the left page.

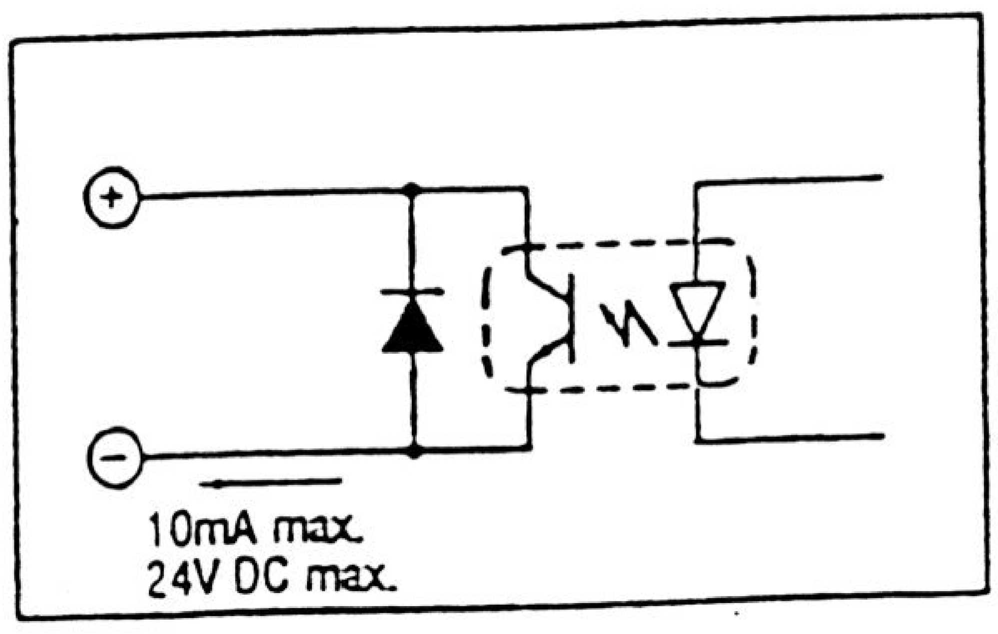
Input/Output Signals

■ Input/Output Signal Circuit

Pulse Input/CW Pulse Input, Direction-of-Rotation Input/CCW Pulse Input, Output-Current-Off Input

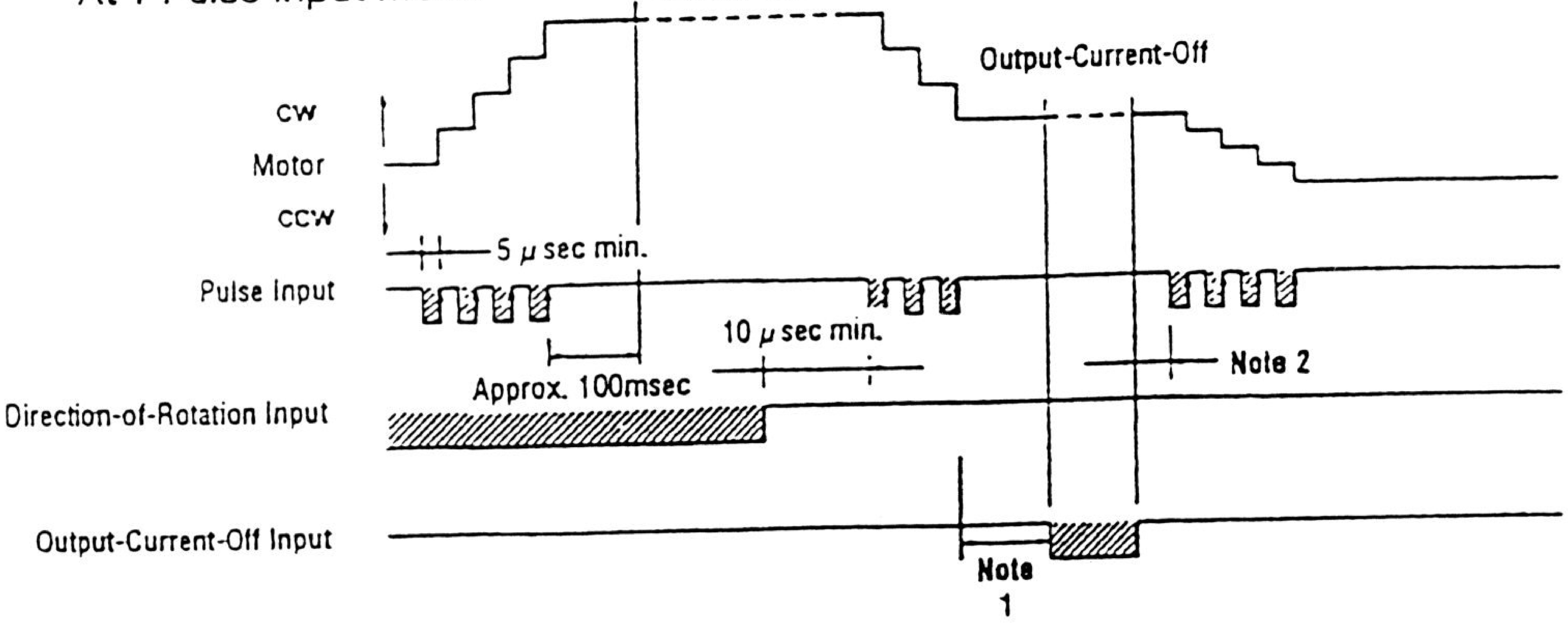


Excitation-Timing Output

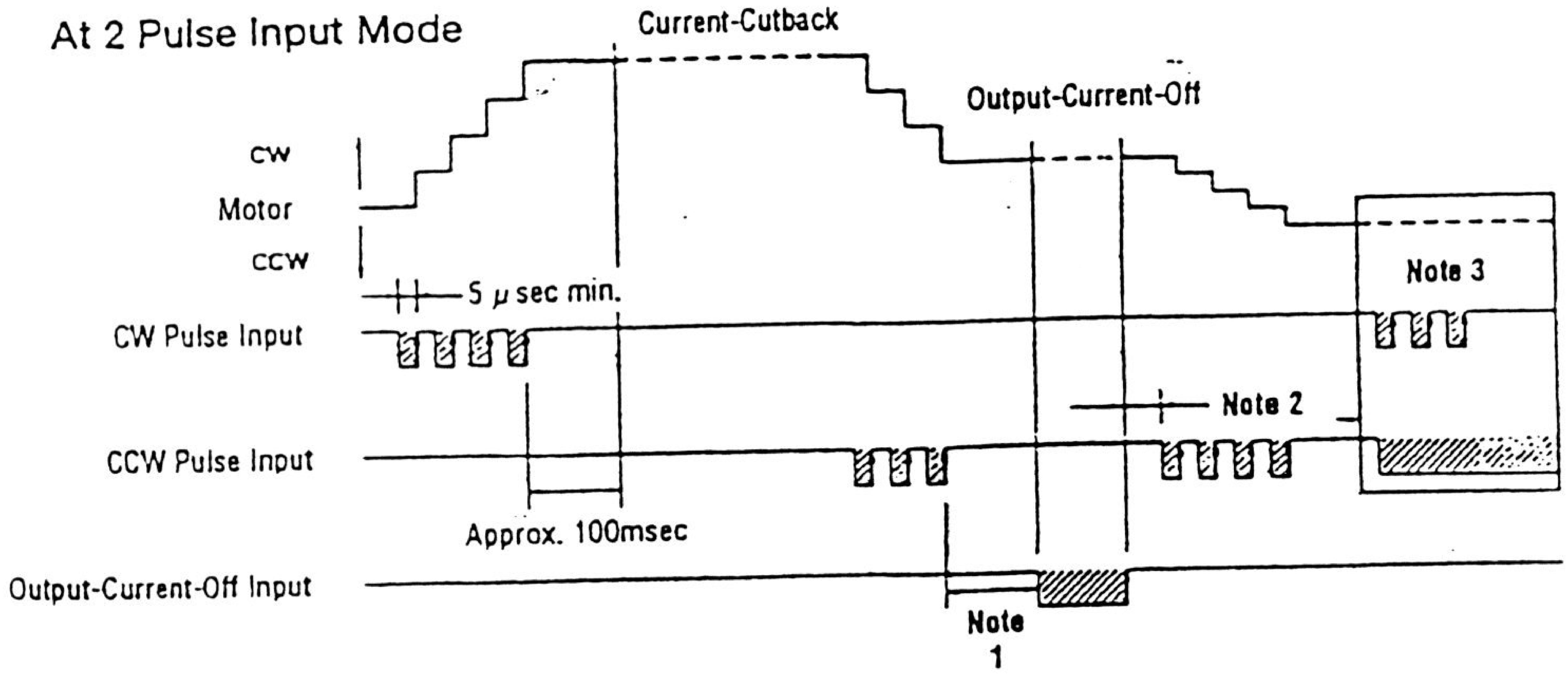


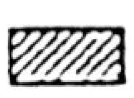
■ Timing Chart

At 1 Pulse Input Mode



At 2 Pulse Input Mode



 : The Photocoupler diode lights in shaded area.

Note 1: After the pulse stops, the stepping motor stays still by repeating a pattern of minutely overshooting and undershooting. The length of time it continues this pattern varies with the inertial load, frictional load, motor type and the like. When output-current-off input comes prior to the motor coming to a stop, it may lose its position, so be sure to input it after coming to a stop.

Note 2: Never input pulse signals immediately after switching the output-current-off input signal to "H" level or the motor may lose synchronism. In general, an interval of 100msec. (minimum) is required.

Note 3: The motor will not operate properly when inputting a pulse signal while either the CW or CCW pulse is at "L" level.

* When the level of the pulse signal is maintaining at "L" level (photocoupler is on), the automatic-current-cutback function will not activate. Always return the level to "H" after the pulse signal ends (photocoupler off).

