HANDBOOK

Two, Three and Four Finger Pneumatic Grippers

MACK CORPORATION

POINT TO POINT TRANSFER

SLEEVE
ROD
SLEEVE
GROOVES OR THD. WITH HELIX
ROD
BALL
TYPICAL FINGER REWORK
RING
WIRES
SLEEVE FLANGE
SHEET
BOLT
ROD

THREE FINGER RIGID DISC GRIPPER

LO-PROfile® CYLINDER MODIFIED TO CREATE A PINCH OFF VALVE

INDEXING PARTS IN A ROTATIONAL SEQUENCE

REPROGRAMMING A GRIPPER BY CHANGING FINGERS

TYPICAL TWO FINGER MODIFICATION

CLOSE COUPLED ROTATIONS

DUAL IN-LINE ROLL ROTATORS

TUBE BRAZING FIXTURE

PNEUMATIC OPERATION INSIDE EXPLOSIVE ENVIRONMENT

PEN TESTING

PACKING WITH VACUUM HEADS

EXAMPLE OF LO-PROfile® CYLINDERS USED IN KEY BOARD TESTING

SINGLE AXIS PROCESSING

PART TRANSFER FROM SPRING LOADED FEEDER

TWO FINGER RIGID DISC GRIPPER

MACHINE LOADING

PICK UP INVERT AND PLACE

HORTIZONTAL TRAVEL WITH VERTICAL EXTENSION

LO-PROfile® CYLINDER MODIFIED FOR USE AS A BRAKE

SIMPLE PARTS TRANSFER

LO-PROfile® CYLINDER MODIFIED TO PRODUCE A ROBOTIC GRIPPER

BOLT PATTERN PROGRAMMED IN CARTESIAN COORDINATES

GRASPING LONG SLENDER OBJECTS

ROBOT UNDERWATER

UNDERWATER OPERATION

TRANSFER OF SMALL PARTS TO A TEST STATION

TEST PART

TEST RIG

LO-PROfile® CYLINDER IN INDUSTRIAL APPLICATIONS

THREE AXIS TRANSFER WITH OPTIONAL INCREMENTER ON VERTICAL MOTION

FILE AND RETRIEVE

SEQUENCE, VERIFY & PLACE PARTS

DUAL IN-LINE PITCH/YAW ROTATORS

PICK UP LONG SLENDER PARTS AND TRANSFER TO ANOTHER LOCATION

TYPICAL THREE FINGER MODIFICATION

MACK CORPORATION

DUAL IN-LINE PITCH/YAW ROTATORS

TWO, THREE AND FOUR FINGER, B•A•S•E® PNEUMATIC GRIPPERS

AUTOMATION TRENDS:

The current trend toward developing automated processing in parallel with new product development leads to an efficient blend of both activities and results in better quality, higher productivity and lower costs. A good example is automobile production--without present levels of automation, a new car would lack quality and cost the wages of a lifetime.

END EFFECTORS:

A key component in developing automated processing is the end effector. End effectors are devices which pick up or otherwise handle objects for transfer or while being processed.

Selecting and end effector early in an automation project is not difficult when characteristics of the work piece and related processing have been defined.

End effectors come in all types and sizes. Some typical examples are shown in Figure 1.
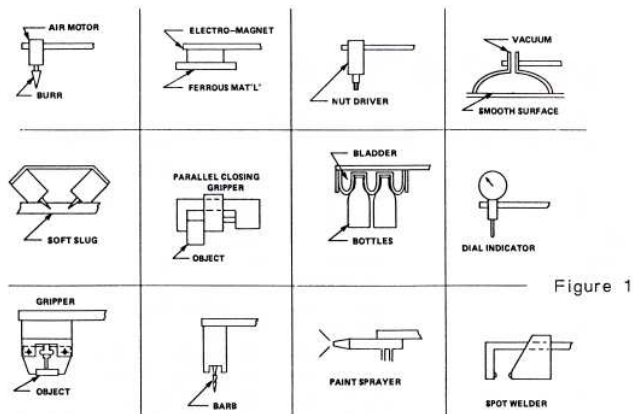
Figure 1

Some automation applications may require an all new, state of the art end effector with extensive development effort, while other applications may require only a stock gripper with modified fingers.

