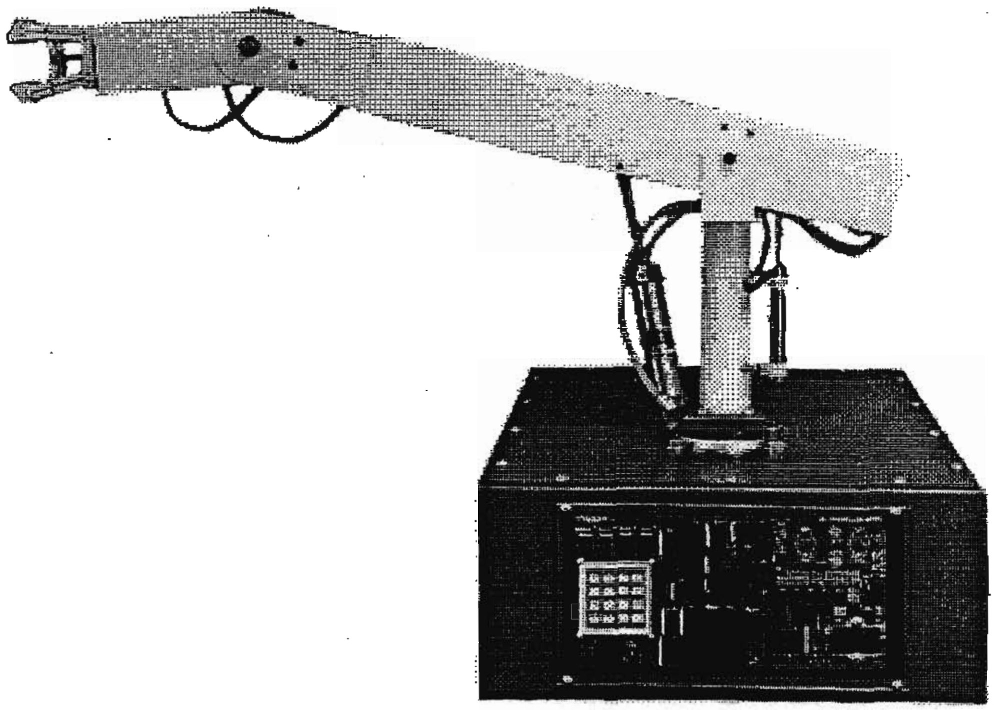
Bulletin 290-9EX ED.3

STUDENT MANUAL

FOR



HAMPDEN MODEL H-MRS-1

MULTI-TECHNOLOGY ROBOT TRAINING SYSTEM

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CHAPTER 1

ROBOTICS AND SAFETY

In working with the Hampden Robot Arm, you will be dealing with four possible hazards: (1) Mechanical; (2) Hydraulic; (3) Pneumatic; and (4) Electrical. For your safety and the safety of others you must be aware of the possible dangers and take the necessary precautions ahead of time.

We have often heard that "accidents don't just happen, they are caused". This does not mean that someone deliberately and destructively "causes" an accident. It does mean that accidents are caused through ignorance, or through failure to see that they don't "happen".

MECHANICAL HAZARD:

A robot is a machine and it is the nature of machinery to move. The motion is produced by powerful electrical, pneumatic or hydraulic "motors". If anything or anyone gets in the way of the moving arm, the arm will not know it. Considerable force is produced in the effort to keep the arm moving. SERIOUS INJURY CAN RESULT.

Fortunately, the arm's potential motions are totally predictable. There is a certain volume of space, called the arm's "work envelope", beyond which it cannot move. To be safe NEVER INTRUDE IN THE WORK ENVELOPE WHILE THE ROBOT IS ON.

The dimensions of the work envelope are shown in Figure 2, page 3-2.

The area must be kept free of any obstructions. There is never any need to be in, or even to reach into the arm's envelope while it is operating. Ideally, the area should be screened off with warning signs posted. Although the robot arm is always totally under control of the operator and thus cannot take off on its own, there is always the one-in-a-thousand chance of an unforeseen programmer or operator error.

Be especially cautious of loose fitting clothing, jewelery, etc, around moving parts. Tie back long hair.

Since your eyes are so vulnerable and so precious, SAFETY GLASSES MUST BE WORN AT ALL TIMES.

HYDRAULIC HAZARD:

The Robot arm is supplied hydraulic oil at considerable pressure (100 psi). The following are safety instructions that must be rigorously followed:

1. If you are aware of being allergic to oil, notify the instructor immediately.

2. Always double-check all fittings before starting the pump to make sure they are secure.

3. Be on the lookout for leaks. If you discover even a small one, shut everything down and fix it.

4. No line is to be disconnected while the pump is running.

5. Fluid propelled by high pressure can be forced through the skin. Should this occur, seek medical help immediately.

6. Hydraulic oil is injurious to the eyes and poisonous if consumed.

7. Clean up oil spills on the robot arm or floor immediately with rag or towels. Do not use granular fluid-absorbing materials because the dust they produce may get into moving parts of the hydraulic system.

8. In the event of fire use a carbon dioxide (CO_2) fire extinguisher.

PNEUMATIC HAZARDS:

The principal pneumatic hazard is its pressure. Air carries with it particles of dirt and oil. A stream of high pressure air could drive the particles into the eyes or the skin. The design of the robot arm confines air inside the hose or machinery. Never attempt to defeat the safety of the design in order to aim a jet of air at anyone. It could result in permanent injury.

ELECTRICAL HAZARDS:

In normal operation none of the electrical portions of the robot arm are accessible, except for the test points, which are at a low voltage level. Upon occasion, however, it may become necessary to remove one of the plastic covers to gain access to electrical portions of the robot arm.

Do not allow any objects to fall into the base. While metal can short out circuits, even dust and dirt can adversely affect electrical circuits. Even if power is OFF, do not touch any of the electrical parts, leads, or printed circuit traces. Oil and dirt from your hands can start the corrosion process, which may end up in circuit failure.

You must be extremely careful when troubleshooting with oscilloscope probes, logic probes, or voltmeter leads. You can easily short the closely-spaced leads and pins with consequent change to the components. Electrical shock, of course is always a potential hazard when working with electricity.

HOW SHOCK OCCURS:

Electricity can travel only in a closed or looped circuit. Normally, travel is through the conductor. Shock occurs when the body becomes a part of the electric circuit. The current must enter the body at one point and leave at another. Shock may occur in one of three ways; the person must come in contact (1) with both wires of the electric circuit; (2) with one wire of an energized circuit and the ground; or (3) with a metallic part that has become "hot" by being in contact with an energized wire, while the person is in contact with the ground.

It is possible to receive a shock by touching only the energized wire, or an energized metallic part, and the ground because of the nature of an electric circuit. An electric circuit constitutes a completely continuous path. It starts at the generator, flows through wires (conductors) to the transformer, and back to the generator. In the transformer, the voltage is reduced (or increased) and flows into the building, where it is used to do useful work, and then back to the transformer. The generator and the transformer both have direct connections to the ground, and the current will use these paths if its normal path of return is broken and if it can get to the ground.

To receive a shock, a person must become part of an actual circuit; that is, the current must flow through his body as it would through a conductor. Under certain conditions, a person may be exposed to electricity but, unless his body becomes part of a circuit, no harm results. If, for instance, a person is standing on an insulating mat and touches only one wire of a 120-volt circuit, no complete circuit is established and he will feel no shock. If, however, a person should touch both conductors of a circuit, even with the same finger, the finger becomes part of the circuit, current flowing through the finger from one side of the circuit to the other. For this reason, shock occurs when a finger is placed in a lamp socket, it being difficult to touch the base of the socket without also touching the side.

SEVERITY OF THE SHOCK

The severity of the shock received when a person becomes a part of an electrical circuit is affected by three primary factors. These factors are: (1) the of flow of current through the body, measured in amperes; (2) the path of the current through the body, and (3) the length of time the body is in the circuit. Other factors which may affect the degree of shock are: the frequency of the current phase of the heart cycle when shock occurs, and the physical and psychological condition of the person.

There are no absolute limits or even known values which show the exact injury from any given amperage. The following, based on 60-cycle, 120-volt alternating current, are merely acceptable measurements of injury as related to amperage. These are stated in milliamperes, which is another way of saying in thousandths of an ampere.

Less than 0.5 milliamp	—	No sensation
0.5 to 2 milliamps	—	Threshold of perception
2 to 10 milliamps	—	Muscular contraction (mild to strong)
5 to 25 milliamps	—	Painful shock, inability to let go
over 25 milliamps	—	Violent muscular contractions
50 to 200 milliamps	—	Ventricular fibrillation
over 100 milliamps	—	Paralysis of breathing

From the above table it may be seen that a difference of only about 100 milliamperes exists between a current which can just be perceived and one which can be immediately fatal. On low-voltage circuits, if the person cannot let go of the circuit and is not rescued from it, the ratio between a current which can just be perceived and one which is dangerous may be less than one to five. This factor should be kept in mind with respect to live parts of low-voltage circuits, as the difference in resistance between dry skin and skin wet by either water and perspiration will usually vary by considerably more than a factor of five. Further, in low-voltage shock, there is much greater danger of having current in the range which will cause ventricular fibrillation (convulsive movement) of the heart, a condition for which there is usually no field treatment. On the other hand, high-voltage shock frequently causes paralysis of breathing and many victims of this are saved by the application of artificial res piration.

The amount of current flowing through the body is governed by the resistance of the body (particularly the skin as the point of entry and exit) and the degree to which the body is insulated from the ground. The skin offers about the only resistance presented by the human body to the flow of current.

When the skin is dry, it may present from 100,000 to as much as 600,000 ohms resistance, depending upon its thickness (0.015 to 0.025 inches) and on other personal factors. But the skins's humidity varies over wide limits. A person working under high temperatures may perspire freely and when the skin, and possibly his clothing, becomes wet, the skin's resistance to electric current drops radically, quite easily to a figure approximately 1,000 ohms. If working on damp or wet surfaces, or there is a break in the skin, it could drop even more than this, at times to a few hundred ohms.

Remembering that Ohm's law states that the number of amperes flowing in a circuit with a given voltage will be inversely proportional to the resistance, it is apparent that great variations of current are possible even with the same voltage. Assuming a 120-volt circuit, and under ideal conditions - a person with a dry skin of 100,000 ohms resistance standing on a wood floor with a resistance on the order of 100,000 ohms - the amperage passing through the skin could be calculated as $120 \div 100{,}000 = 0.001$ amperes (1 milliampere), which would not be particularly harmful. If however, the resistance of the skin were reduced to 1,000 ohms because of perspiration, and if the person were standing on a wet or damp ground, the current passing through the body would be in the nature of $120 \div 1000 = 0.1$ ampere (100 milliamperes) - more than enough to kill.

From the foregoing it is obvious that even so-called low-voltages are dangerous. When the low voltage remains constant, the determining factor becomes the person's resistance. But resistance varies over such wide limits that any circuit, even a circuit of 50 volts or less, can, under certain conditions, become dangerous.

With respect to the path of current through the body, this factor is concerned with whether the current passes through that part of the body containing the vital organs, particularly the heart and lungs. It is important, therefore, that electrical circuits be arranged in such a way that a ready path for electricity from hand to hand or from head to hands is not provided. Electrical fixtures or equipment should be so placed that a person would not be able to touch them and a water pipe or other grounded object at the same time.
The length of time the body is in the circuit may also be important, particularly with respect to the severity of burns. Burns break down the resistance of the skin, the more extensive the burn, the greater the flow of current and the more severe the shock.

Usually, you are assigned to work with another student - as a two-man team. It is suggested that the two of you alternate as team leader. The other student not only follows the instructions of the leader, he acts as a checker on the accuracy of every phase of the experimentation.

APPROACH LABORATORY EXPERIMENTATION IN A BUSINESSLIKE MANNER. OBSERVE SAFETY RULES.

Electricity is often referred to as a servant of man. The reason man has able to turn electricity into a servant is its predictability. We know if we make certain connections, certain things will happen. We know, too, that misuse of electricity can bring disaster. Electricity is inherently dangerous and must be treated with respect. Hampden's power sources all have a red light to indicate when the power is ON. Never turn on the power unless you are sure where the power is going. Most sources are variable. That is, even though they are ON, when the control knob is in its minimum position there is no power output. The knob, then, can be turned clockwise to obtain any voltage value between zero and the maximum for that source. For example, a 0- 15V DC power source can be set to supply any voltage up to 15 volts. Always have the knob in the minimum position at the time you turn the power ON. Always turn the power OFF immediately after you complete an experiment. Except in the experiments where you are specifically told to do so, never connect or disconnect circuits with the power ON.