Switching the Functions

Factory setting of the driver can be changed using the following setting switches.

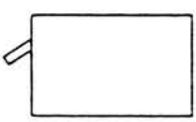
■ Function of Switches

Indications	Name	Function		Settings When Shipped
		ON	OFF	
ACD	Automatic-Current-Cutback at Motor Standstill	Approximately 100msec. after the pulse stopped, current set with the STOP potentiometer will flow to the motor. *To suppress heat generation of motor and driver, the switch should always be on.*	Will not functioning. (Turn to OFF only when the output current is being adjusted.)	ON
F/H	Step-Angle	Full Step (Rotates 1.8° per pulse)	Half Step (Rotates 0.9° per pulse)	ON
1P/2P	Pulse Input Mode	1-Pulse Input Mode (Controlled by pulse signal and direction-of-rotation signal.)	2-Pulse Input Mode (Controlled by 2 pulses of CW and CCW pulses.)	OFF
24/36V	Power Supply Voltage	Using a 24V DC power Supply.	Using a 36V DC power supply.	ON

■ Working the Switches

ON

OFF



Operate one switch after the other using a precision flatheaded screwdriver or the like.

When multiple switches are operated aat onece by fingertip, excessive force ends up being applied to the switch mountings.

Note:

The automatic-current-cutback switch should stay on at all times except when adjusting the output current.

Adjusting the Driver Output Current

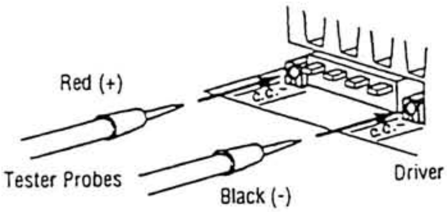
The rated output current is set at the factory, so it can be used without re-adjusting (when used with a 24V DC power supply). When it is necessary to change the current setting for reducing heat generation and vibration or to change the power supply voltage, follow the procedures described below.

1. Preparations

* A tester
* A small flatheaded driver (a precision screwdriver or the like pf the right size to adjust the RUN and STOP potentiometer.)

2. Procedure

(1) Connect the motor and power supply.
(2) Match the power supply voltage switch to the power supply being used.
(3) Make sure that no signal is being input. (Do not input anything until the measurements are complete.)
(4) Switch the tester to voltage measurement. When there is a measurement range switch, match it to a range that allows you to masure 0 to 2V.
(5) Insert the tester probe into the current check terminal.



Note:
Avoid vent, rusted or clouded probes as they cause errors in measurement.

(6) Turn on the power.
(7) Adjust the output current.

◆ **Setting the Running Current**

0.98 A 50% of 0.98A is 0.49A

Flip the automatic-current-cutback (ACD) switch to OFF.
Turn the RUN potentiometer to set it.
The tester voltage at this point indicates the output current per 1 phase.

Example:

Tester Reading	Output Current per Phase
1V	1A
1.5V	1.5A
2V	2A

*Never set the motor current beyond the rated value.
(When shipping, this potentiometer is set to the rated current for a 24V DC power supply.)

Package Model	Ratd Current [A/phase]
CSK243-□P	0.95
CSK244-□P	1.2
CSK245-□P	1.2
CSK264-□P	2.0
CSK266-□P	2.0
CSK268-□P	2.0

◆ **Setting the Output Current at Motor Standstill**

0.45 A

Flip the automatic-current-cutback (ACD) switch to ON.
Turn the STOP potentiometer to set it.
This should never be set higher than 50% of the rated current of the motor. (When shipping, this potentiometer is set to about 40% of the rated current.)

(8) When setting is completed, turn the power supply off and remove the tester's probe.
(9) Turn the automatic-current-cutback switch back to ON.
- Completed -

3. Cautions

For accurate settings, pay attention to the followings:

- Set the current quickly while both the motor and the driver are at normal ambient temperature.
- Use a power supply that is the same as taht which will be used in your set (24V or 36V) and which has an accurate output voltage. When the voltage is changed, the settings also must be changed.
- For 0.5A or less, we recommended that an ammeter be used in setting. (See below.)

When the operating current is changed, the current at motor standstill also changes.
The output current during pulse input cannot be monitored with the current check terminal.

For Reference

◆ The Relationship between Torque and Current Settings (when motor stops or operating at low-speed)

- The holding torque is almost proportional toa the output current at motor standstill.
- The torque at low-speed is almost proportional to the operating output current.

◆ The Relationship between Motor Temperature Rises and Current Settings (when motor stops or operating at low-speed)

- The lower the current, the smaller the rise in motor temperature both when stopped and when operating at low-speed.
  (As a rough guide, it is proportional to the square of the output current. This varies with the speed, load, heat discharge and other conditions.)

◆ The Relationship between Motor Vibration and Current Settings

- Motor vibration is generally less with lower operating output current. (Torque also decreases as the output current is lowered, so set at an appropriate point after allowing a sufficient margin.)

■ Setting the Output Current with an Ammeter (A second method)

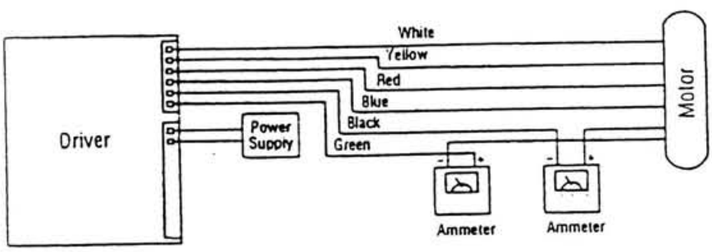
The driver uses special current control, so the current value set by the above method and the average output current value will differ somewhat. In ordinary use there is not much fifference, but when the average value must be adjusted more precisely, set as follows.

1. Preparations

- Two ammeters (able to measure up to rated current of the motor)
- A small flatheaded driver (a precision screwdriver or the like pf the right size to adjust the RUN and STOP potentiometer.)

2. Procedure

(1) Connect the motor, power supply and ammeters as follows.



(2) Make sure that no signal is being input. (Do not input anything until the measurements are complete.)

(3) Mqtch the power supply voltage switch to the power supply being used.

(4) Turn the power on.

(5) Set the output current.

◆ **Setting the Operating Current**

Switch automatic-current-cutback (ACD) switch to OFF.
Turn the RUN potentiometer to set it.
The total of readings of the two ammeters at this point is the average value of the output current per phase.
Never set the motor current beyond the rated value.

◆ Setting the Output Current at Motor Standstill

Switch the automatic-current-cutback (ACD) switch to ON.
Turn the STOP potentiometer to set it.
This should never be set higher than 50% of the rated current of the motor.

(6) When setting is completed, turn the power supply off.

(7) Turn the automatic-current-cutback switch back to ON.

- Completed -

Installation

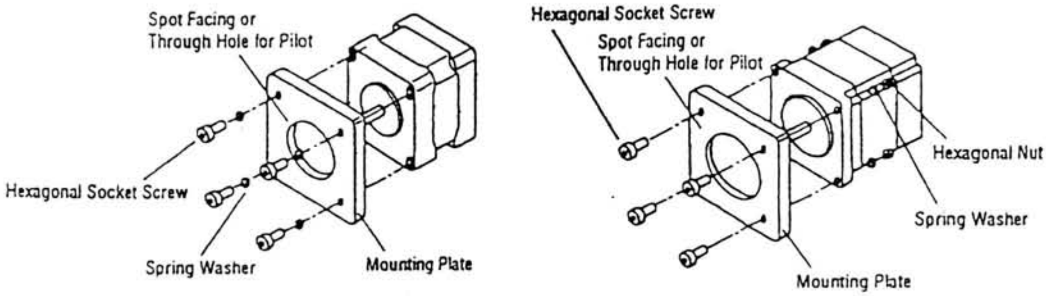
1. Precaution on Installation

Installing motors and drivers in place that meet following conditions.

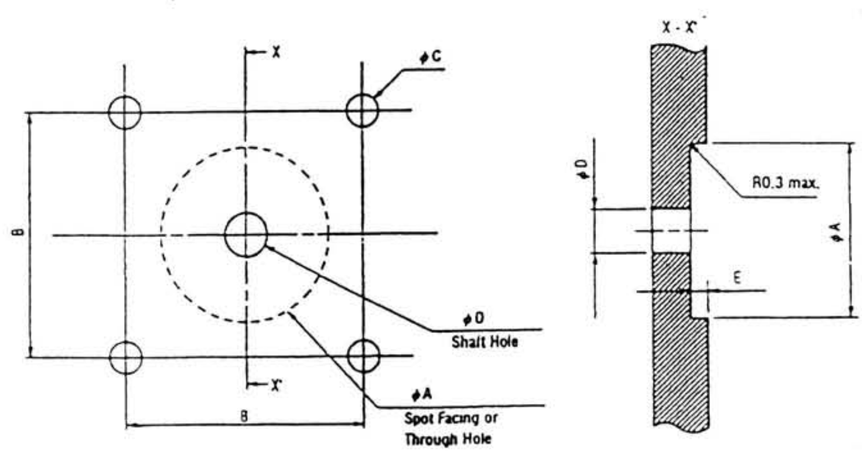
* Install the motor tightly against a metal surface with good thermal conductivity such as steel or almimum.
* Free from dust, oil mist, salt or corrosive gas.
* Free from excessive vibration or shocks.
* Leave at least 25mm of open space between each side of the driver and any other apparatus or structures.
* In the case that the drivers are located close to a large noise source such as high voltage lines, high voltage machines or power units, etc., take steps to prevent noise interference, either by inserting noise filters or connecting the driver to a separate circuit.
* Good ventilation and radiation. Forced cooling by a fan is recommended when the temperature of driver radiating plaate exceed 85°C.
* Ambient temperature is 0°C to +40°C.
* Take care that pieces of conductive material (filings, pins, pieces of windings, etc.) not to enter the drivers.