GRIPPERS:

The text of this article relates to the latter in the form of two, three and four finger, angular closing, double acting, pneumatic grippers. This class of end effector is simply an air operated pliers with capability to grip internally as well as externally.

Categorically, grippers are found near the end of the family of automation components as shown in Figure 2.
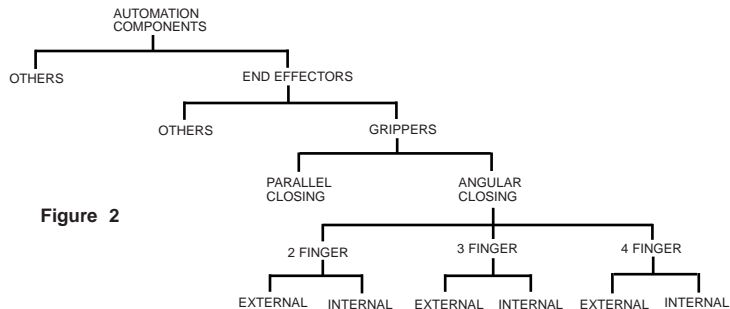
Figure 2

TWO FINGER GRIPPERS:

Two finger grippers simulate the motions of the thumb and index finger for reaching into channels, grasping parts within confined space or picking and placing any object of simple geometry. See Figure 3 and Photograph 1.
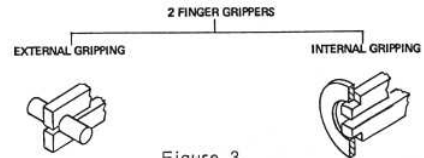
Figure 3

Positioning a work piece in the plane of the fingers is inherently good. Positioning in a plane perpendicular to the fingers is not controlled unless a work piece has a shoulder or is presented to the gripper in a uniform way.

THREE FINGER GRIPPERS:

Three finger grippers duplicate the motions of the thumb, index finger and a third finger for grasping bodies of revolution and objects of spherical or cylindrical shape. See Figure 4 and Photograph 2.
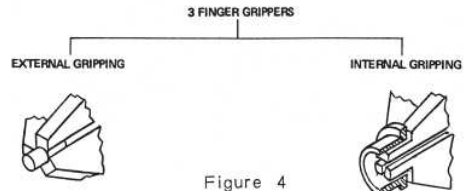
Figure 4

Three fingers close simultaneously and provide self centering about a body of revolution. Depth is controlled by steps on the fingers or a shoulder/recess on the part.

FOUR FINGER GRIPPERS:

Four finger grippers provide a means for grasping square or rectangular parts. One pair of opposing fingers is wide for angular orientation of the part as the combination of four fingers close simultaneously to position the centroid. See Figure 5 and Picture 3.
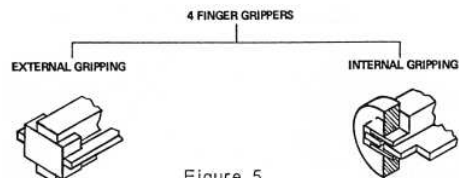
Figure 5

Angular orientation and centroid location, is inherently good. A pocket in externally closing fingers and shoulders on internally closing fingers provide depth control.

MECHANICS:

The kinematics of converting linear motion from an air cylinder to angular motion for driving fingers can take many forms. Motion conversion for B•A•S•E® grippers is shown in Figure 6.
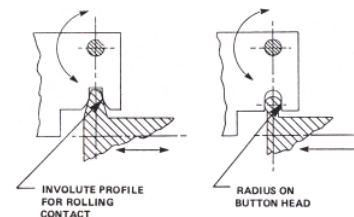
PICTURE 1

PICTURE 2

PICTURE 3

Adding an adjustment between cylinder linear motion and finger angular motion provides additional open travel and reduces the critical nature of fitting fingers to a work piece. See Figure 7. This crossection is typical for B•A•S•E® GRIPPERS.
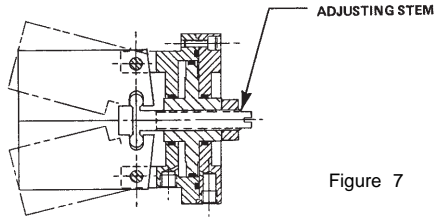
Figure 7

GRIPPER CONFIGURATIONS:

Basic configurations may vary as dictated by the application. Advantages from using double acting pneumatic drive includes rugged construction with light weight and low inertia for rapid transit, simple control, positive opening and closing action, capability for gripping internally and externally and ease for reducing pinch force for delicate items. The recognized reliability and speed of pneumatic components is also a significant advantage.