Hampden power supplies are protected by circuit breakers, like the electrical circuits of schools and some homes. This means that if the service is called upon to supply more power than it is capable of, it will disconnect the output to protect itself and the equipment. So, if the red light is on but you don't have power, check the circuit breaker. But first, turn the control knob back to minimum and go over your circuit to be sure all your connections are correct. Then reset the circuit breaker with the pushbutton on the front of the power source.

Although the power levels used in this program will not harm any normal person under normal circumstances, there are particular situations where particular caution is advised. First, remember that electric shock is no joke - for three reasons: (1) A shock, even a small one, is more harmful if it passes through the heart. Electrical leads should be handled with one hand only, while the other is safely out of the way. (2) Under certain conditions, electricity can produce a painful burn. (3) A sudden, unexpected shock causes a fast reaction and the reaction can result in injury, either to the person getting shocked, or a bystander. Be especially cautious when circuit contains coils and capacitors. These can cause shocks after power has been turned off.

It is a good idea in any lab where electricity is used to learn where the master disconnect is in case of emergency. All students should be aware of elementary first aid and what to do if an accident occurs, either to himself or another student. .

A few suggestions:

DON'T ever turn power on until the circuit is checked.

DO be ready to turn the power off fast.

DON'T ever clown around.

DO make connections with one hand.

DO turn the power off after every use.

DO be prepared ahead.

DO put everything carefully away after use.

DO keep leads neat and area clean.

DO follow instructions.

CHAPTER 2

BACKGROUND AND HISTORY OF ROBOTICS

Ever since the dawn of time, mankind has dreamt of a world in which no human would have to work—at least not have to do any heavy, hard, or dangerous work. Indeed, all of the discoveries and inventions over the centuries have been designed to reduce the amount of manual labor.

The ultimate dream has been that of a "mechanical man", who can see better, hear better and perform all tasks well, no matter how hard or dangerous it would be for a human. This is, of course, in the realm of science fiction. Sci-fi writers imagined what a race of these mechanical people would be like. They reasoned that if machines were to replace people, the machine would have to be programmed so that they could make independent decisions — that is, exercise judgement.

Taking this to its logical conclusion, story writers added emotions. Robots would soon grow tired of doing all the work while their human masters sat around all day. They would revolt and kill all the humans.

This was a common theme of the stories about "cyborgs", "androids" and other human-like machines. In fact, it was one such story that produced the name "robot". In 1923 a Czechoslovakian writer, Karl Capek wrote a play "R.V.R." (Rossums's Universal Robots). In the play, Rossum and his son build a number of mechanical men to be workers ("Robot" is the Czech word for "worker".). In the end, the robots do indeed turn on their masters and kill them.

It took a more recent science fiction writer, Isaac Asimov, to change the image of the robot. Asimov, who was the first to use the term "robotics", reasoned that the programmer could, and would, add safeguards to robots' programs. In 1942, he published his famous "Three Laws of Robotics":

1. A robot must not harm a human being, nor through inaction allow one to come to harm.

2. A robot must always obey human beings, unless that is in conflict with the first law.

3. A robot must protect itself from harm, unless that is in conflict with the first or second laws.

Since then, robots have been seen as benefactors rather than as threats to the human race. Of course, we are still a long way from having machines that look and act like people. But for many jobs, industrial robots are replacing people for dangerous, unhealthy, backbreaking and repetitive jobs.

It was twenty years from the coining of the word "robot" to the coining or the word "robotics". Nineteen years later, in 1961, George C. Deval was issued a patent on a "Programmed Article Transfer" device. As you study the subject of Robotics, it would help to keep the name of this device—Programmed Article Transfer—in mind because it is an accurate description of the nature of robots today.

The Robot Institute of America, a trade association made up of major robot manufacturers and users, defines an industrial robot this way:

"A reprogrammable multifunctional manipulator designed to move material, parts, tools, or specialized devices through variable programmed motions to accomplish a variety of tasks."

The industrial robot, or more precisely the robot arm, is a manipulator. It moves something from one place to another. You might very well wonder what makes this different from other devices, a conveyer belt for example, that moves things from one place to another.

The difference lies in a robot arm's reprogrammability. Although robot arms are designed for specific applications (a painting robot, a welding robot, a materials handling robot, etc.), they are not limited, as are fixed automatic devices, to doing the same job in the same way forever. A painting robot, for example, can paint a large variety of shapes. A welding robot can vary the type, number, and location of welds. And, of course, a robot arm that handles material can move all kinds of different shapes and sizes from different sources to different destinations. It could be reprogrammed as the needs change. The industrial robot has these main components: the manipulator, the controller, and the power source.

The manipulator consists of a stationary base, arm with a wrist flange, and the "end effector", which may be a gripper, a welding gun, a paint sprayer, a suction cup, or some specified tool.

The controller contains the program storage, the programming means, and the control devices needed to execute the desired tasks.

The power source is primarily electrical. In some cases the elecrical energy is used to produce motion directly through the servo and stepper motors. In others, the electrical energy is converted to mechanical energy and transmitted via hydraulic, pneumatic, or mechanical links to the motion-producing devices.

Robots can be classified structually according to the coordinate system of their three major axes of motion, which are: (1) the vertical lift stroke; (2) the in-and-out reach stroke of the arm; and (3) the rotation motion about the vertical axis (called waist swivel).

The simplest robot structure is the cylindrical coordinate. A horizontal arm is assembled to a vertical axis, which is mounted on a rotating base. The horizontal arm can move in and out and vertically up and down. The arm assembly can rotate left and right.

The rectangular coordinate structure is similar, except that the arm assembly is mounted on a linear traverse base. Thus, all points capable of being reached by the end effector can be located by X-Y-Z coordinates.

The Hampden Multitechnology Robot System, H-MRS-1, combines the in-and-out stroke of the cylindrical coordinate structure with the elbow joint of the jointed arm structure. This allows the end-of-arm assembly to fold up close to the base, producing less unreachable space.

The era of the robot is just beginning. Today, robots have no, or very limited, vision and tactile (sense of touch) capabilities. Not only will these be improved but someday, robots will be built with heuristic ability. This means they will be able to plan their own action. We can only hope that these will be programmed to contain Asimov's three laws of Robotics.

CHAPTER 3

OPERATING INSTRUCTIONS

The Hampden H-MRS-1 is a six-axis robot arm designed expressly for training in all of the motion control technologies need in commercial industrial robots. Each of the six motions is produced by separate, fully independent drives and detected by different position sensors. The operator may control the arm's motion from the on-board keypad, or externally through a computer interface connection. Figure 1 is a sketch that identifies the parts of the H-MRS-1, and the degrees of movement.

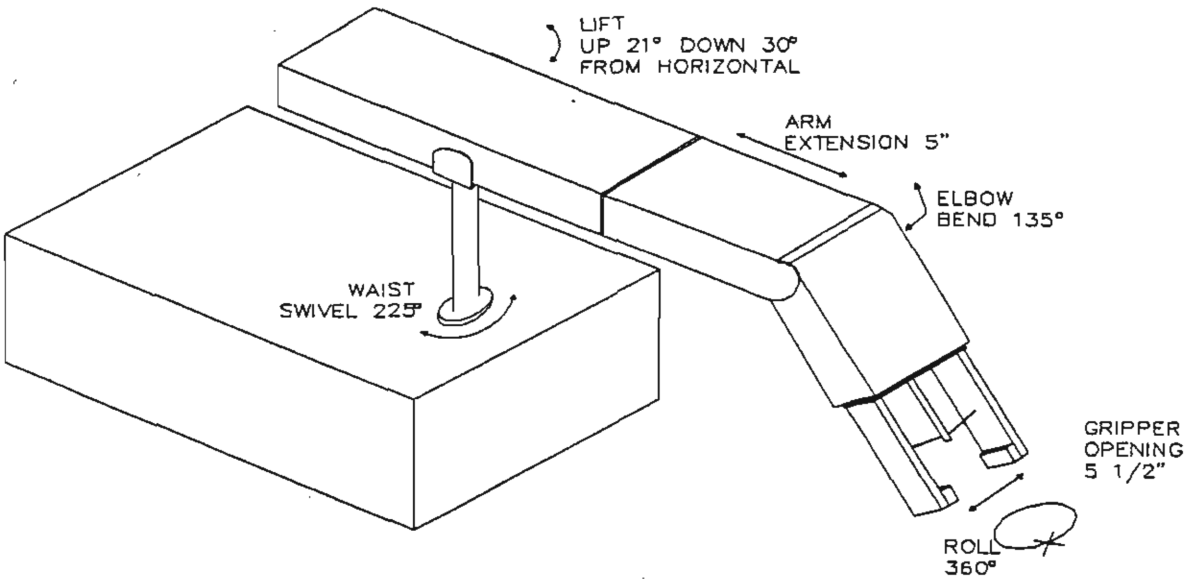


Figure 1

A. PREPARATION OF AREA

The "work" envelope of a robot is composed of all the points in space that can be reached by any part of the arm. THE WORK ENVELOPE MUST ALWAYS BE CLEAR. Figure 2 shows the plan and elevation projections of the envelope.

Be sure there are no obstructions overhead which the arm can bang into. Remember that the arm can swing a full 180° from side to side. Make sure the arm has the full area to itself. NEVER ENTER THE ROBOT'S ENVELOPE AREA WHEN IT IS TURNED ON. The operator controls are all at the end of the base that cannot be reached by the arm.

Do not attempt to force any of the robot arm's components into any position. The only possible exception is the position of the arm itself about its vertical axis (that is, side-to-side). This may be done slowly and gently, if it must be done.

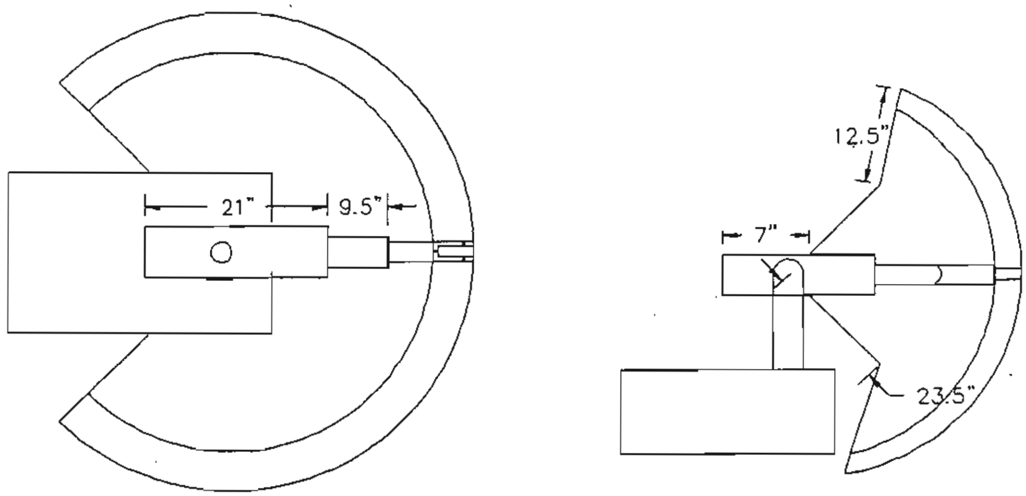


Figure 2

B. HYDRAULIC AND PNEUMATIC POWER

The base of the MRS-1 is provided with one pneumatic and two hydraulic couplings. To these are connected the hydraulic supply hose, the hydraulic return hose and the pneumatic hose. (No return is needed for the pneumatic system since air is exhausted into the atmosphere and not returned to the compressor.) Be sure that these lines are securely coupled before starting the hydraulic pump and air compressor. Air supply should be set for approximately 100 psi and hydraulic supply should be set for 250 psi. The hydraulic pump runs continuously while the compressor cycles ON and OFF.

C. ELECTRICAL POWER

The Hampden Robotics Trainer plugs into a standard single-phase AC grounded outlet. The unit is turned ON and OFF with the circuit breaker switch located just to the left of the keypad.