2. Installing the Motor

Install the motor tightly against a mounting plate referring to the panel cut out shown below.



■ Panel Cutout for Motor Mounting unit:mm



■ Thickness of Mounting Plate unit:mm

Model	Thickness of Mounting Plate	φA	B	φC	φD	E	Size of Mounting Screw
CSK24□	3 minimum	22H7	31±0.3	3.5	7 minimum	2.5 minimum	M3
CSK26□	4 minimum	38.1F8	47.14±0.35	4.5	8 minimum	2 minimum	M4

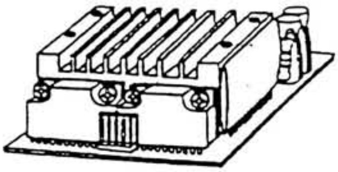
10

3. Installing the Driver

Install the driver in the following manner to control overheating, as much as possible.

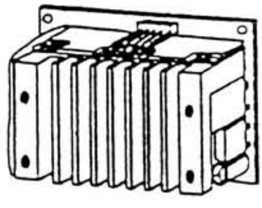
■ Horizontal Installation:

Position the heat sink on the upper surface.



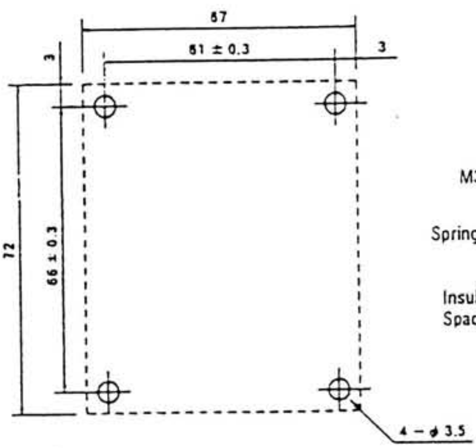
■ Vertical Installation:

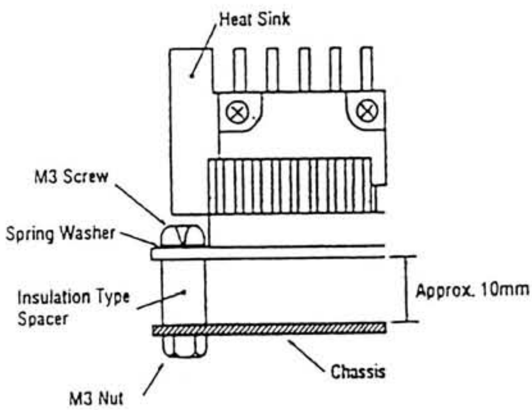
Position the terminal blocks on the upper surface.



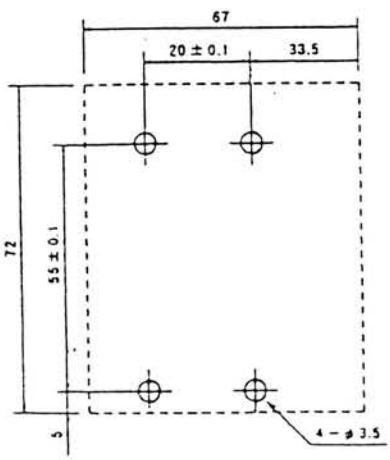
■ Mounting through the Circuit Board

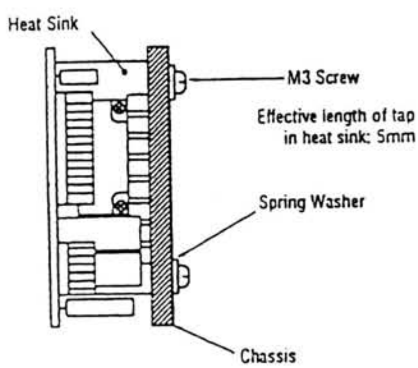
unit:mm





■ Mounting with the Heat Sink





Caution: When using screws to install the driver not to touch any component. The length of screws should be 5mm plus the thickness of the chassis.

	Item	Unit						
Package Model	Single Shaft		**CSK243-AP**	**CSK244-AP**	**CSK245-AP**	**CSK264-AP**	**CSK266-AP**	**CSK268-AP**
	Double Shaft		**CSK243-BP**	**CSK244-BP**	**CSK245-BP**	**CSK264-BP**	**CSK266-BP**	**CSK268-BP**
Motor Unit	Motor Model	Single Shaft	PK243-01A	PK244-01A	PK245-01A	PK264-02A	PK266-02A	PK268-02A
Motor Unit		Double Shaft	PK243-01B	PK244-01B	PK245-01B	PK264-02B	PK266-02B	PK268-02B
Motor Unit	Maximum Holding Torque	N·m	0.16	0.26	0.32	0.39	0.9	1.35
Motor Unit		kgcm	1.6	2.6	3.2	3.9	9	13.5
Motor Unit	Rotor Inertia	$kg \cdot m^2$	35×10^{-7}	54×10^{-7}	68×10^{-7}	120×10^{-7}	300×10^{-7}	480×10^{-7}
Motor Unit		gcm^2	35	54	68	120	300	480
Motor Unit	Rated Current	A/phase	0.95	1.2	1.2	2.0	2.0	2.0
Motor Unit	Resistance per Phase	Ω/Phase	4.2	3.3	3.3	1.4	1.8	2.25
Motor Unit	Mass	kg	0.21	0.27	0.35	0.45	0.7	1.0
Motor Unit	Step Angle		1.8°					
Motor Unit	Insulation Resistance		100MΩ or more under normal ambient temperature and humidity when the megger reading between the windings and the frame is DC500V.					
Motor Unit	Dielectric Strength		Under normal ambient temperature and humidity, sufficient to withstand 0.5kV at 50Hz applied between the windings the frame for one minute.					
Motor Unit	Insulation Class		Class B (130°C)					
Motor Unit	Ambient Temperature		-10°C ~ +50°C					
Driver Unit	Driver Model		CSD2109-P	CSD2112-P		CSD2120-P		
Driver Unit	Voltage		24V DC or 36V DC±10% 1.4A minimum *2	24V DC or 36V DC±10% 1.6A minimum *2		24V DC or 36V DC±10% 2.8A minimum *2		
Driver Unit	Output Current		0.3 ~ 0.95A/phase	0.3 ~ 1.2A/phase		0.3 ~ 2.0A/phase		
Driver Unit	Excitation Mode		Full Step: 1.8°/step (2phase excitation) Half Step: 0.9°/step (1-2phase excitation)					
Driver Unit – Input/Output Signals	Pulse Signal Input		Photocoupler Input Input Impedance 220Ω, Input Current 20mA maximum Pulse Width 5 μ sec. minimum, Pulse Rise/Fall Time 2 μ sec. maximum Pulse Duty 50% maximum L: 0 ~ 0.5V, H: 4 ~ 5V (Selectable between 1-pulse input mode and 2-pulse input mode.)					
Driver Unit – Input/Output Signals	Direction-of-Rotation Input Output-Current-Off Input		Photocoupler Input Input Impedance 220Ω, Input Current 20mA maximum L: 0 ~ 0.5V, H: 4 ~ 5V					
Driver Unit – Input/Output Signals	Excitation-Timing Output		Photocoupler Open-Collector Output, 24V DC maximum, 10mA maximum					
Driver Unit – Switch	Automatic-Current-Cutback		ON: ON			OFF: OFF		
Driver Unit – Switch	Excitation Mode		ON: 2 Phase Excitation			OFF: 1-2 Phase Excitation		
Driver Unit – Switch	Pulse Input Mode		ON: 1-Pulse Input Mode			OFF: 2-Pulse Input Mode		
Driver Unit – Switch	Power Supply Voltage		ON: 24V DC			OFF: 36V DC		
Driver Unit	Automatic-Current-Cutback Function		Output current is automatically reduced by 25 ~ 50% (adjustable, 0.3A minimum) within 100msec of rising edge of the input pulse.					
Driver Unit	Monitoring the Setting Current		Analog Voltage Output For simple current setting using a tester Conversion: Voltage reading of tester used as the output current value per phase. (e.g., Monitor output voltage of 1V=Current setting of 1A)					
Driver Unit	Mass	kg	0.12					
Driver Unit	Ambient Temperature		-10°C ~ +40°C					

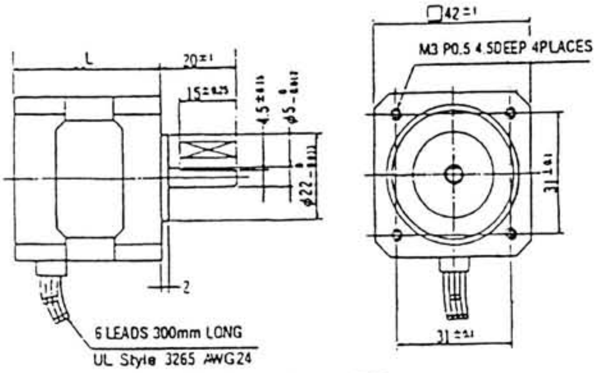
*1 The value given for holding torque is the value operated with rated current and 2 phase excitation.

*2 The minimum required value varies with voltage, motor type, operating speed and load. (See page 5.)