Figure 8 shows a typical configuration and a failsafe modification.

PRESSURE TO OPEN
PRESSURE TO CLOSE

PRESSURE TO CLOSE
FAILSAFE OPEN
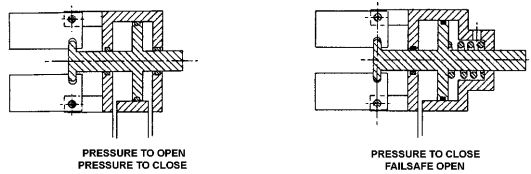
Figure 8

STRUCTURAL CONSIDERATIONS:

Aside from safety factors involved in the design of the pneumatic section, a good piston guide is essential to assure simultaneous action and repeatability for finger motion. Examples of good piston guide are shown in Figure 9.

STRADDLE GUIDE

LONG GUIDE

DOUBLE ACTING DOUBLE ENDED

Figure 9

DOUBLE ACTING SINGLE ENDED
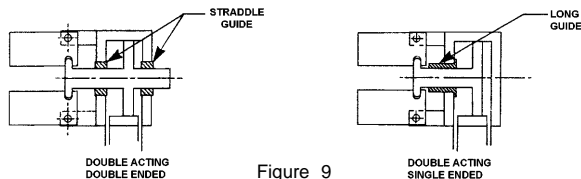
MONITORING, SENSING AND FEEDBACK:

Pneumatic components are noted for reliability and the need for monitoring may not be necessary. An array of sensing circuits tends to defeat the inherent simplicity of a pneumatic gripper.

However, all gripper applications involving safety and potential equipment damage should be monitored and shut down when a serious problem develops.

Figure 10 is an example of monitoring finger position directly and indirectly.

SENSOR TO MONITOR FINGER POSITION

SENSOR TO MONITOR PISTON POSITION
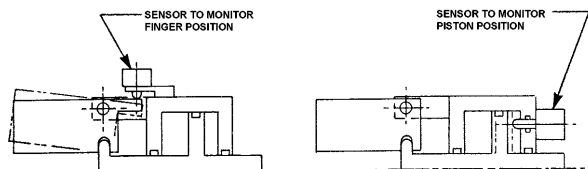
Figure 10

GRIPPER SIZE:

Size is not a limitation. Large grippers are being used commercially with sufficient pinch force to hold a multi-tom steel billet horizontally from the end for processing in forging dies.

Grippers as small as a thimble to the size of a human hand are common.

Larger grippers use hydraulics while smaller versions operate on plant air or with electric circuilts.

FITTING FINGERS TO A WORK PIECE:

Many stock grippers are supplied with blank fingers or with provisions for attaching blanks to finger motions elements. See Figure 11.

BLANK FINGERS

FINGER MOTION ELEMENT

BLANK DETACHABLE BLOCK
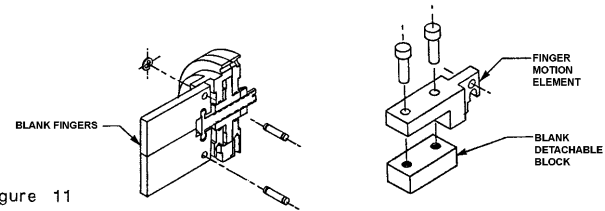
Figure 11

Finger blanks are then easily contoured to fit a work piece as suggested in Figure 12.