D. POWER ON

When you turn ON the trainer, it will automatically begin to move until all of the components reach their "home" position. The arm will be centered and horizontal facing away from the operator. "Power up" conditions are LOCAL (active keypad), LED display in degrees, and the waist swivel selected.

from the operator. "Power up" conditions are LOCAL (active keypad), LED display in degrees, and the waist swivel selected.

E. INDICATING AND DISPLAY LEDS

Just above the keypad are six 7-segment hex displays. These 7- segment hex displays show quantities in a digital form (0-9).

To the right of the keypad are a column of LEDs that show the status of the control. One of the top two LEDs will be lit to indicate whether the key pad is active for control (LOCAL) or control may only be effected from some external devices (REMOTE).

One of the next two LED's will be lit to indicate whether the 7-segment LED displays are reading in INCHES (for the arm extension), or angular degrees (for the rotational motions).

The remaining six LED's indicate which of the six motions is being controlled, as follows:

SWIVEL	- The torso swivel with respect to the base
ROLL	- The wrist flange roll with respect to the arm
GRASP	- The opening or closing of the gripper
BEND	- The bend of the elbow with respect to the upper arm
EXTENSION	- The extension of the arm in inches
LIFT	- The lift of the shoulder with respect to the torso

F. POSITIONING THE ARM

The "home" position for each of the axes is as follows:

1. The torso is swivelled 112.5° clockwise (parallel to base).
2. The wrist flange is at a 0° roll (gripper horizontal).
3. The gripper is open.
4. The elbow is "bent" to 90° (in line with arm).

5. The lower arm is fully retracted (0 inches).

6. The shoulder is lifted 30° so that the arm is horizontal.

The various parts of the robot arm may be moved to new locations via the keypad. Each motion has two keys associated with it—one for one direction; the other for the opposite direction. The procedure for operation is as follows:

First select the movement you want and the direction of that movement. This determines the correct key.

To start the motion, press the key. To stop the motion, press the key again.

The LED's will display the part being moved, the units of measure, and the number of units from the reference, or zero, position. More than one axis can be controlled at a time, but the posiiton of only one part can be displayed at a time.

G. THE KEYPAD

The on-board keypad provides both direct control and a means of programming arm motions. The keypad is active when the trainer is in the LOCAL mode. Figure 3 is a sketch of the keypad. Note there are twenty-four keys, twelve of which control arm motion.

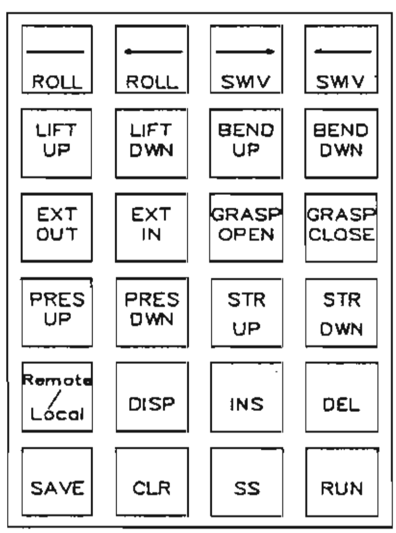
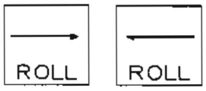


Figure 3



Wrist ROLL. The wrist flange swivels (rolls) a full 360° (continuous) in either direction of rotation. This, of course, determines the orientation of the gripper. The horizontal orientation represents either 0° or 180°. The motion is produced by a DC stepper motor with gear drive. Wrist flange position is detected by an optical sensor.

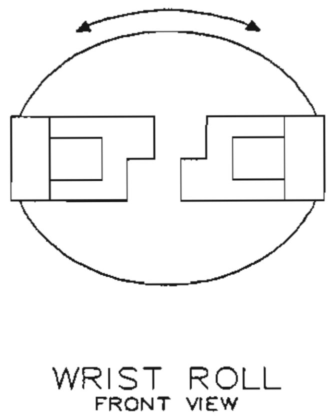
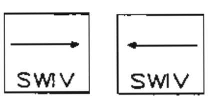


Figure 4



Torso SWIVEL. The torso (cylindrical support) swivels 225 degrees with respect to the base. The reference position (zero degrees) is fully counterclockwise. The motion is produced by an AC synchronous servomotor with a chain and sprocket drive. Torso position is detected by a rotary potentiometer.

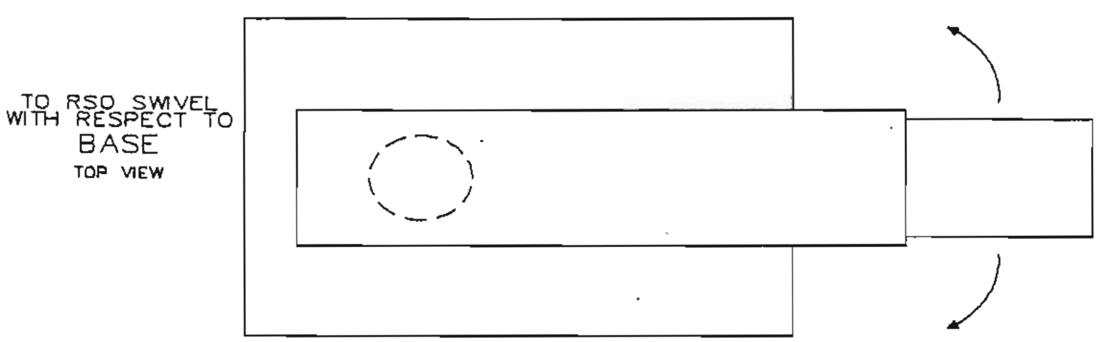


Figure 5

LIFT UP | LIFT DWN

Shoulder LIFT. The entire arm pivots at the shoulder from an angle 30 degrees below the horizontal (the 0° reference position) to 21 degrees above the horizontal (the 51° position). The lifting and lowering motion is produced by a double-acting hydraulic cylinder with solenoid-operated directional valve control. Arm position is detected by a linear variable differential transformer (LVDT).

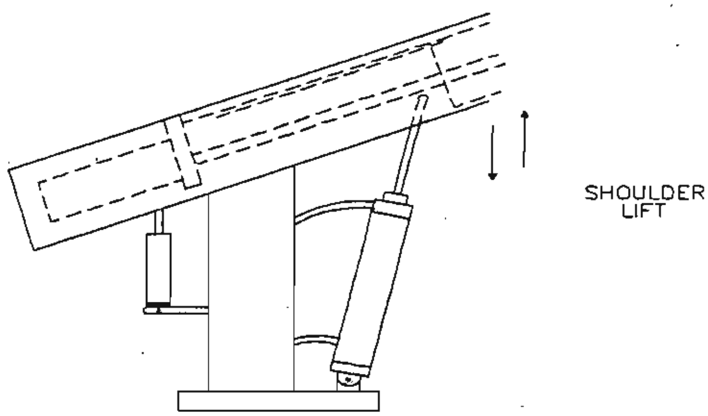


Figure 6

BEND UP | BEND DWN

Elbow BEND. The lower arm bends from a position 90 degrees below the attitude of the upper arm (the zero-degree reference position) to 37 degrees above the altitude of the upper arm (the 127° position). The bending motion is produced by a DC servomotor with a gear drive. The lower arm angle relative to the upper arm is detected by a rotary potentiometer.

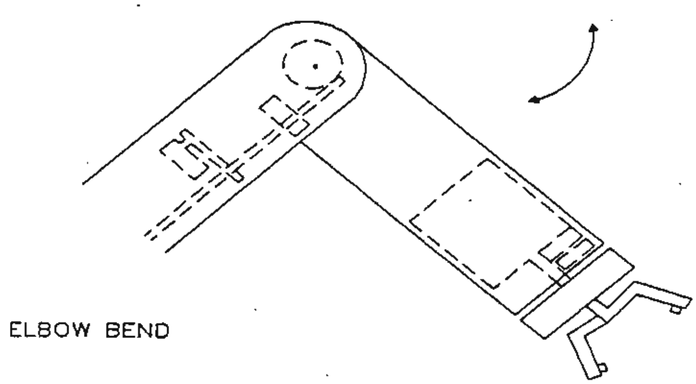


Figure 7

EXT OUT | EXT IN

Upper Arm EXTEND. The arm can be extended up to five inches from its fully retracted (0-inch) position. This extends the upper arm's length (measured from shoulder pivot to elbow pivot) from 18 1/2" to 23 1/2". The key marked EXT. OUT controls the extension; the one marked EXT. IN controls the retraction. This motion is produced by a direct acting hydraulic cylinder and detected by a linear

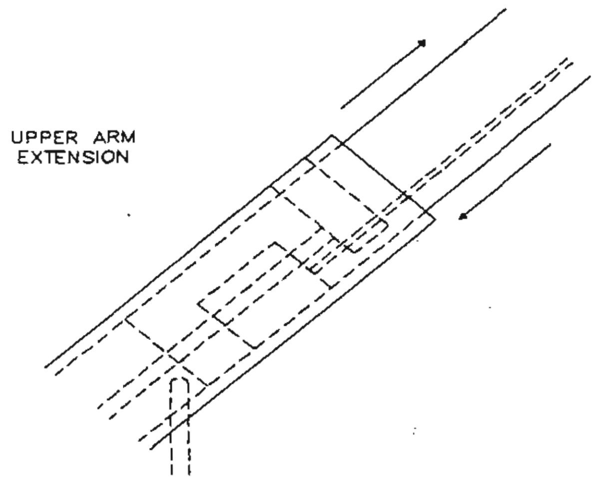


Figure 8

GRASP OPEN | GRASP CLOSE

Hand GRASP. The gripper may be either open or closed (grasping). In this case, the display indicates the position of the gripper (OPENED or CLOSED). The grasping and releasing happens "all at once", so that it is necessary to press the appropriate GRASP key only once. The motion is produced by a direct drive pneumatic cylinder with a servovalve to adjust cylinder pressure.

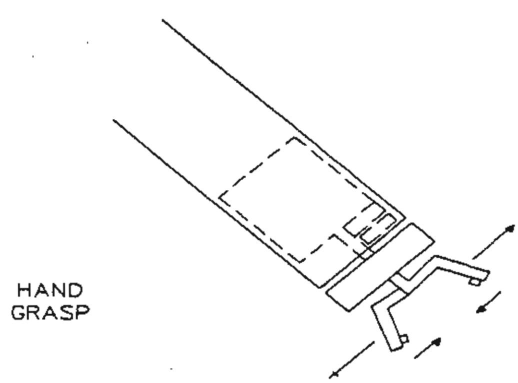


Figure 9

The remaining keys permit you to program the arm, run the programs and review the positions of each section of the arm.

DISP

The DISP key has several possible actions: if the next key pressed is a motion key, such as EXT IN, it will show the current position of the extension, but will not affect its position. If the next key is SS, it will show how many positions are saved in the current string. If the next key is either of the STR # keys, then the current string number will be displayed.

REM/LOCAL

This key permits control of the arm movements to be switched from local to remote or from remote to local. Pressing it once will toggle it to the appropriate condition. It is the only active key on the keypad when the REMOTE led is on.

SAVE

Pressing the SAVE (position store) key causes the arm's current position to be saved in a sequential memory area of the current string. Up to 30 separate positions may be stored per string. The arm will move to each of these positions in sequence when instructed to do so (see RUN and SS keys). Follow this procedure:

1. Move the arm to the desired position using the motion keys.
2. Press the SAVE key.

CLR

Pressing this key clears the memory of the current sequence that have been entered in it. If CLEAR is pressed twice in succession, the arm will also assume its "home" position.

SS

Pressing this key causes the arm to move to the next sequential position in the current string.

RUN

Pressing the RUN key causes all of the positioning commands stored in the current string to be executed once. If the length of the current string is zero positions, then the arm will not move.

INS

This inserts the current position of the robot at the current stepped position of the current string. For instance, say you have a string of five positions. However you wish to insert a position between positions #2 and #3. Press SS twice, so that you've reached position #2. Now move the arm to where you want it for the new position. Press INS. This position has become #3. The previous #3 has now become #4, #4 has become #5, etc.

DEL	This will delete the position that would normally be executed next. For example, say that the current string has four positions, and you wish to delete position #3. Press SS twice so that the next position that the MRS-1 would move to is the one that you wish to delete. Now press DEL. Position #3 has been deleted and position #4 has replaced it.
PRES DOWN PRES UP	These two keys adjust the pressure of the grasp.
STR # DOWN STR # UP	These change the current string number by one, either up or down.