Dimensions unit:mm

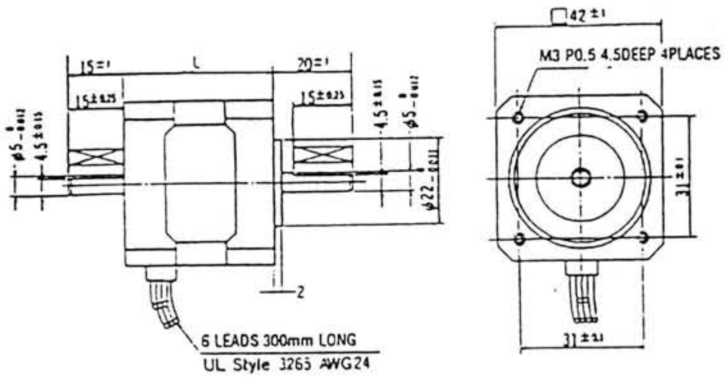
■ Motor

PK24□-01A (Single Shaft) . scale 1/2



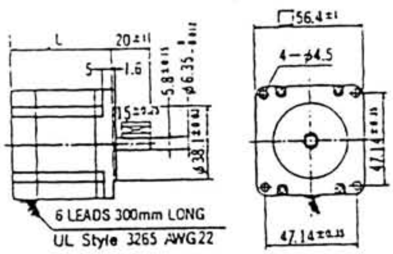
Model	L
PK243	33
PK244	39
PK245	47

PK24□-01B (Double Shaft) . scale 1/2



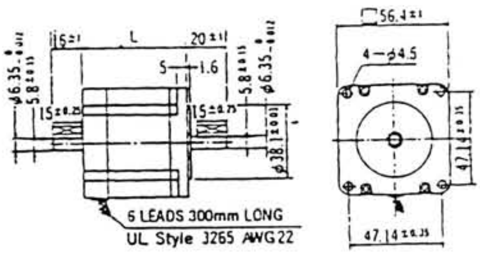
Model	L
PK243	33
PK244	39
PK245	47

PK26□-02A (Single Shaft) . scale 1/4



Model	L
PK264	39
PK266	54
PK268	76

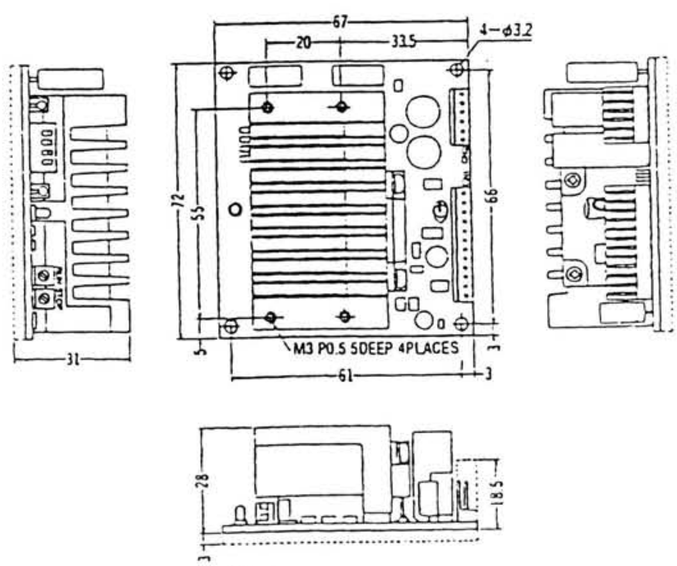
PK26□-02B (Single Shaft) . scale 1/4



Model	L
PK264	39
PK266	54
PK268	76

■ Driver

CSD2109-P
CSD2112-P
CSD2120-P . scale 1/2



Trouble Shooting

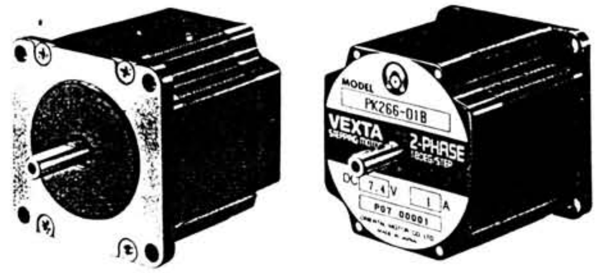
Check the unit once again before requesting service.
When the stepping motor is not functioning properly, perform the following checks and take the following measures. If the motor continues to malfunction, please call your nearest Oriental Motor or our distributors.

Problem	Check Point	Corrective Measures
Motor is not energized or motor has no holding torque. (The motor shaft rotates easily by hand.)	1. Power supply	• Check that the power is connected.
	2. Output-Current-Off input	• Check that the connector is properly and firmly connected. • When the output-current-off signal is at "L" level (photocoupler is ON), the motor ceases to be energized (has no holding torque).
	3. Motor and driver connection	• Check that the motor and driver are connected properly.
	4. RUN and STOP potentiometers	• These potentiometers are used to adjust the output current to motor. (If they have been turned too far down, return them to their initial settings and then check the results.)
	5. Connectors	• Check that the connector housing is properly connected.
Motor does not rotate. Motor rotates in the opposite direction.	Check the above points.	
	6. Pulse input and direction-of-rotation input	• Check the connections, voltages and waveform of pulse signal. • When using 2-pulse input mode, the motor will not operate if the other pulse is at "L" level (photocoupler isON).
Motor is not functioning properly.	Check the above points.	
	7. Are the CW and CCW signals input simultaneously when using 2-pulse input mode?	• When the CW and CCW pulses are input at the same time, the motor will not operate properly.
	8. Are the motor and the load properly centered? Is the load too large?	• Re-tighten the coupling screws or check the load disengaged.
Motor does not move far enough.	9. Does the actual motor step angle conform with the motor step angle required by the device?	• Check the setting of the step angle switch on the driver.
	10. Are the pulse generator settings for the input pulse number appropriate for the amount of motor movement?	• Check the settings.
The motor loses synchronism during acceleration (or during operation).	Check the point 2.	
	11. Is the starting pulse too high?	• Lower the rate and check the results.
	12. Is the acceleration/deceleration time too short?	• Lengthen the time and check the results.
	13. Is there enough current capacity in the power supply?	• Change to a power supply with a capacity of 2.8A or more and recheck. (Then select the right power supply capacity. See page 5.)
	14. Is there any effect from external electrical noise?	• Check the motor movement independently, without operating any other apparatus which could be potential sources of noise.
There is excessive vibration.	15. There may be excessive motor output torque.	• Try reducing the motor running current.
	16. Try changing the pulse rate.	• If the vibration is reduces after changing the pulse rate, the problem might lie in the resonance of the motor. Try changing the pulse rate or step angle.

Problem	Check Point	Corrective Measures
The motor is excessively hot. (The tempeature should be less than 100℃ at motor case and 85 ℃ at driver radiating plate.)	17. The motor has been operating for too long.	• Shorten the motor operating time or lengthen its rest time.
	18. Automatic-Current-Cutback (ACD) switch is off or potentiometer setting is high.	• Turn the ACD switch on and lower the current setting at motor current-cutback.
	19. Does the power supply voltage switch match the power supply?	• Change the switch to match the power supply.
Automatic-current-cutback-at-motor-standstill function does not work.	20. Has automatic-current-cutback (ACD) switch turned off?	• Turn the ACD switch on.
	21. Is the STOP potentiometer in the maximum position?	• Current cannot be lowered when this potentiometer is in MAX position. Turn this potentiometer to the left. (Adjust to the optimal value by making reference to page 9.)
	22. After conclusion of the pulse, is the pulse signal returned to "H" level?	• When the pulse signal is maintained at the "L" level (photocoupler is ON) the current cannot be lowered. Be sure to return the pulse signal to the "H" position.
The motor makes noise when stopped.	23. Does the power supply voltage switch match the power supply?	• Change the switch to match the power supply.
	24. Is the current at motor standstill setting proper?	• Set so that the current cutback at motor standstill is between 0.3A/phase and 50% of the motor rated voltage with automatic-current-cutback on. (set to approximately 40% when shipping.)

2-Phase Stepping Motors High-Torque Type

Step Angle 1.8°



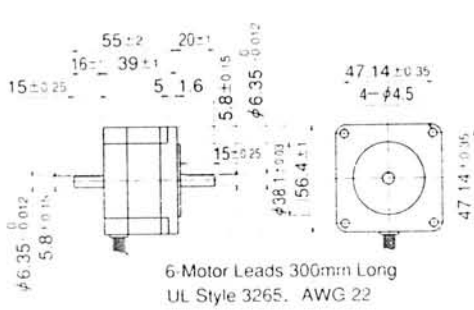
SPECIFICATIONS (at 2-phase excitation)

Model (Single Shaft / Double Shaft)	Holding Torque kgcm N·m	Current Per Phase A/phase	Voltage V DC	Resistance Per Phase Ω/phase	Rotor Inertia J gcm² kg·m²	Corresponding AC-input Motor Unit	Page with Speed-Torque Characteristics
PK264-01A / **PK264-01B**	3.9 / 0.39	1	5.7	5.7	120 / 120×10^{-7}	—	B-161
PK264-02A / **PK264-02B**	3.9 / 0.39	2	2.8	1.4	120 / 120×10^{-7}	**UMK264**	B-127
PK264-03A / **PK264-03B**	3.9 / 0.39	3	1.9	0.63	120 / 120×10^{-7}	—	B-161
PK266-01A / **PK266-01B**	9 / 0.9	1	7.4	7.4	300 / 300×10^{-7}	—	B-161
PK266-02A / **PK266-02B**	9 / 0.9	2	3.6	1.8	300 / 300×10^{-7}	**UMK266**	B-127
PK266-03A / **PK266-03B**	9 / 0.9	3	2.3	0.75	300 / 300×10^{-7}	—	B-161
PK268-01A / **PK268-01B**	13.5 / 1.35	1	8.6	8.6	480 / 480×10^{-7}	—	B-161
PK268-02A / **PK268-02B**	13.5 / 1.35	2	4.5	2.25	480 / 480×10^{-7}	**UMK268**	B-127
PK268-03A / **PK268-03B**	13.5 / 1.35	3	3	1	480 / 480×10^{-7}	—	B-161

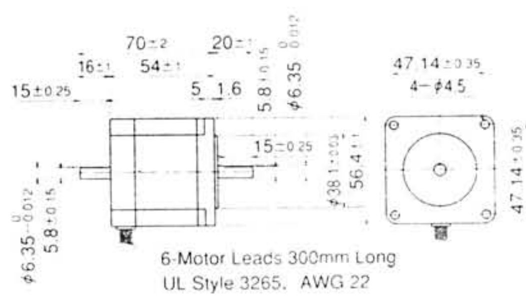
If you are considering buying both a motor and a driver, we recommend the purchase of one of the AC-input **UMK** Series products, which combine a dedicated motor and driver into a single unit.
The motors in the table above cannot be connected to **UMK** Series drivers. Consult your local sales office regarding drivers before your purchase.
For the speed-torque characteristics of the motors in the above table, see the corresponding **UMK** series characteristics. If there is no applicable motor unit, see the speed-torque characteristics on page B-161.

DIMENSIONS unit = mm

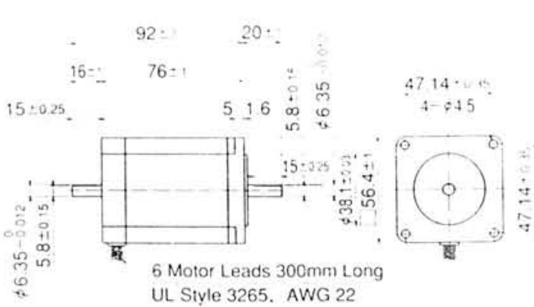
PK264-01A, -02A, -03A (Single shaft) Mass 0.45kg
PK264-01B, -02B, -03B (Double shaft) Mass 0.45kg



PK266-01A, -02A, -03A (Single shaft) Mass 0.7kg
PK266-01B, -02B, -03B (Double shaft) Mass 0.7kg



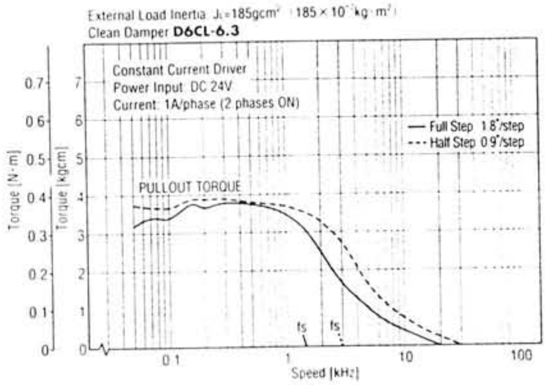
PK268-01A, -02A, -03A (Single shaft) Mass 1kg
PK268-01B, -02B, -03B (Double shaft) Mass 1kg



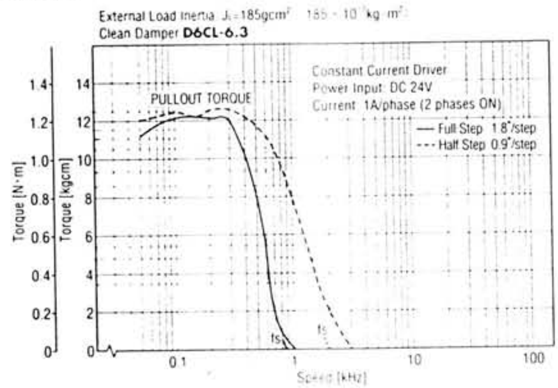
* These dimensions are of a double-shaft models. For a single shaft models, ignore the colored areas.

See page [B-32] for information on motor installation.

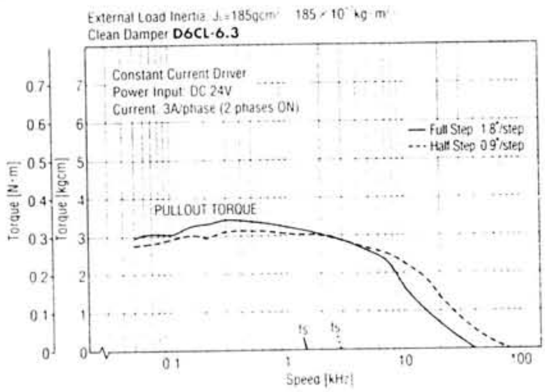
PK264-01B



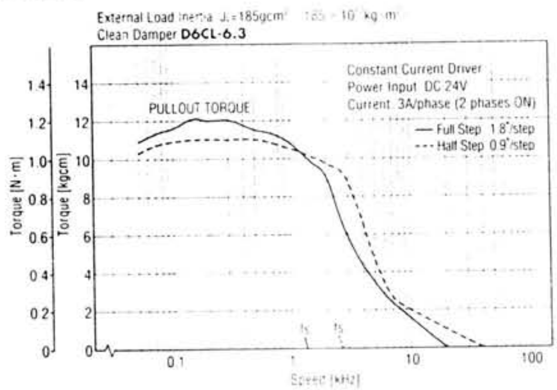
PK268-01B



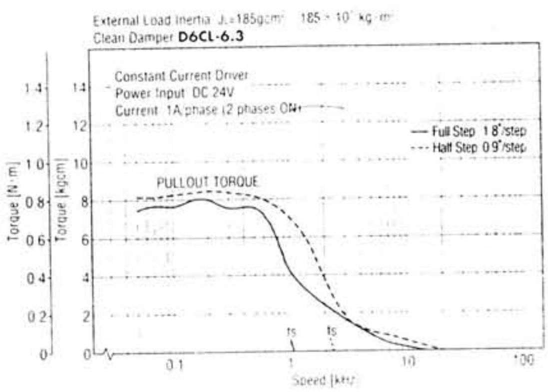
PK264-03B



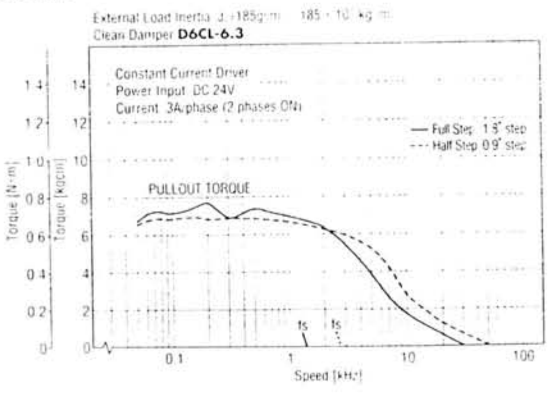
PK268-03B



PK266-01B



PK266-03B



2-Phase Stepping Motors

The motor may become exceptionally hot under some drive conditions. Keep the motor case temperature to 100°C or less.

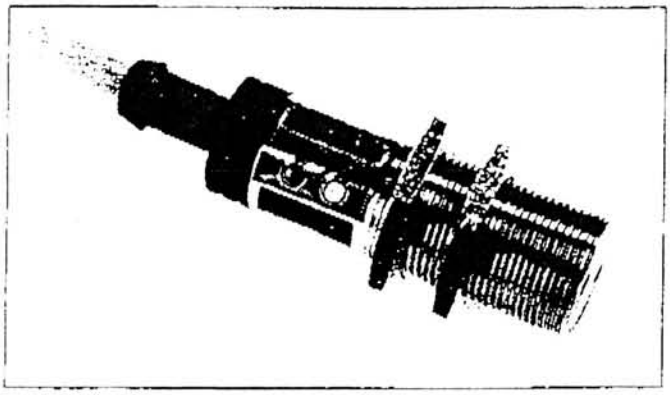
254 496

To : Mr Chew Chuen Hee

From : Kathryn. Tan.

Photoelectric Switch Diffuse-reflective Type EO 1804

electromatic



- Range: 400 mm
- Modulated infrared light
- Adjustable sensitivity
- Voltage supply: 10 to 40 VDC and 20 to 250 VAC
- Output NPN or PNP, SCR light and dark switching
- Protection: Reverse polarity, short-circuit, transients
- LED output indication
- Cable and plug connection
- M18 all-metal housing

Product Description

Diffuse-reflective photoelectric switch with extended range up to 400 mm. Easily adjustable sensitivity with 270° potentiometer. LED output indication. All are in M18 metal housing for heavy duty applications. IP 67. Cable and plug versions for DC and AC types.

Ordering Key EO 18 04 NPA S-1

- Type — EO
- Housing diameter (mm) — 18
- Range — 04
- Output type — NPA
- Nickel-plated brass — S
- M12 plug — -1

Type Selection - DC types

Housing diameter	Range	Ordering no. NPN/cable dark & light switch.	Ordering no. NPN/plug dark & light switch.	Ordering no. PNP/cable dark & light switch.	Ordering no. PNP/plug dark & light switch.
M18	400 mm	EO 1804 NPAS •	EO 1804 NPAS-1 •	EO 1804 PPAS •	EO 1804 PPAS-1 •

Type Selection - AC types

Housing diameter	Range	Ordering no. SCR/cable light switching	Ordering no. SCR/plug light switching	Ordering no. SCR/cable dark switching	Ordering no. SCR/plug dark switching
M18	400 mm	EO 1804 TBOS •	EO 1804 TBOS-3 [1]	EO 1804 TBCS •	EO 1804 TBCS-3 [1]

• Stock item
[1] In preparation

[redacted]

Specifications

	Transistor NPN/PNP	SCR output AC types
Range (S_n)	0 - 400 mm. Reference: Kodak test card R27 white, 90% reflectance, 200 x 200 mm	0 - 400 mm. Reference: Kodak test card R27 white, 90% reflectance, 200 x 200 mm
Temperature drift	0.4%/°C	0.4%/°C
Hysteresis	3 to 20%	3 to 20%
Supply voltage range (U_e)	10 to 40 VDC (ripple included)	20 to 250 VAC, 45 to 65 Hz (AC12, AC140)
Ripple (U_{rpp})	10%	
Output current Continuous (I_e) Short-time (I)	 ≤ 200 mA 200 mA, max. load capacity 100 nF	 ≤ 500 mA (AC12) ≤ 3 A, max. 20 ms (AC140)

Type EO 1804

electromatic

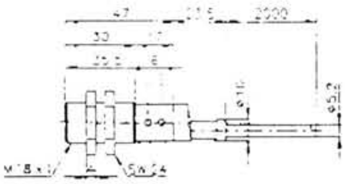
Specifications (cont.)