H. POSITIONING THE ARM:

After the power to the unit is turned on, all components are automatically moved to their 'home' position. The future position of any component is measured relative to its home location. To move a component to a new position, press the appropriate key for the component and direction desired. The arm will begin its movement. When the desired position is reached, press the same key and movement will stop. In this way, all of the keys can be said to be toggle-action keys. The keyboard display will indicate the component being moved and, the number of units from the home position. The units of measure are indicated by LED's. More that one component can be moving at once; however, only one position can be displayed at any one time.

I. PROGRAMING AUTOMATIC TASKS:

The most powerful feature of any robot lies in its ability to execute a series of programmed tasks over and over again, maintaining both speed and precision in the broad spectrum between mundane and critically complicated procedures. The H-MRS-1 is capable of 'remembering' up to 30 different sequences of up to 32 positions each and execute them automatically. All of these programmed steps will be executed in the same order they were entered.

The SAVE key is used to store a position in memory. In setting up a position, the operator uses the various motion keys to get the arm to some desired position, and then executes the SAVE function. Only the final position of the arm is remembered, not the steps used by the operator to position the arm. When later executed, the arm will automatically move to the position, calculating for itself the proper movements needed for each component. New positions saved, with the SAVE key, are always added to the end of the sequence, allowing the operator to test steps as the full task is being programmed. Use the CLEAR function to erase the program memory in preparation for a new series of positions.

J. EXECUTING A PROGRAMMED TASK

There are two ways to execute a sequence of programmed postions. After programming the steps as described in section D, the operator can either execute all of the steps continuously, or can execute one step at a time. Use of the RUN funciton causes continual execution of all of the program positions starting from the beginning. Execution will continue until the sequence is completed. To execute one position at a time, use the SS (single step) function. When first used, the SS key will execute the first programmed position and then stop. Subsequent presses of the SS key will cause execution of the next position in the sequence. If gripper open/close is part of the instruction, it will take place after the movement.

K. SUMMARY OF PROCEDURES - KEYPAD (LOCAL) CONTROL

1. To Start Up
   a. Clear the robot arm's work area and make sure that no one is in the way of the arm.
   b. Turn ON the circuit breaker switch. The arm will assume its "home" position.
2. To Move Arm
   a. Select the motion desired and direction of that motion.
   b. Press the corresponding key—once to start the motion; a second time to stop it.
3. To Return To "Home"
   a. Press the CLEAR key twice.
   b. Turning the unit OFF then ON also "homes" it.
4. To Examine Any Position
   a. Press the DISP key then the desired motion key.
   b. Corresponding position (in inches or degrees from reference) will be displayed.
   c. While motion is taking place, the exact position of that part is displayed.

5. To Program Sequence of Motions

   a. Follow (b) above to establish gripper position and condition.

   b. Press SAVE key.

   c. Repeat (1) and (2) for each point.

6. To Clear Memory

   a. Press the CLEAR key once.

   b. Turning OFF the arm will also clear the memory.

7. To Run a Program

   a. Press the RUN key once to start the program.

   b. The program may also be executed one command at a time by pressing the SS key each time.

L. EXTERNAL CONTROL OF THE ROBOT ARM

The microprocessor controller of the H-MRS-1 can obtain its positioning information from two sources: the first would be an operator moving the arm to some position and using the keypad commands to "SAVE" that position; or a sequence of steps can be sent to the microprocessor via the RS232 serial interface. The microprocessor will then use this data, and the commands which are inferred from the position data, to execute a sequence.

The RS232C port of the MRS-1 is a DTE device with data being input on pin 3, and data output on pin 2. Grounds are pin 1 and pin 7. A busy line is provided on pin 20. The port is set up for 9600 baud, 8 data bits, 2 stop bits, 1 start bit and no parity.

In the Appendix are several listings of a BASIC program to control the Hampden MRS-1. These programs have been run on the referenced computers.

CHAPTER FOUR

FAMILIARIZATION

Experiment Section

EXPERIMENT 4-1

INTRODUCTION TO THE KEYPAD - PART ONE

PURPOSE:

To acquaint the student with the basic operation of the H-MRS-1 keypad and related operations.

BACKGROUND:

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some robot positioning sequences.

EQUIPMENT AND MATERIALS REQUIRED:

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions

PROCEDURE A:

1. Turn on the power as per instructions pages 3-1 to 3-3.

2. Did the robot initialize (go to home position)? Y or N

NOTE If answer is NO check system carefully and repeat step #1.

3. Using the SWIV pushbutton, move the arm first to its fully CCW position. What does the display read?______________. Then move it fully CW. What does the display read?_____________. The attempt to move it 45° from its zero reference position. (Use the jog technique to get as close as possible.) What was the final resting position as read on the display? ___________.

4. The swivel function is provided by the AC synchronous servomotor with a chain and sprocket drive. The locating of various positions in the operating envelope is very important. In the following table locate the positions indicated and copy the results in the spaces provided.

	Position	Final Location
1.	90°	____________
2.	180°	____________
3.	220°	____________
4.	75°	____________
5.	155°	____________

PROCEDURE B

1. We will now use the LIFT keys to position the arm at various angles. Move the arm to its upper limit. What does the display read?____________. Move the arm down to lower limit. What does the display read?____________.

2. The shoulder lift is accomplished by a double-acting hydraulic cylinder with a solenoid-operated bidirectional valve. Observe the operation of this system as you locate, as closely as possible, the positions in the table below.

	Position	Final Location
1.	40°	____________
2.	45°	____________
3.	20°	____________
4.	5°	____________
5.	34°	____________

PROCEDURE C

1. Now let's try elbow positioning - the BEND keys. Move the elbow to its upper limit. What does the display read? ____________. Then move the elbow to its lower limit. What does the display read? ____________. Now attempt to line up the lower arm with the upper arm. What does the display read? ____________.

2. This motion is accomplished by a DC servomotor using a worm and wheel drive. While maintaining a safe distance in regard to the operational envelope, observe the action of this positioning system by obtaining the target positions below.

	Position	Final Location
1.	110°	____________
2.	100°	____________
3.	80°	____________
4.	40°	____________
5.	20°	____________

PROCEDURE D

1. We will now put all three motions together using the following terminology:
   a. The torso swivel function will be designated by a 'S' and the target position in degrees.
   b. The shoulder lift function will be designated by a 'L' and the target position in degrees.
   c. The elbow bend function will be designated by a 'B' and the target position in degrees.

2. A particular group of data for a position will look like this:
   S = 55°
   L = 15°
   B = 115°

   Locate these previous positions for the three axes as close as possible and record the data here.
   S = ____________
   L = ____________
   B = ____________

ASSIGNMENT #1

1. Using the terminology in the previous experiment, locate the following positions as closely as possible.

	TARGET	FINAL
1.	S = 20°	S = ________
	L = 40°	L = ________
	B = 85°	B = ________

	TARGET	FINAL
2.	S = 90°	S = ________
	L = 15°	L = ________
	B = 20°	B = ________

	TARGET	FINAL
3.	S = 180°	S = ________
	L = 45°	L = ________
	B = 5°	B = ________

	TARGET	FINAL
4.	S = 220°	S = ________
	L = 10°	L = ________
	B = 100°	B = ________

	TARGET	FINAL
5.	S = 110°	S = ________
	L = 45°	L = ________
	B = 45°	B = ________

EXPERIMENT 4-2

INTRODUCTION TO THE KEYPAD - PART TWO

PURPOSE

To acquaint the student with the basic operation of the H-MRS-1 keypad and related operations.

BACKGROUND

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some robot positioning sequences. This time we will exercise the grip, the extend and the rotate functions.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions
A Tennis Ball (rubber)
Steel Rule

PROCEDURE A

1. Turn on the power as per instructions on pages 3-1 and 3-3.

2. Did the robot initialize (go to home position)? circle Y or N

NOTE: If the answer is no, check system carefully and repeat step #1.

3. Using the extend control buttons move the arm from the in limit to the out limit. Next observe the distances of the extend function (5 in.) and compare it to the total arm length capabilities.

4. Now try to position the arm as closely as possible to the center of the extend function. What is the total length of the upper arm measured from shoulder pivot to elbow pivot (18.5" fully retracted; 23.5" fully extended)? __________

5. The extend function is accomplished by a direct acting hydraulic cylinder. Carefully observe the operation of this cylinder from a safe distance. Locate the positions in the table below as closely as possible.

	POSITION:	DISPLAY:
1.	19 in.	E = ________
2.	21 in.	E = ________
3.	23.5 in.	E = ________
4.	22.5 in.	E = ________
5.	20.5 in.	E = ________

PROCEDURE B

1. We will now use the wrist controls to locate the gripper at particular angles. The wrist roll operates in a continuous fashion for a complete 360°. Locating the appropriate angle is accomplished simply by rotating the wrist in the direction that will achieve the target angle the quickest. Operate the wrist roll in both directions for a while until you develop a feel for the control.

2. The wrist motion is accomplished by a DC servomotor driving bevel gears to change direction. Observe this operating system from a safe distance to gain better understanding of the motion.

3. Locate the angular positions below as closely as possible using the keypad.

	POSITION	LOCATION
1.	270°	________
2.	90°	________
3.	45°	________
4.	225°	________
5.	180°	________

PROCEDURE C

1. Now let's try the gripper. You will note that (1) this motion happens all at once so that the display reads either OPENED or CLOSED and (2) there is a way to control the grasping pressure. The direct drive pneumatic cylinder and the servovalve which controls this pressure provide the focus of this experiment. Operate the grasp mechanism a few times to familiarize yourself with the system.

2. The "PRES UP" and "PRES DOWN" pushbuttons are used to increase and decrease the pressure of the grasp.

3. For this experiment it would be advisable to obtain a sponge rubber ball or some sort of soft rubber ball. Make a stand for the ball that will allow you to position the gripper on both sides. Close the gripper and using a ruler or tape measure record the width of the gripper about the ball. Next adjust the grip by changing the servo and repeat the measurement. Adjust the servo in the opposite direction and repeat the measurement once more.

PROCEDURE D

1. We will now put all three motions together using the following terminology:

   a. The extend function will be designated by a 'E' and the target position by inches.
   b. The wrist roll function will be designated by a 'R' and the target position by degrees.
   c. The gripper, G, for now, will be simply open 'O' or closed 'C'.

2. For example, a particular group of data for a position will look like this:

   E = 21 in.
   R = 90°
   G = C

3. Locate the previous positions for the three functions as closely as possible and record the data here.

   E = ____________
   R = ____________
   G = ____________

ASSIGNMENT #1

1. Using the terminology in the previous experiment, locate the following positions as closely as possible.

TARGET	FINAL LOCATION
1. E = 20.5 in.	E = __________
R = 45°	R = __________
G = 0	G = __________

	TARGET	FINAL LOCATION
2.	E = 18.5 in.	E = ________
	R = 85°	R = ________
	G = C	G = ________
	TARGET	FINAL LOCATION
3.	E = 23.5 in.	E = ________
	R = 185°	R = ________
	G = C	G = ________
	TARGET	FINAL LOCATION
4.	E = 22 in.	E = ________
	R = 320°	R = ________
	G = 0	G = ________
	TARGET	FINAL LOCATION
5.	E = 21 in.	E = ________
	R = 177°	R = ________
	G = C	G = ________

EXPERIMENT 4-3

INTRODUCTION TO THE KEYPAD - PART THREE

PURPOSE

To acquaint the student with the basic operation of the H-MRS-1 keypad and related operations.

BACKGROUND

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some complete robot positioning sequences. The objective of this experiment is to utilize all the motion controls for simulating actual operating techniques.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions
A block of wood (2 x 2 x 4) or similar

PROCEDURE A

1. Turn on the power as per instructions on pages 3-1 to 3-3.

2. Did the robot initialize (go to home position)? circle Y or N

NOTE: If the answer is no, check system carefully and repeat step #1.

3. Take some time to practice the positioning of the robotic arm. Use all the controls you have become familiar with during the last two experiments and try to develop your coordination.

4. Using all the positioning techniques presented in the previous two experiments, we will now find positions using all six robot axes. For a start let's try to locate the following as closely as possible.