	Transistor NPN/PNP		SCR output AC types	
Current consumption (I_o)	Max. 20 mA			
Min. load current (I_m)	0.5 mA		10 mA	(AC12)
Leakage current (I_r)	Max. 100 μA		≤ 5 mA, typ. 2.6 mA	(AC12)
Voltage drop Typically (U_d) Max.	 ≤ 2.5 VDC 		 ≤ 7 VAC ≤ 10 VAC	 (AC12) (AC12)
Transient voltage	1 kV/0.5 J		1 kV/0.5 J	
Power-on delay (t_d)	Typ. 70 ms		Typ. 70 ms	
Protection	Reverse polarity, short-circuit, transients		Transients	
Light source	GaAlAs, LED, 880 nm		GaAlAs, LED, 880 nm	
Light type	Infrared, modulated		Infrared, modulated	
Detection angle	± 25° at 1/2 range (reference card)		± 25° at 1/2 range (reference card)	
Sensitivity	Adjustable, single turn potentiometer, 270°		Adjustable, single turn potentiometer, 270°	
Ambient light	Max. 10,000 lux		Max. 10,000 lux	
Operating frequency (t_v)	Max. 100 Hz, light-dark ratio 1:2		Max. 25 Hz, light-dark ratio 1:2	
Response time Off-on (t_{on}) On-off (t_{off})	 ≤ 3.2 ms ≤ 5 ms		 ≤ 20 ms ≤ 30 ms	
Output Function Indication	 Dark and light (antivalent) switching LED, red		 Dark (NC) or light (NO) switching LED, red	
Environment Installation cat. Degree of protection Pollution degree Operating temperature Storage temperature	 III IP 65, IP 66, IP 67 3 - 20 to + 60°C (-4 to + 140°F) - 30 to + 70°C (- 22 to + 158°F)	 (IEC 664/664A; 947-1) (IEC 529, 947-1) (IEC 664/664A; 947-1) 	 III IP 65, IP 66, IP 67 3 - 20 to + 60°C (-4 to + 140°F) - 30 to + 70°C (- 22 to + 158°F)	 (IEC 664/664A; 947-1) (IEC 529, 947-1) (IEC 664/664A; 947-1)
Vibration & Shock	10-150 Hz, 0.5 mm/7.5 g 2 x 1 m + 100 x 0.5 m	(IEC 68-2-6) (IEC 68-2-32)	10-150 Hz, 0.5 mm/7.5 g 2 x 1 m + 100 x 0.5 m	(IEC 68-2-6) (IEC 68-2-32)
Isolation voltage	500 V	(IEC 364-4-41)	1500 V	(IEC 364-4-41)
Housing material Body Front Back Nut	 Nickel-plated brass Luran, black PVC, black Nickel-plated brass		 Nickel-plated brass Luran, black PVC, black Nickel-plated brass	
Connection Cable Plug	 2 m, 4 x 0.35 mm², Ø 5.2 mm, grey, oil proof PVC CONB1A-., CONL1A-..		 2 m, 2 x 0.50 mm², Ø 5.2 mm, grey, oil proof PVC CON.3A-...	
Weight (cable included)	175 g		230 g	

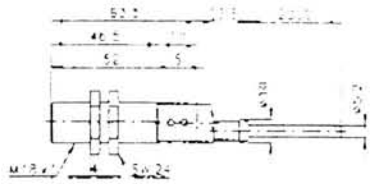
Type EO 1804

electromatic

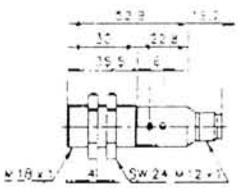
Dimensions



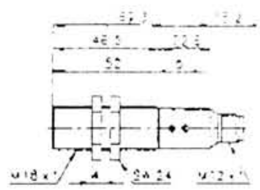
EO 1804 .PAS



EO 1804 TB.S



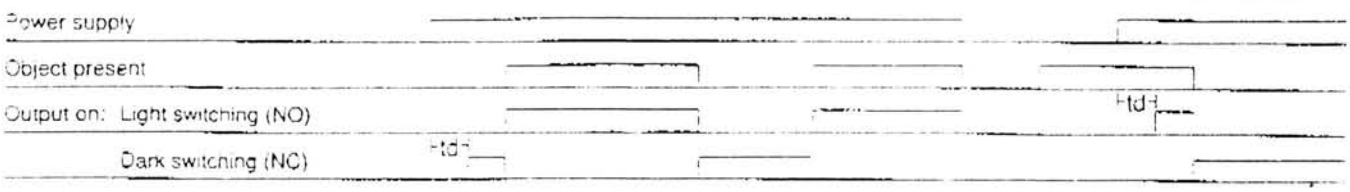
EO 1804 .PAS-1



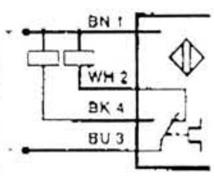
EO 1804 TB.S-1

All measurements in mm

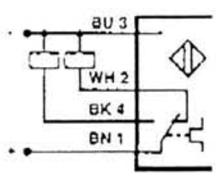
Operation Diagram



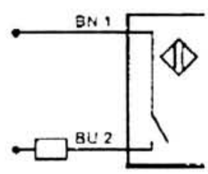
Wiring Diagrams



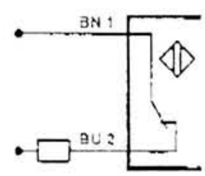
NPA



PPA



Light switching
TBO (NO)



Dark switching
TBC (NC)

Reduction Factors

Object	
Kodak test card R27, 200 x 200, white	1.0
Kodak test card R27, 200 x 200, grey	0.4
Dead black card board	0.1 - 0.4
Raw wood	0.4 - 0.8
White cotton	0.5 - 0.8
White Styropack	1.0 - 1.2
Bright metal	1.2 - 2.0

Accessories

Plugs	90° angle	Straight
DC versions		
M12 plug without cable	CONB1A-A◊	CONB1A-S◊
M12 plug with 2 m cable	CONL1A-A2◊	CONL1A-S2◊
M12 plug with 5 m cable	CONL1A-A5◊	CONL1A-S5◊
Optical fibres:	• Glass fibre (in preparation) • Polymer fibre (in preparation)	

Truth Table

	Light switching		Dark switching	
Object present	No	Yes	No	Yes
DC types				
LED	Off	On	Off	On
Load	Non -active	Active	Active	Non-active
Output NPN	High	Low	Low	High
Output PNP	Low	High	High	Low
AC types				
LED	Off	On	On	Off
Load	Non -active	Active	Active	Non-active

Delivery Contents

- Photoelectric switch: EO 1804 ...
- 2 nuts
- Packaging: Plastic bag

◊ Item not produced by the holder of the ISO 9001 certificate

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CARLO GAVAZZI

S30 Series Fixed-field Sensors

DC diffuse sensors with far-limit sensing cutoff (200 or 400 mm)

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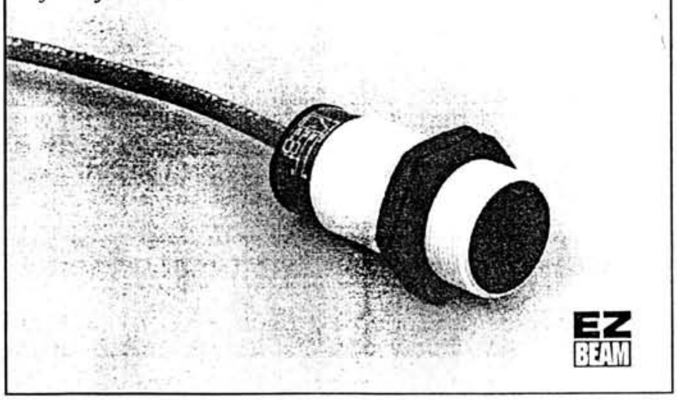
- **Fixed-field diffuse mode 30-mm diameter barrel sensors with far-limit sensing cutoff**
- **Models available with far-limit cutoff of 200 or 400 millimeters (8 or 16 inches)**
- **Totally self-contained; 10 to 30 volt dc operation**
- **Complementary outputs: one normally open, one normally closed; choice of NPN (sinking) or PNP (sourcing) configuration, 150 mA max. (continuous)**
- **LED indications for POWER ON, OUTPUT OVERLOAD, OBJECT SENSED, and LOW GAIN conditions**
- **One output may be wired as a normally open low-gain alarm output** (US patent no. 5087838)

S30 Series dc fixed-field sensor



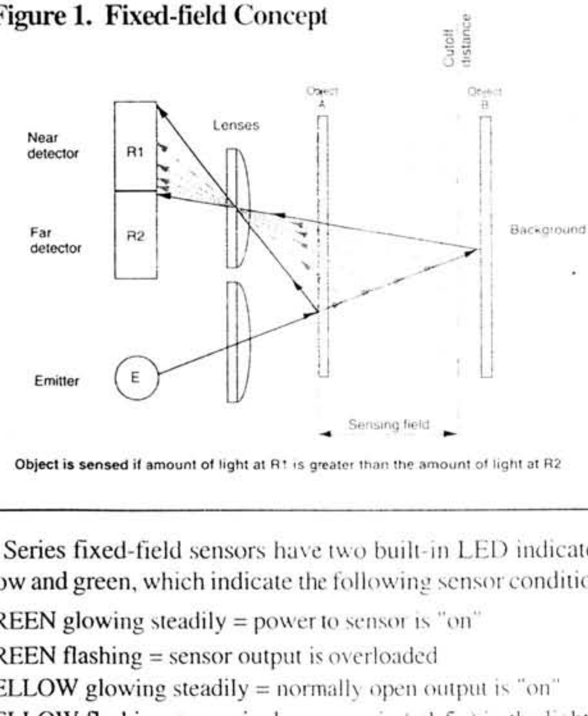
Description

Banner S30 Series sensors are powerful infrared fixed-field diffuse mode sensors with far-limit cutoff (see excess gain curve, page 2). The high excess gain of these sensors makes it possible for them to detect objects of low reflectivity, while their fixed-field design helps them to ignore backgrounds lying beyond the far-limit cutoff distance. Models are available with far-limit cutoffs of 200 mm (8 inches) or 400 mm (16 inches). These sensors are ideal for detecting a part or surface that is directly in front of another surface.