TARGET	FINAL LOCATION
S = 20°	S = ________
L = 50°	L = ________
B = 85°	B = ________
E = 20.5 in.	E = ________
R = 45°	R = ________
G = C	G = ________

PROCEDURE B

1. We will now continue our familiarization through more practical operations. Up until now we have been locating positions, so let's do some practical operations. Find an object to grip and move around, like a wooden block. Position the block within the operating envelope and practice gripping and moving the block.

2. After you feel comfortable gripping and moving the block, set up some sort of platform inside the operating envelope and practice moving the block from the table to some other location and back again (make sure that you release the block, move the arm and grip the block again for each move).

3. Next establish a second platform or location so you will be able to move between them. Arrange the two platforms in positions that utilize all the robot motions and experiment with the grip pressure to familiarize yourself with this adjustable utility.

ASSIGNMENT #1

1. Using the two platforms and the block in the previous experiments, mark each end of the block either with two different colors or two different marks. Next stand the block on one mark and move the block between the two locations while switching the mark (alternately) that it will be standing on.

2. Repeat step #1 several times with different positions of the platforms, making it increasingly more difficult to go from one to the other.

EXPERIMENT 4-4

INTRODUCTION TO THE KEYPAD - PART FOUR

PURPOSE

To acquaint the student with the basic operation of the H-MRS-1 keypad and related operations.

BACKGROUND

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some complete robot positioning sequences. The objective of this experiment is to utilize all the motion controls and automatic functions to simulate actual operations.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions
A block of wood (2 x 2 x 4 or similar) and a tennis (or rubber) ball

PROCEDURE A

1. Turn on the power as per instructions on pages 3-1 to 3-3.

2. Did the robot initialize (go to home position)? circle Y or N

NOTE: If the answer is no check system carefully and repeat step #1.

3. Again, using the two platforms so that the movement is relatively simple, mark the exact position of the block on the first platform (tape, outline etc.). Manually (use keypad) move the arms to the position where it is grasping the block. Then press the 'SAVE' key. Move (and reverse) the block as before to platform 2, opening the grip. Then press the 'SAVE' key.

4. Now pick up the block yourself and return it to the original position on the other platform (align with the mark).

5. Next, clear yourself and any other obstacles from the operating envelope and press the 'RUN' button. What happened?

PROCEDURE B

1. We will now make things a little more difficult by locating the two platforms at positions that require more robot motions. try to establish locations that will use all the six axes at least once.

2. Manually move the block again with the robot finishing with the release of the grip and pressing 'SAVE' button.

3. Recolate the block in the original position yourself (align with the marks) and press 'RUN'. Did the robot automatically perform the original operation again?

PROCEDURE C

1. Keeping everything as it was in the previous experiment, press 'STR UP' (this gives us a new string for control data, more on this later) and manually use the robot to move the block back to its original position, finishing with an open grip and pressing 'SAVE'.

2. Next press 'RUN'. What happened?

PROCEDURE D

1. Without moving anything from the end of the last experiment, press 'STR DOWN' and press 'RUN'. You have now returned to the first string of commands that caused the original movement of the block.

2. Run the robot back and forth a couple of times using the STR UP/DOWN keys as in the previous operations until you feel comfortable with the function.

ASSIGNMENT #1

1. Select several new and varied positions for the platforms and try running the block back and forth a couple of times.

2. Make a similar setup for the ball and repeat the exercise in the previous step a few times. Make whatever adjustment is necessary not to deform the ball with the gripper. You may need to improvise a holder to prevent the ball from rolling.

3. Now add another platform and a third, fourth and fifth string to practice moving the ball/block to and from each possible location.

EXPERIMENT 4-5

INTRODUCTION TO THE KEYPAD - PART FIVE

PURPOSE

To acquaint the student with the basic operation of the H-MRS-1 keypad and related functions.

BACKGROUND

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some complete robot positioning sequences. The objective of this experiment is to utilize all the motion controls and automatic functions to simulate actual operations and to present different techniques for programming operations.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions
A block of wood (2 x 2 x 4) or similar and a tennis (or rubber) ball

PROCEDURE A

1. Turn on the power as per instructions on pages 3-1 to 3-3.

2. Did the robot initialize (go to home position)? circle Y or N

NOTE: If the answer is no check system carefully and repeat step #1.

3. Again, using the two platforms and the marked block, position the platforms so that the movement is relatively simple and mark the exact position of the block on the first platform (tape, outline etc.) then manually (use keypad) move and reverse the block. This time, however, after each motion (movement of a particular axis) press the 'SAVE' key.

4. Next place the block back on the original platform and press the 'SS' key, you will note that the robot will do only one motion per press of this button. Complete the transfer of the block.

ASSIGNMENT #1

1. Using the 'SS' key, the preceding procedure, and the 'STR UP/STR DOWN' function move the block back and forth between the platforms a few times.

2. Repeat this assignment with a more difficult arrangement of platforms.

PROCEDURE B

1. Strings have a maximum capacity of 32 steps, any operation more than that number must utilize more than 1 string. The string number that you are using is available to you simply by pressing the 'DISP' (display) key and one of the STR keys.

2. The 'DISP' key also will allow us to look at a particular location of an axis with regard to home. Single step ('SS') through a block transfer and after each press of the 'SS' key, press one of the motion keys and record the location of each axis below.

ASSIGNMENT #2

1. Using the ball, the techniques presented in this experiment and a few varied positions of the platforms examine the axes positions and the string numbers a couple ball position transfers for several platform positions and record all the data.

2. Now add another platform and a third, forth and fifth string to practice moving the ball/block to and from each possible location and record the appropriate data for each setup.

EXPERIMENT 4-6

INTRODUCTION to the KEYPAD - PART SIX

PURPOSE

To acquaint the student with the basic operation of the H-MRS-1 keypad and related operations.

BACKGROUND

In order to create a deeper rapport between the student and the H-MRS-1 we will run through some complete robot positioning sequences. The objective of this experiment is to utilize all the motion controls and automatic functions to simulate actual operations and to present facilities for change present operations.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Hampden Robotics Operating Instructions
A block of wood (2 x 2 x 4) or similar and a tennis (or rubber) ball
Something that can be used as an obstacle to robot motion (i.e. a box or crate)

PROCEDURE A

1. Turn on the power as per instructions on pages 3-1 to 3-3.

2. Did the robot initialize (go to home position)? circle Y or N

NOTE: If the answer is no check system carefully and repeat step #1.

3. Again, using the two platforms movement and the marked block, position the platforms so that the is relatively simple and mark the exact position of the block on the first platform (tape, outline etc.) Then manually (using keypad) move and reverse the block, this time finishing with opening the grip and pressing the 'SAVE' key after each axis motion.

4. Now using the 'STR UP' key function return the block to the original position on the other platform.

5. Next, place an obstacle between the two platforms so that the operation cannot be done using the program you have entered.

6. If you were to use 'STR DOWN' and 'RUN' the robot would obviously knock down the obstacle. Therefore, it is appropriate to make a change in the string of commands. The 'INSERT' and 'DELETE' keys are specifically designed for this function. Press 'STR DOWN' to prepare the robot to move the block once again and then press 'S.S.' After the arm has grasped the block, press 'INS'. The robot will now allow you to add a *motion to the string.* Move the arm to a safe height and press 'SAVE'. Now run the robot. What happened?

____

____

____

ASSIGNMENT #1

1. Using the 'INSERT' key alter the other string so that it will allow the robot to pass the obstacle and return the block to the other platform.

PROCEDURE B

1. The 'DELETE' key has the opposite effect on the control string. It allows us to remove steps from the control strings.

2. Take the obstacle out of the way and return the two control strings to their original conditions by pressing the 'DEL' key just before the step you wish to eliminate.

3. Relocate the block in the original position yourself (align with the marks) and press 'RUN'. Did the robot automatically perform the original operation again?
   Circle Y or N

PROCEDURE C

1. Setup your platforms again and use the ball for this procedure. Using all the techniques you have learned so far transfer the ball back and forth under the following circumstances:
   a. Automatic operation without any obstacles.

b. Single step operation with any obstacles.
c. Single step operation without any obstacles.

2. Add a third platform and repeat step #1.

3. Add a fourth platform and repeat step #1.

ASSIGNMENT #2

1. The purpose of this entire section is to provide expertise in the basic operation and use of the keypad functions. By adding a second block to our setup practice moving block #1 (label them) and block #2 back and forth between the platforms. Use two platforms first and move block #1 first then block #2 etc. Try different techniques and utilize all the keypad functions.

2. Now use the block and the ball for some operations like, having the robot balance the ball on the block and then reestablishing the same arrangement on the other platform etc.

3. Next bring in the obstacles and run the robot through several transfers. Use your imagination or ask your instructor for some guide lines. Document your results on paper. Build your confidence for the following experiments.

NOTE: The REMOTE/LOCAL key will be used later and not at the present time. It is for using an external computer as a controller.

CHAPTER FIVE

MECHANICAL SYSTEMS AND POSITION SIGNALS

Experiment Section

EXPERIMENT 5-1

MECHANICS OF THE TORSO AND POSITION SIGNAL

PURPOSE

To acquaint the student with the mechanical power transmission system used with the torso swivel and the position signal that is transmitted to the electronics circuits.

BACKGROUND

In order to further our understanding of robotic systems, we will investigate the mechanical system that transmits power from the AC synchronous servomotor to the torso. Further, we will make use of the test points provided to examine the torso position signal. If electronically controlled devices, such as robots, are to move to various positions accurately and reliably, the movement must be monitored and location information must constantly by provided to the electronic circuits.

Power to swivel the torso comes from an AC synchronous motor. Separate chain drives transmit this power, first to the shaft of the rotary potentiometer - then to the torso itself. As the drive shaft and sprocket turn, the chain turns a sprocket on the potentiometer shaft. A second sprocket on the same shaft becomes the power transmitter for the second chain, which turns the sprocket on the torso shaft.

As with other types of drives, the chain and sprocket arrangement permits the change of angular velocity, and torque while transferring power from one shaft to another. The chain drive takes the place of the gear drive when the distances between shaft centers is too great for economical gearing.

Consider a chain drive in which the input and output sprockets are the same size (have the same number of teeth). The output shaft would rotate once for each rotation of the input shaft. Similarly, both shafts would rotate at the same angular velocity (degrees, or radians, per second). Finally the torque applied to the input shaft would be available at the output shaft unchanged.. However, when the two sprockets have different tooth counts, all of these factors change.

For simplicity, assume that the output sprocket has twice as many teeth as the input. Refer to Figure 5-1. While the input sprocket makes one revolution, the output sprocket turns only half way. The ratio between degrees turned by the output (θ_{out}) to the degrees turned by the input (θ_{in}) is the ratio between the tooth count of the input (N_{in}) to the tooth count of the output (N_{out}.) Mathematically:

$$\frac{\theta_{out}}{\theta_{in}} = \frac{N_{in}}{N_{out}} \text{ or } \theta_{out} = (\theta_{in}) \times \frac{N_{in}}{N_{out}}$$

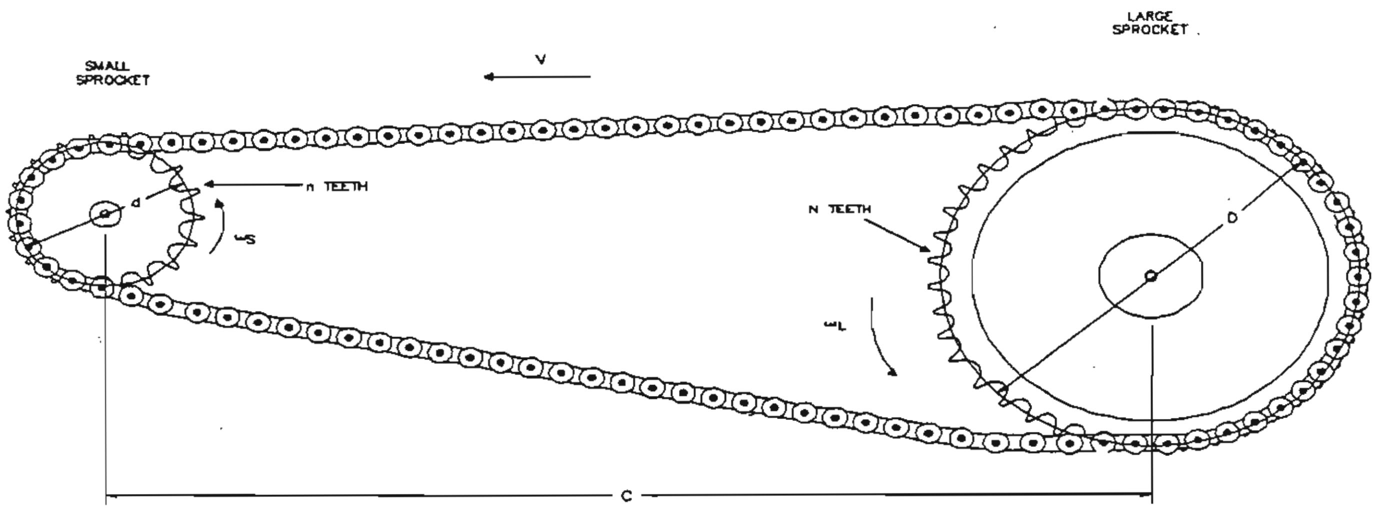


Figure 5-1

For example, if the input sprocket has 5 teeth and the output sprocket has 10, the in-to-out ratio is 0.5. An input sprocket rotation of 360°, then, causes the output shaft to rotate 180° (0.5 x 360 = 180).