In operation, an S30 fixed-field sensor compares the reflections of its emitted light beam (E) from an object back to the sensor's two differently-aimed detectors R1 and R2 (see drawing at right). If the near detector (R1) light signal is stronger than the far detector (R2) light signal (see object A, closer than the cutoff distance), the sensor responds to the object. If the far detector (R2) light signal is stronger than the near detector (R1) light signal (see object B, beyond the cutoff distance), the sensor ignores the object. At the cutoff distance (dashed line), the signals from the two detectors are equal. Orientation of the two sensor fields, and therefore of the sensor itself, with respect to the object or the background can be important for some applications (see discussion, page 3).

S30 Series fixed-field sensors operate from 10-30V dc, and draw 35 milliamps maximum (exclusive of output load current). Outputs are complementary (one normally open and one normally closed). Each output is capable of 150 milliamps maximum (continuous). Outputs are available in either an NPN current sinking or a PNP current sourcing configuration (see model listings, page 2). Both outputs are protected from overload, shorted load, and low voltage conditions, and are automatically reset when the cause of the problem is cleared. The normally-closed output of each sensor may be wired as a normally-open low-gain alarm output (US patent no. 5087838), depending upon the sensor's hookup to the power supply. Some current limitations apply (see *Specifications*, page 2). If alarm hookup is used, the sensor can be used to signal a PLC or energize an external alarm whenever its excess gain in the light condition drops below 1.5x.

Figure 1. Fixed-field Concept



Object is sensed if amount of light at R1 is greater than the amount of light at R2

S30 Series fixed-field sensors have two built-in LED indicators, yellow and green, which indicate the following sensor conditions:

GREEN glowing steadily = power to sensor is "on"
GREEN flashing = sensor output is overloaded
YELLOW glowing steadily = normally open output is "on"
YELLOW flashing = marginal excess gain (<1.5x) in the light condition; the flashing YELLOW coincides with the "on" state of the alarm output.

S30 Series fixed-field sensors are enclosed in an M30x1.5 threaded yellow VALOX® barrel housing with a black acrylic lens. Two jam nuts are included for mounting. Sensors are rated NEMA 6P (IEC IP67) for use in wet locations. Models are sold with either a 4-wire 6-1/2 foot long attached cable or a 4-pin Quick Disconnect (QD) connector that requires mating QD cable model MQDC-415 (4 conductors, 15 feet long, straight connector; order separately). QD cable with right-angled connector (model MQDC-415RA) is also available. *QD sensors carry the letter "Q" in their model number suffix.* S30 Series fixed-field diffuse sensor models are listed in the *Specifications* section on page 2.

Printed in USA

P/N 33068

Specifications, S30 Series Fixed-field Sensors

Cutoff distance (curve, right, based on 90% reflectance white test card):
FF200 models: 200 mm (8 inches) from sensor face (±10%)
FF400 models: 400 mm (16 inches) from sensor face (±10%)

Sensing beam: infrared, 880 nanometers.

Supply voltage:
10 to 30V dc at 35 mA maximum (10% maximum ripple), exclusive of load current.

Output configuration:
Solid-state dc output; two output types available.
- NPN sinking; complementary (1 normally open, 1 normally closed)
- PNP sourcing; complementary (1 normally open, 1 normally closed)
- See listing of models, below.

Output rating* (sinking and sourcing outputs: see diagrams on page 4):
150 mA maximum each in standard hookup; short-circuit protected.
Off-state leakage current <1 microamp at 30V dc.
On-state saturation voltage is <1volt at 10 mA dc and <1.50 volt at 150 mA dc.
*When wired for alarm output, the *total load* may not exceed 150 mA.

Response time: 3 milliseconds "on" and "off". No false pulse on power-up; outputs are non-conducting for 100 milliseconds after power-up.

Repeatability: 750 microseconds.
NOTE: Response time and repeatability are independent of signal strength.

Indicators: Two LEDs, one yellow and one green.
Indications are as follows:
- GREEN glowing steadily = power to sensor is "on"
- GREEN flashing = output is overloaded
- YELLOW glowing steadily = normally open output is "on"
- YELLOW flashing = excess gain is marginal (1 to 1.5x)

Flashing YELLOW corresponds to the "on" state of the alarm output.

Construction (see Dimension drawing, page 4): M30x1.5 threaded yellow VALOX* barrel with black acrylic lens. Two jam nuts supplied. Meets NEMA standards 1, 2, 3, 3S, 4, 4X, 6, 6P, 12 and 13. IEC IP67.

Cabling options:
6-1/2 foot long (2 meter) attached PVC-covered 4-wire cable, or 4-pin *eurofast*™ QD (Quick Disconnect) fitting. QD models require model MQDC-415 (straight connector) or MQDC-415RA (right-angled connector) 4-conductor QD cable. QD cables are 15 feet long (order separately).

Vibration and mechanical shock: meets Mil. Std. 202F requirements. Method 201A (Vibration: frequency 10 to 60 Hz, max., double amplitude 0.06-inch, maximum acceleration 10G). Method 213B conditions H & I (Shock: 75G with unit operating; 100G for non-operation).

Operating temperature range and humidity: -40° to +70°C (-40° to 158°F). Maximum relative humidity 90% (non-condensing).

Available models:

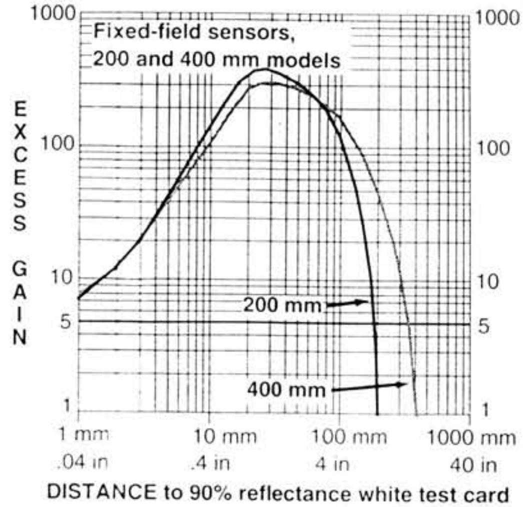
200-mm fixed-field sensors:

S30SN6FF200	NPN sinking, N.O. and N.C. outputs, 6-1/2 ft. cable
S30SN6FF200Q	NPN sinking, N.O. and N.C. outputs, QD connector
S30SP6FF200	PNP sourcing, N.O. and N.C. outputs, 6-1/2 ft. cable
S30SP6FF200Q	PNP sourcing, N.O. and N.C. outputs, QD connector

400-mm fixed-field sensors:

S30SN6FF400	NPN sinking, N.O. and N.C. outputs, 6-1/2 ft. cable
S30SN6FF400Q	NPN sinking, N.O. and N.C. outputs, QD connector
S30SP6FF400	PNP sourcing, N.O. and N.C. outputs, 6-1/2 ft. cable
S30SP6FF400Q	PNP sourcing, N.O. and N.C. outputs, QD connector

Excess Gain Curve



The excess gain curve above shows excess gain vs. sensing distance for S30 Series fixed-field sensors with 200- and 400-millimeter cutoffs. Maximum excess gain for all models occurs at a lens-to-object distance of about 25 millimeters. Sensing at or near this distance, if possible, will make maximum use of each sensor's available sensing power.

Backgrounds and background objects must *always* be placed beyond the cutoff distance.

This excess gain curve was generated using a white test card of 90% reflectance. Objects with reflectivity of less than 90% reflect less light back to the sensor, and require proportionately more excess gain to be sensed with the same reliability as more reflective objects. When sensing an object of very low reflectivity, it may be especially important to sense it at or approaching the distance of maximum excess gain.

The effects of object reflectivity on cutoff distance may be important for some applications. Sensing of objects of less than 90% reflectivity causes the cutoff distances to be "pulled" in toward the sensor. For example, an excess gain of 1 for an object that reflects 1/5 as much light as the 90% white card is represented by the heavy horizontal graph line at excess gain = 5. An object of this reflectivity results in far limit cutoff distances of approximately 190 and 350 millimeters (for 200- and 400-mm cutoff units, respectively).

Objects with reflectivity greater than 90% return more light to the sensor. For this reason, highly reflective backgrounds or background objects such as mirrors, polished metal, and other sources of specular reflections require special consideration. If it is necessary to use a highly reflective background, it should be placed as far beyond the cutoff distance as possible and angled to direct reflected light away from the sensor (see page 3).

Setup Tips: S30 Series Fixed-field Sensors

General

For highest sensitivity, the sensor-to-object distance should be such that the object will be sensed at or near the point of maximum excess gain (see excess gain curve and discussion, page 2). The background *must* be placed beyond the cutoff distance. Following these two guidelines makes it possible to detect objects of low reflectivity, even against close-in reflective backgrounds.

In the drawings and discussion on this page, the letters E, R1, and R2 identify how the sensor's three optical elements (Emitter "E", Near Detector "R1", and Far Detector "R2") line up across the face of the sensor. In Figures 3, 4, and 5, these elements line up parallel to the surface of the page. In Figure 6, they line up perpendicular to the surface of the page. Note how the pattern on the sensor's lens helps to differentiate the two positionings and defines the *sensing axis* of the sensor (Figure 2, below). The sensing axis becomes important in the type of situations illustrated in Figures 5 and 6, discussed below.