Because both must rotate simultaneously, the same time applies to each. Therefore, the angular speed of the output shaft must be related to the input by the same ratio as angle turned. Letting ω (omega) represent angular speed, the equation is.

$$\frac{\omega_{out}}{\omega_{in}} = \frac{N_{in}}{N_{out}} \text{ or } \omega = (\omega_{in}) \times \frac{N_{in}}{N_{out}}$$

In the above example, if the motor (smaller input sprocket) is turning at 10 rpm, the output (larger sprocket) turns at 5 rpm.

Although not as easily seen, the torque supplied by a motor is amplified by a chain drive whose output sprocket is larger than its input sprocket. The principle is quite similar to a lever. Less force applied over a greater distance at the transmitting end produces greater force over a shorter distance at the receiving end. The ratio between output torque (T_{out}) and input torque (T_{in}) is the same as between output tooth count and input tooth count. The equation is:

$$\frac{T_{out}}{T_{in}} = \frac{N_{out}}{N_{in}} \text{ or } \omega_{out} = (\omega_{in}) \times \frac{T_{out}}{T_{in}}$$

Figure 5-2 is a sketch of the chain drive arrangement on the H-MRS-1 torso swivel.

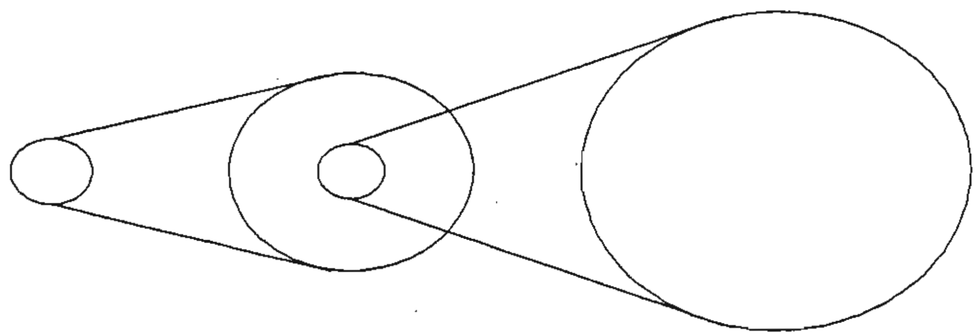


Figure 5-2

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Oscilloscope
Stopwatch or other timer

PROCEDURE - A

1. Compute the following:
   A. Tooth count ratio of input (motor) sprocket to potentiometer sprocket
   B. Tooth count ratio of potentiometer sprocket to output (torso) sprocket
   C. Tooth count ratio of input sprocket to output sprocket

2. The torso swivels through an arc of 225°. Compute the number of degrees turned by the motor. ________°.

ASSIGNMENT #1

Power up the Hampden H-MRS-1 and verify that it is operating properly. With the controls, cause the torso to swivel from one extreme to the other while measuring the elapsed time. (You may wish to do this several times and average your measurements.) ________ seconds. Compute the motor speed ________ rpm.

PROCEDURE - B

1. As we have seen, the shaft of a rotary potentiometer turns as the torso swivels. This produces a DC voltage signal to drive the display lamps. This voltage is measurable between Test Points TPA1 (-) and TPB3 (+).

2. Attach the oscilloscope ground clip to TPA1 and connect the probe to TPB3.

3. Swivel the torso fully clockwise. The display reads __________ degrees. The voltage as read on the oscilloscope is __________ volts.

4. Swivel the torso fully counterclockwise. The display reads __________ degrees. The voltage as read on the oscilloscope is __________ volts.

5. Complete the table below for the various positions of the torso, as read on the display.

POSITION (degrees)	VOLTAGE (VDC)
0	
25	
50	
75	
100	
125	
150	
175	
200	
200	

ASSIGNMENT #2

1. Plot a curve showing how potentiometer voltage changes with torso position. Let degrees be the abscissa (horizontal) and volts be the ordinate (vertical).

EXPERIMENT 5-2

MECHANICS OF THE SHOULDER AND POSITION SIGNAL

PURPOSE

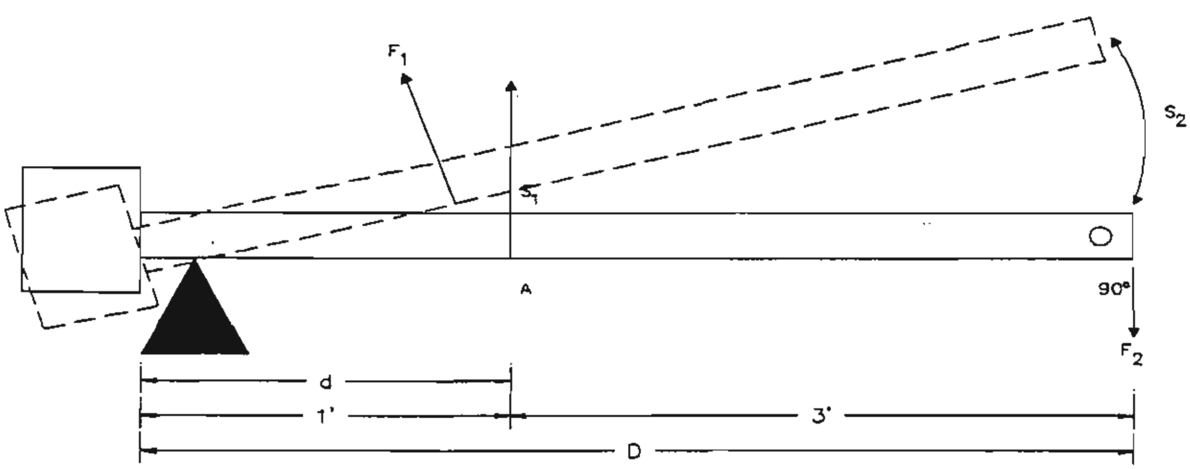
To acquaint the student with the mechanical power transmission systems used with the shoulder lift and the position signal that is transmitted to the electronics circuits.

BACKGROUND

In order to further our understanding of robotics systems, we will investigate the mechanical system that transmits power from the hydraulics cylinder to the arm for the raising and lowering action. Further, we will make use of the test points provided to examine the shoulder lift angle signal. If electronically controlled devices, such as robots, are to move to various positions accurately and reliably, the movement must be monitored and location information must constantly be provided to the electronics circuits.

In swivelling the torso, we gained torque while reducing the rotating angle by a chain connecting a small sprocket to a larger one. In lifting the arm at the shoulder, we do just the opposite. We cause the gripper at the end of the arm to travel further than the hydraulic cylinder rod, but in doing so, torque is reduced.

The robot arm is a class-three lever. A lever, as you know is one of the basic machines. Every lever has a load (output force), an effort (input force) and a fulcrum. For a class-three lever, both the load and effort are on the same side of the fulcrum. Further, the input force is closer to the fulcrum. This is illustrated by the following diagram:



CLASS–THREE LEVER

A force (F1) of 400 pounds acting upward at point A (which is 1 foot from the fulcrum produces a torque of 400 pound-feet (400 x 1 = 400). To see how much torque that 400 lb ft. will produce at F2 (4 feet from the fulcrum) we must divide the 400 pound-feet by 4. The answer is 100 pounds. This is what-is-called "fractional mechanical advantage". The output (100) divided by the input (400) produces a fraction (1/4).

If we let d equal the distance of the input force (Fin) from the fulcrum, and D equal the distance of the output from the fulcrum, the output force (Fout) is computed from the equation:

$$F_{out} = (F_{in}) \times \frac{d}{D}$$

Or if you know the load and want to calculate the amount of effort needed:

$$F_{in} = (F_{out}) \times \frac{D}{d}$$

We must sacrifice torque, so we can gain distance and speed. If we let S, be the distance over which the effort (input) force acts, and S_2 be the distance the load moves, we can state mathematically.

$$\frac{S_2}{S_1} = \frac{d}{D} \quad \text{or} \quad S_2 = (S_1) \times \frac{d}{D} \text{ inches}$$

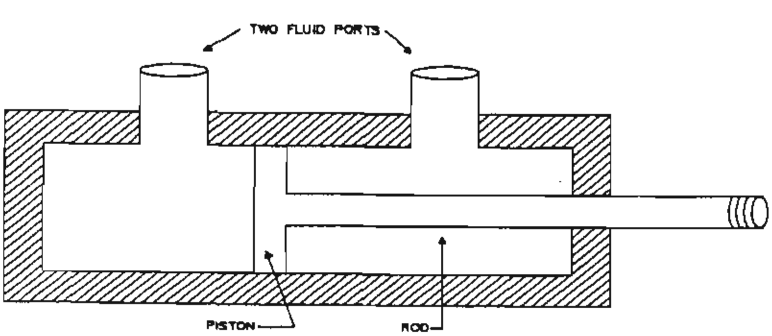
Because the distances are traveled simultaneously, the linear velocities (v and V) have the same relationship as the distances, namely:

$$\frac{V}{v} = \frac{d}{D} \quad \text{or} \quad V = (v) \times \frac{d}{D} \text{ inches per second}$$

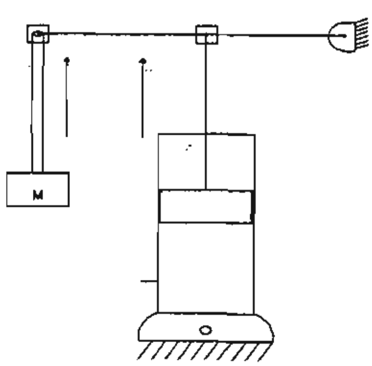
In our example, the load moves 4 times the distance at 4 times the speed of the input force.

The effort (or input force) is produced by a hydraulic cylinder. Inside the cylinder is a disc-shaped piston with a rod extending out one end. See sketch below.

DOUBLE-ACTING PISTON CYLINDER



THIRD CLASS LEVER



When oil under pressure is forced into the cylinder, it pushes against the piston surface. The amount of force, F (in pounds), transmitted through the rod depends on both the pressure, P (pounds per square inch), of the oil and the surface area, A (in square inches), of the piston. The equation is:

$$F = PA$$

For example, if the piston has a one-inch diameter, its surface area is:

$$A = \pi r^2 = 3.1416 \times 0.5^2 \approx 0.8 \text{ in}^2$$

Further, assume oil is being pumped at a pressure of 100 psi. The force is therefore:

$$F = P \times A = 100 \times 0.8 = 80 \text{ pounds thrust}$$

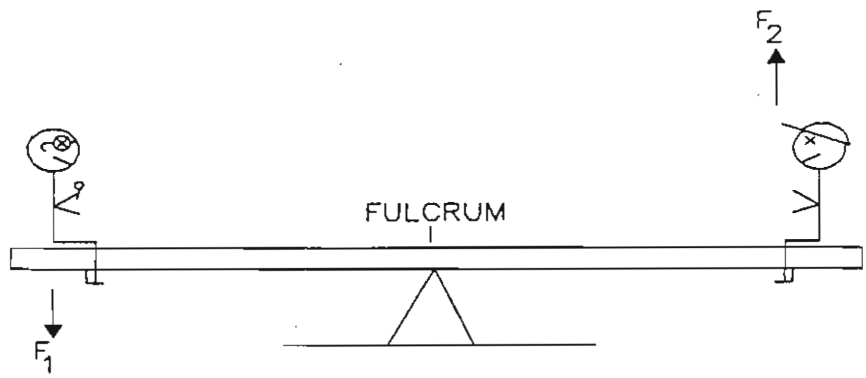
The cylinder is lowered by pumping oil into the opposite end. A four-way solenoid-operated reversing valve switches the oil flow from one side of the piston to the other.