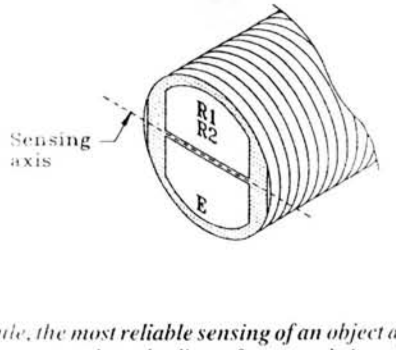
Background reflectivity and placement

Avoid mirror-like backgrounds that produce specular reflections. False sensor response will occur if a background surface reflects the sensor's light more strongly to the *near detector* (R1) than to the far detector (R2). The result is a false "on" condition (Figure 3). *Use of a diffusely-reflective (matte) background will cure this problem.* Other possible solutions are to either angle the sensor or angle the background (in any plane) so that the background does not reflect back to the sensor (see Figure 4).

An object beyond the cutoff distance, either moving or stationary (and when positioned as shown in Figure 5), can cause unwanted triggering of the sensor because it reflects more light to the near detector than to the far detector. The problem is remedied by rotating the sensor 90° (Figure 6) to place the sensing axis parallel to the the surface of the page. The object now reflects the R1 and R2 fields equally, resulting in no false triggering.

Unwanted triggering of the sensor from an object beyond cutoff can also be caused by attempting to sense a small object that is moving perpendicular to the sensor face, or by an object moving through the off-center position shown in Figure 5. Making the object larger, centering the sensor relative to the object, or rotating the sensor to place the sensing axis perpendicular to the longer dimension of the object (Figure 6) will solve the problem.

Figure 2. The *sensing axis* runs at right angles to a line connecting the sensing elements E, R1, and R2.



As a general rule, the most reliable sensing of an object approaching from the side occurs when the line of approach is parallel to the sensing axis.

Figure 3. Reflective background - problem

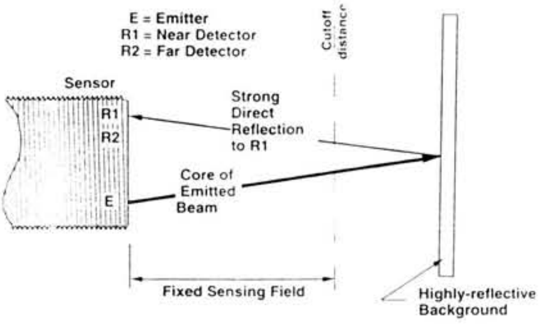


Figure 4. Reflective background - solution

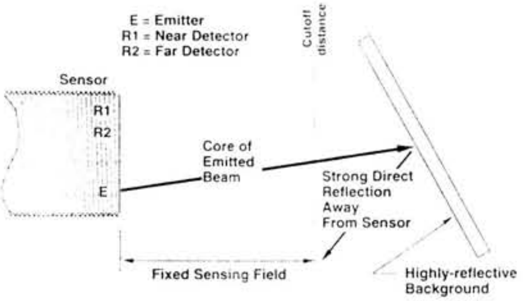


Figure 5. Object beyond cutoff - problem

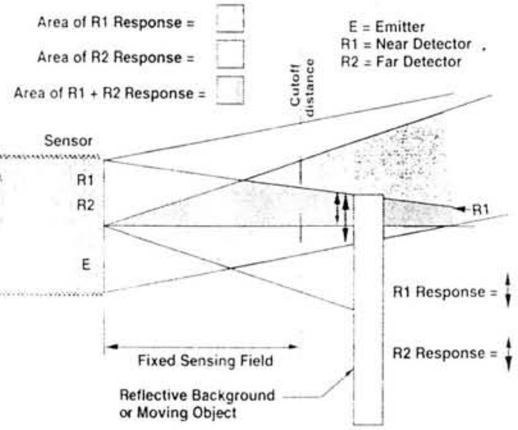
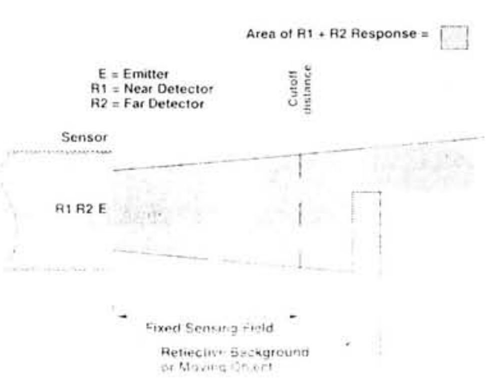


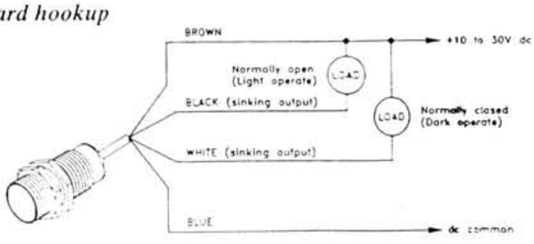
Figure 6. Object beyond cutoff - solution



Hookup, S30 Series dc fixed-field sensors

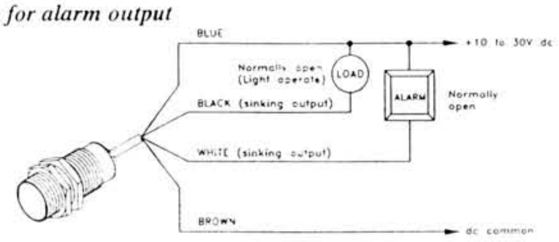
NPN (sinking) S30SN6FFxxx(Q)models

Standard hookup



Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

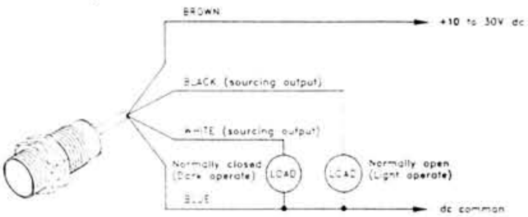
Hookup for alarm output



Note: Use model MQDC-415 (RA) cable for "Q" model sensors (ordered separately)

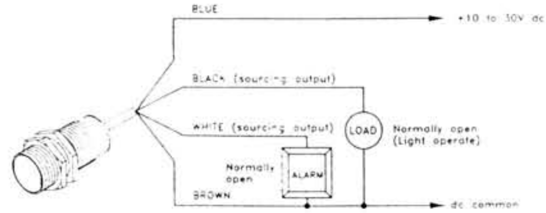
PNP (sourcing) S30SP6FFxxx(Q) models

Standard hookup



Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

Hookup for alarm output



Note: Use model MQDC-415(RA) cable for "Q" model sensors (ordered separately)

Mounting Options for S30 Series Sensors

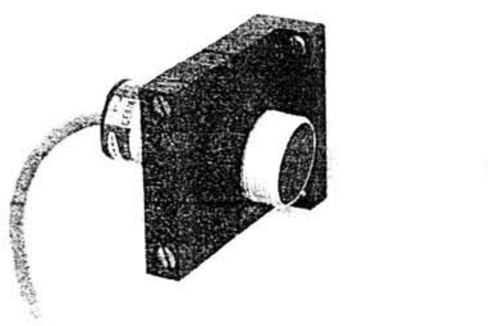
The **model SMB30A two axis mounting bracket** has a curved mounting slot for versatility and orientation. The S30 Series sensor mounts to the bracket using jam nuts (two supplied with sensor). The bracket's curved mounting slots have clearance for 1/4-inch screws. Bracket material is 11-gauge stainless steel.

The **model SMB30S swivel-mount bracket** (right) offers the ultimate in flexibility and convenience. This bracket mounts by its base. The S30's lens housing threads into the adjustable captive "ball" of the bracket, which locks snugly in position when two clamping bolts are tightened. Bracket material is black VALOX®. Hardware is stainless steel, and mounting bolts are included.

The model SMB30C split clamp mounts to a flat surface and grips the S30 Series sensor by its threaded barrel.

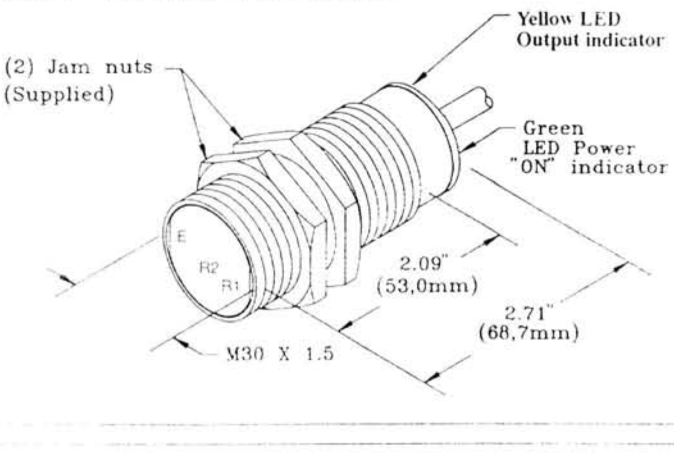
S30 Series sensors may also be mounted in a 30-mm clearance hole, using the supplied jam nuts.

SMB30S Swivel Mount Bracket



Dimensions, S30 Series dc fixed-field sensors

Cabled model shown. Quick Disconnect fitting adds .34" (9 mm) in overall length to QD models.



WARNING These photoelectric presence sensors do NOT include the self-checking redundant circuitry necessary to allow their use in personnel safety applications. A sensor failure or malfunction can result in *either* an energized or a de-energized sensor output condition.

Never use these products as sensing devices for personnel protection. Their use as safety devices may create an unsafe condition which could lead to serious injury or death.

Only MACHINE-GUARD and PERIMETER-GUARD Systems, and other systems so designated, are designed to meet OSHA and ANSI machine safety standards for point-of-operation guarding devices. No other Banner sensors or controls are designed to meet these standards, and they must NOT be used as sensing devices for personnel protection.

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