Oddly enough, there is not as much force available when the piston is retracting as when it is extending. The reason is the rod. It occupies a part of that side of the piston area. The effective piston area, therefore, is that surface in contact with the oil, which is less than the side without the rod.

By the same token, the volume of the cylinder when the piston is retracted is less than when it is extended. That's because part of the volume is occupied with the rod. Yet oil is coming in under the same pressure both times. It takes longer to fill the empty cylinder on extension (arm raising) than it does to fill the cylinder containing the rod on retraction (arm lowering).

The display indicates the degrees of shoulder lift. The signal that drives the display comes from a LVDT (Linear Variable Differential Transformer), also known as a "Movable Core Transformer". The transformer is composed of two coils, wound on the same coil form. One coil, called the primary, is connected to a source of alternating current. This produces an alternating magnetic field, which links the other coil, called the secondary. The result is an induced voltage in the secondary. The value of the secondary voltage is directly related to the position of a movable iron core. Iron has a way of concentrating the magnetic lines of force. When the core is centered, the magnetic field is the strongest and the secondary has the maximum voltage induced into it. When the core is extracted from the transformer, the magnetic field is weakest and minimum voltage is induced into the secondary. The secondary voltage (rectified to DC) is observable between Test Points TPA1 (-) and TPB4 (+).

Motion of the arm is transmitted from a point that is one inch from the fulcrum, through a class-one lever, to the rod connected to the movable core. A class-one lever has the fulcrum located between the effort (input) and the load (output). The best known example of a class-one lever is a child's see-saw. See sketch below.



It is possible to change speed and force, as well as direction, with a class-one lever. However, in this application, the distance from the input to the fulcrum has been made equal to distance from the fulcrum to the output. Therefore, only the direction is changed. When the arm goes down, the core is pulled upward, and vice versa.

Note that although the connecting rod itself is located 2 1/2 inches from the arm's fulcrum, its travel is what it would be if it were 1 inch from the fulcrum. The output of the LVDT is directly proportional to the core position, which, in turn, is directly proportional to the cylinder extension and thus the angle of shoulder lift.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Oscilloscope
Measuring Rule
Stopwatch or other timer.

PROCEDURE - A

1. Power up the H-MRS-1 and verify that it is operating properly.

2. Position the elbow, if necessary, so that the forearm is in a direct line with the upper arm. Have the forearm fully retracted.

3. Turn OFF and unplug the H-MRS-1

4. Measure the distance from the center of the fulcrum to the center of the cylinder connecting rod pivot. d= _______ inches.

5. Measure the distance from the center of the fulcrum to the center of the gripper. D= _______ inches.

6. Plug the H-MRS-1 back in, turn it ON and position the shoulder at 9°. Then turn it OFF and unplug it.

7. Measure the vertical distance from the bench top to the cylinder connecting rod pivot. (You may have to do this in three steps: (1) Measure the height of the base, (2) Measure the distance from the base top to the pivot, and (3) add them.) _______ inches.

8. Measure the vertical distance from the bench top to the center of the gripper. _______ inches.

9. Plug the H-MRS-1 back in, turn it ON and position the shoulder at 51° (full lift). Then turn it OFF and unplug it.

10. Measure the vertical distance from the bench top to the cylinder connecting rod pivot. _______ inches. Subtract the value in Step 7. Rod travel _______ inches.

11. Compute the distance travelled by the gripper according to the class-three lever equation. Distance = _______ inches.

12. Measure the vertical distance from the bench top to the center of the gripper. Distance _______ inches. Subtract the value in Step 8. Gripper travel = _______ inches. Does this agree with your computed value in Step 11? Y or N (circle one)

ASSIGNMENT #1

1. Repeat Steps 6 through 12 with the forearm fully extended. Predicted distance travelled by the gripper = _______ inches. Actual distance travelled by the gripper = inches.

2. With a stopwatch (or other timer) measure the time it takes for the shoulder to lift from 9° to 51° _______ seconds.

3. Compute the linear speed of the cylinder: _______ inches/sec.

4. Calculate the linear speed of the gripper: _______ inches/sec.

5. Repeat Steps 2 through 4 for downward movement of the arm, from 51° to 9°.
Cylinder speed _______ in./sec. Gripper speed _______ in./sec.

6. Repeat Steps 4 and 5 for forearm fully retracted.
Gripper speed UP _______ in./sec. Gripper speed DOWN _______ in./sec.

7. Turn OFF and unplug the H-MRS-1.

PROCEDURE - B

1. Power up the H-MRS-1 and verify it is operating properly.

2. Read the gauge on the hydraulics oil pump. _______ psi.

3. Assuming the cylinder piston has a surface area of 0.8 in^2, compute the cylinder thrust (force during extension) _______ psi.

4. Calculate the theoretical lifting force available at the gripper.
Forearm extended _______ lbs. Forearm retracted _______ lbs.
(The reason this is not the actual lifting force available is that the elbow gearing must also carry that load.)

5. Measure the time for full 51° lifting rotation of the arm. (You may wish to do this three or more times and average the time.) _______ seconds.

6. Measure the time for full 51° lowering of the arm. _______ seconds.

7. Turn OFF and unplug the H-MRS-1.

8. Based on the ratio of the extension and retracting times, calculate the effective area of the piston during retraction: _______ in^2.

9. Calculate the downward pulling force available.
Forearm extended _______ lbs. Forearm retracted _______ lbs.

ASSIGNMENT #2

1. In the above procedure, we assumed the arm was weightless. Actually it weighs 17.25 pounds. Manufacturers rate the lifting power of their robot arms by the theoretical value. Actual lifting power is less than rated. In lever calculations, the weight of the arm is considered as a downward force, concentrated at a point (called the center of gravity). Assuming the weight to be evenly distributed, the arm's center of gravity would be halfway from the back of the arm to the gripper. Calculate the distance the center of gravity is from the fulcrum. ________ inches.

2. You know from previous calculations the torque produced by the cylinder. From that must be subtracted the torque produced by the weight of the arm, itself, to arrive at the lifting force available (without considering the elbow).

	CYLINDER TORQUE	BAR TORQUE	LIFTING TORQUE
Forearm extended			
Forearm retracted			

PROCEDURE C

1. Connect the negative clip of the oscilloscope to TPA1 and the probe to TPB4.

2. Power up the H-MRS-1 and verify that it is operating properly.

3. Lower the shoulder to its lowermost position. The display reads ________ degrees. The voltage as read on the oscilloscope is ________ volts.

4. Lift the shoulder to its uppermost position. The display reads ________ degrees. The voltage as read on the oscilloscope is ________ volts.

5. Complete the following table for the various positions of the shoulder, as read on the display.

POSITION (degrees)	VOLTAGE (VDC)
0	
5	
10	
15	
20	
25	
30	
35	
40	
45	
50	

ASSIGNMENT #3

1. Plot a curve showing how the LVDT voltage changes with the shoulder position. Let degrees be the abscissa (horizontal) and volts be the ordinate (vertical).

EXPERIMENT 5-3

MECHANICS OF ARM EXTENSION AND POSITION SIGNAL

PURPOSE

To acquaint the student with the mechanical power transmission system used with the arm extension and the position signal that is transmitted to the electronic circuits.

BACKGROUND

In order to further our understanding of robotic systems, we will investigate the mechanical system that produces an extension of the arm. Further, we will make use of the test points provided to examine the arm extension position signal. If electronically controlled devices, such as robots, are to move to various positions accurately and reliably, the movement must be monitored and location information must constantly be provided to the electronic circuits.

A hydraulic cylinder like the one used for shoulder lift, is used to extend the arm. As the arm extends and retracts, it carries with it the wiper arm of a linear potentiometer. This produces an output signal (observable at a test point) that is directly proportional to arm extension. The display indicates inches from full retraction.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Oscilloscope
Measuring Rule
Stopwatch or other Timer

PROCEDURE - A

1. Power up the Hampden H-MRS-1 and verify that it is operating properly.

2. Retract the arm. Make a light mark on the movable portion part of the arm so you can measure the distance it extends. Extend the arm fully. How far did it move?____.

3. Retract the arm and extend it several times while measuring the time of travel in both directions. Time for full extension _______ seconds. Time for full retraction _______ seconds.

4. Calculate speed for movement in both directions. Speed of extension _______ inches/second. Speed of retraction _______ inches/second.

PROCEDURE - B

1. Power up the H-MRS-1. Raise the shoulder fully and extend the arm fully.

2. Turn off the H-MRS-1 and unplug it from the wall.

3. Observe the underside of the arm. You will see the linear potentiometer above the connecting rod from the pneumatic cylinder.

4. Once you are safely back outside the arm's work envelope, plug the H-MRS-1 back in.

5. Connect the negative clip of the oscilloscope to TPA1 and the probe to TPB2.

6. Power up the H-MRS-1 and verify that it is operating properly.

7. Extend the arm fully. The display reads _______ . The voltage as read on the oscilloscope is _______ volts.

8. Retract the arm fully. The display reads _______ . The voltage as read on the oscilloscope is _______ volts.

ASSIGNMENT #1

1. Using the display and the oscilloscope, extend the arm to the following locations and record the voltage:

ASSIGNMENT #2

1. Plot a curve showing how potentiometer voltage changes with arm extension. Let inches be the abscissa (horizontal) and volts be the ordinate (vertical).

	VOLTS
1.0 in.	
1.5 in.	
2.5 in.	
3.0 in.	
4.0 in.	
5.1 in.	

EXPERIMENT 5-4

MECHANICS OF THE ELBOW BEND AND POSITION SIGNAL

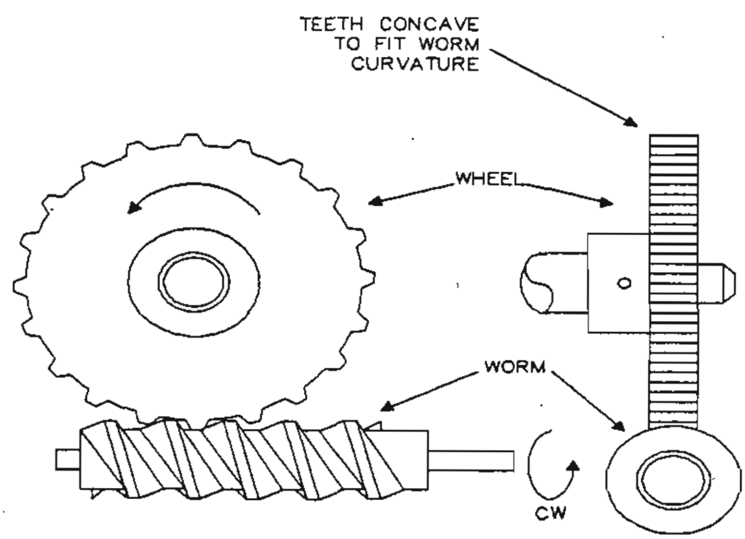
PURPOSE

To acquaint the student with the mechanical power transmission system used with the elbow bend and the position signal that is transmitted to the electronic circuits.

BACKGROUND

In order to further our understanding of robotic systems,we will investigate the mechanical system that produces the bending of the elbow. If electronically controlled devices, such as robots, are to move to positions accurately and reliably, the movement must be monitored and location information must constantly be provided to the electronic circuits.

Power to bend the arm at the elbow comes from a DC servomotor. A "worm-and-wheel" assembly transmits this power to the arm. At the same time, a rotary potentiometer is driven through a set of spur gears. See sketch below.



A worm pinion is a cylinder having a helical thread cut on its outer surface. The worm is meshed with a type of spur gear called a worm wheel, which is manufactured with curved tooth tips to provide a better fit with the worm.

When a worm having a single helical thread is meshed with worm wheel, the wheel rotates the distance of one tooth for each revolution of the worm. Therefore, the gear ratio is equal to the number of teeth on the wheel. In the H-MRS-1, the wheel has 40 teeth, making the gear ratio 40:1. The DC servomotor, then, turns through an angle of 40 times the angle of the forearm with respect to the upper arm. It is left as a student exercise to determine the number of revolutions turned by the servomotor to produce the full 127° bend of the elbow. How many revolutions? ____________

The equations on Page 5-2 apply to the worm-and-wheel assembly the same as they do to spur gears. Worm-and-wheels, however, tend to be less efficient then spur gears. You would not expect, therefore, to get an output torque of 40 times that supplied by the servomotor twenty times (efficiency of 50%) would be more typical.

The gear ratio of the assembly driving the rotary potentiometer is 1:1. It therefore turns 127° as the arm bends 127° at the elbow. The output of the potentiometer is directly related to the angle the forearm makes with the upper arm.

PROCEDURE - A

1. Power up the Hampden H-MRS-1 and verify that it is operating properly.

2. Operate the elbow bend controls to verify their proper operation.

3. Operate the elbow bend over the full 127° while measuring the time in each direction. You may wish to do this several times and average the results.
   Bend up time _____________ seconds. Bend down time _____________ seconds.
   Were they equal? circle Y or N . Why or why not?

   ____

   ____

ASSIGNMENT #1

1. Calculate the speed of the motor shaft rpm. (Don't forget to take into account the gear ratio.)

2. Calculate the number of revolutions of the motor shaft needed to produce the following elbow bend angles:

PROCEDURE - B

1. Power up the H-MRS-1. Raise the arm fully and bend the elbow up fully.

POSITION	MOTOR REVOLUTIONS
9°	
18°	
36°	
45°	
58.5°	
72°	
94.5°	
112.5	
126	

2. Turn off the H-MRS-1 and unplug it from the wall.

3. Observe the underside of the elbow joint. Sketch below the worm-and-wheel assembly and the set of gears driving the rotary potentiometers.

4. Once you are safely back outside the arm's work envelope, plug the H-MRS-1 back in.

5. Connect the negative clip of the oscilloscope to TPA1 and the probe to TPB1.

6. Power up the H-MRS-1 and verify that it is operating properly.

7. Bend the elbow down fully. The display reads ________. The voltage as read on the oscilloscope is ________ volts.

ASSIGNMENT #1

1. Using the display and the oscilloscope, position the elbow to the following angles and record the voltage:

	VOLTS
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	
110	
120	

ASSIGNMENT #2

1. Plot a curve showing how the potentiometer voltage changes with forearm position. Let degrees be the abscissa (horizontal) and volts be the ordinate (vertical).

EXPERIMENT 5-5

MECHANICS OF WRIST ROLL AND POSITION SIGNAL

PURPOSE

To acquaint the student with the mechanical power transmission system used to rotate the wrist and with the position signal that is transmitted to the electronic circuits.

BACKGROUND

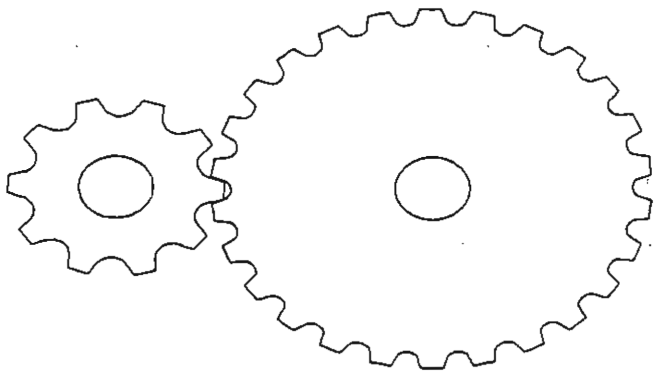
In order to further our understanding of robotic systems, we will investigate the mechanical system that produce a rotation of the wrist. Further, we will make use of the test points provided to examine the wrist roll position signal. If electronically controlled devices, such as robots, are to move to various positions accurately and reliably, the movement must be monitored and location information must constantly be provided to the electronic circuits.

As you read about the mechanics of wrist rotation, you may wish to position the arm (elbow full down, arm horizontal and retracted) so that you can examine the power producing and transmitting mechanism.

The power to roll the wrist comes from a DC stepper motor that you see mounted so that its shaft is perpendicular to the arm. A stepper motor has a permanent magnet rotor and a stator wound with 4 coils. When a pair of coils are energized, they produce a magnetic field having a definite N-S orientation. The rotor then lines up its magnetic field in the same N-S direction. The stator's magnetic field is made to rotate by energizing a different pair of coils each step. There is a sequence of 4-steps (coils 1 and 4; 1 and 3; 2 and 4; 2 and 3) that is repeated over and over.

The rotor of the stepper motor used in the H-MRS-1 advances 15° each step; 60° for each 4-step sequence. The motor drive, then, goes through 6 sequences for a 360° roll. You will notice that the shaft emerging from the motor is not centered. There is, between that shaft and the motor shaft, a 30:1 gear reduction. The shaft, then, rotates 1/2° for each stepper motor step. The motor actually rotates 30 times for each rotation of the shaft. On the shaft there is a bevel gear, meshed with a second bevel gear. Bevel gears are used to change the axis of motion while transmitting power. Both bevel gears have the same number of teeth. There is, therefore, no change in speed or torque; only direction.

Attached to the bevel gear shaft is a small gear meshing with a larger gear. See sketch below.



These gears reduce the speed and increase the torque still further. It is left as a student exercise to determine the gear ratio and the angle the wrist turns for each motor step. Gear ratio. Angle.

The stepper motor runs either forward or reverse. The signal that governs direction is observable on the test points. Observable on the test points also is the triggering signal that turns on and off the electronic switches that energize one of the coils. Because each coil is on half of the time during a 4-step sequence, and off the other half, we can measure the frequency of one repetitive cycle of one coil, double it, and have the motor's frequency (speed) in steps per second.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Oscilloscope
Stopwatch or other timer

PROCEDURE - A

1. Power up the Hampden H-MRS-1 and verify that it is operating properly.

2. Operate the wrist roll controls to verify their proper operation.

3. Starting at the zero position, roll the wrist through a full 360 ° and measure the time of one revolution. __________ seconds.

4. Reverse the direction of the wrist to repeat Step 3. __________ seconds. Was the time the same for both directions? Y or N

5. Calculate the revolutions-per-second speed of the wrist. ____________ rev/sec.

6. From the gear ratio you calculated in the Background, determine the speed of the shaft coming from the motor gear box. Shaft speed is ____________ rev/sec

7. Knowing that the gearbox reduces by 30:1 the speed of the stepper motor, calculate the motor speed. ____________ rev/sec.

8. Knowing that each motor step is 15° (24 steps per revolution), calculate the motor speed (frequency) in steps per second. ____________ steps/sec.

9. For every 24 steps (one complete revolution) of the stepper motor, the wrist rolls how far? ____________ degrees.

ASSIGNMENT #1

1. Using the previously calculated information, calculate the number of steps the stepper motor must make from zero in order to turn the gripper the following number of degrees. (Remember, for angles greater than 180° (180° < x < 360°), it's quicker to roll the wrist in the opposite direction for 360 – x°.) Indicate opposite direction steps with a minus sign.

	VOLTS
10°	
45°	
270°	
180°	
300°	
95°	
350°	
60°	
185°	

PROCEDURE - B

1. Power up the H-MRS-1. Position the arm (horizontal, retracted, elbow fully down) so as to observe the operation of the wrist roll mechanism without entering the arm's work envelope.

2. Connect the negative clip of the oscilloscope to TPA1 and the probe to TPC2.

3. Let the wrist roll continuously while observing the trace on the scope screen. This is the triggering signal that controls the electronic switches that energize one of the stepper motor coils. Sketch the waveform below and, on it, indicate the period (in milliseconds) of one cycle.

4. From the time of one period, calculate the frequency of the triggering pulse train. (Don't forget to convert the milliseconds to seconds.) __________ Hz.

5. Double the frequency calculated in Step 4 to obtain the frequency (speed in steps per second) of the stepper motor. __________ steps/sec. Does this agree with step 8 of Procedure A? Y . or N

ASSIGNMENT #1

1. On TPC1 you can observe the direction signal.
   What is the value when the unit is rolling clockwise? ________
   What is its value when the wrist is rolling counterclockwise? ________

2. On TPB5 is the signal that indicates the "home" (0) position of the wrist.
   What is its value at 0°? _________
   What is its value at every other position? __________

EXPERIMENT 5-6

MECHANICS OF HAND GRASP AND POSITION SIGNAL

PURPOSE

To acquaint the student with the mechanical power transmission system used with the hand grasp and the position signal that is transmitted to the electronic circuits.

BACKGROUND

In order to further our understanding of robotic systems, we will investigate the mechanical system that closes and opens the hand. Further we will make use of the test points provided to examine the hand "open/closed" signal. If electronically controlled devices, such as robots, are to move to various positions accurately and reliably, the movement must be monitored and location information must be constantly provided to the electronic circuits.

As you read about the mechanics of hand grasping, you may wish to position the arm (straight ahead, slightly elevated, elbow down and arm retracted) so that you can examine the power producing and transmitting mechanism.

The power to close and open the grippers comes from a pneumatic cylinder. The cylinder produces a straight in/out motion. Linkage is used to translate that motion into a grasping action. When you press the OPEN key, the cylinder extends, forcing the gripper faces apart by means of two pivoted links. These links draw the gripper surfaces together when the piston retracts.

Pneumatic cylinders look very much like hydraulic cylinder, and they operate on the same principle. There are, however, two important differences between oil and air as power transmitting media. Air can be compressed; oil cannot. Oil must be returned to a reservoir; air is exhausted to the atmosphere.

Pneumatic components are used extensively in Robotics. No special fluid is needed. Air is abundant and relatively cheap to compress. Because of the mechanical advantage possible from pistons, tremendous power can be produced by compressed air. An example is the pneumatic drill, or jackhammer.

The source of pneumatic power is an air compressor. A pump "squeezes" air into a tank. The pump is set for a specific pressure. Then when the air in the tank reaches that pressure, the pump shuts off. When the tank pressure falls a certain amount, the pump turns back on and runs until the set pressure is reached again. When you first turn on the compressor, you will see the pressure gauge gradually increase as air is compressed. The pneumatic cylinder will not operate properly until air pressure is approximately 100 psi.

Air from the compressor is not fed directly to the pneumatic cylinder. Air for the cylinder comes through a motor driven regulator. The air pressure, then, depends on the setting of the regulator, which is controlled by the PRESS UP and PRESS DOWN keys. As you press these keys you can hear the motor running until it reaches either the minimum pressure stop switch or the maximum pressure stop switch. By regulating force of cylinder retraction, you are regulating the amount of grasping pressure.

A logic level (5 VDC) pulse triggers the solenoid-operated pneumatic directional valve, The "close" pulse is observable on test point C3.

EQUIPMENT AND MATERIALS REQUIRED

Hampden H-MRS-1 Robotics Trainer
Oscilloscope, Dual Trace
Measuring Rule
A Small Sponge or piece of sponge rubber

PROCEDURE - A

1. Power up the Hampden H-MRS-1 and verify that it is operating properly.

2. Operate the grasp controls several times to verify their proper operation.

3. Run the air pressure to maximum. Lay the piece of sponge rubber on the table and position the arm to grasp it. Measure the internal distance between the gripper surfaces. __________ inches.

4. Open the gripper. Run the air pressure to minimum. Again make the arm grasp the sponge rubber and measure the distance between gripper surfaces. ________ inches.

PROCEDURE - B

1. Connect the negative clip of the oscilloscope to TPA1 and the probe to TPC3.

2. Power up the H-MRS-1 and verify that it is operating properly.

3. Observe what happens to the oscilloscope trace when you press the CLOSE key. To what voltage did it go? ________ volts.

4. What happens to the oscilloscope trace when you press the OPEN key. To what voltage did it go? _________ volts.

ASSIGNMENT #1

1. Connect the negative clip of the oscilloscope to TPA1, one probe on TPC4, and the other TPC5. These test points are the "forward" and "reverse" signals on the motorized air pressure regulator.

2. Press the PRESS UP key. Read the voltages on the oscilloscope.

   TPC4 volts ______________
   TPC5 volts ______________

3. Press the PRESS DOWN key. Read the voltages on the oscilloscope.

   TPC4 volts ______________
   TPC5 volts ______________