SLEEVE
ROD
SLEEVE
GROOVES OR THD. WITH HELIX
ROD
BALL
RING
WIRES
SLEEVE WITH FLANGE
SHEET
BOLT
ROD
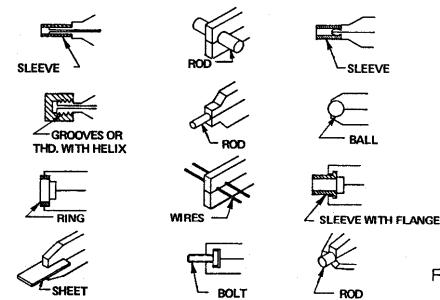
Figure 12

Reprogramming a gripper to handle another part is a matter of changing fingers or detachable blocks.

Fabricating special fingers of unique shape is common. Figure 13 and Picture 4 is an example of "dog legged" fingers attached to stock grippers for handling discs.

TWO FINGER VERSION

THREE FINGER VERSION
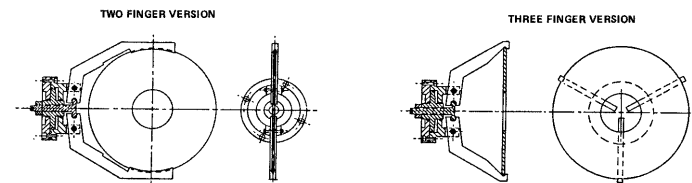
Figure 13

In some cases, several different products can be handled with the same finger/gripper combination as shown in Figure 14.

PRODUCT 1

PRODUCT 2

PRODUCT 3
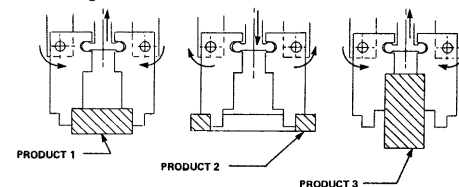
Figure 14

PICTURE 4

GRIPPER MOUNTING STANDARDS:

In general, very few standards exist in the field of automation. Each manufacturer of components has his own ideas concerning mounting and interfacing. However, some of the better ideas will eventually evolve as accepted standards.

Fortunately, mounting a gripper to a motion device is relatively easy and usually involves only a simple adaptor with appropriate fasteners. See Figure 15.
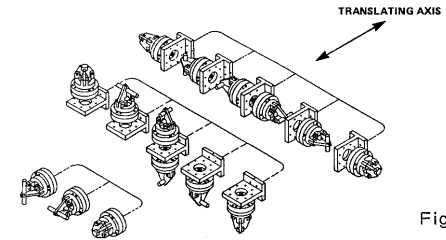
Figure 1

GRIPPER MOUNTING:

Pneumatic grippers operate well in any position leading to many options for mounting. However, gripper orientation deserves special consideration when mounted to transport devices with blind spots and limitations in linear travel or angular position. For example, by compromising reach into an upper quadrant, a gripper mounted perpendicular to the principal axis can reach into a blind spot in the lower quandrant. See Figure 16.
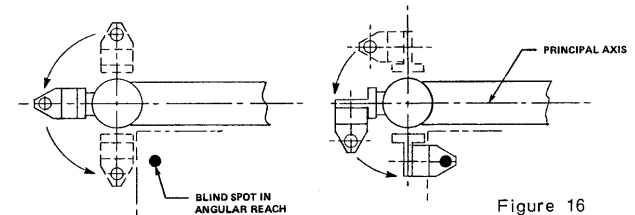
Figure 16

Where there is a choice, mounting grippers in a situation which reduces time in transit and distance traveled is obvious.

An example is mounting several grippers to a turret where a variety of parts can be picked up at point A for a single tansfer to point B for uploading. See Figure 17 and Front Cover.
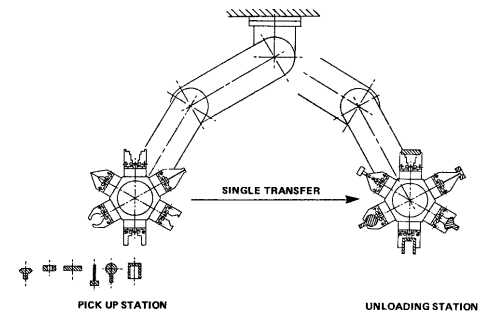
Figure 17

Another practical approach to mounting involves interchangeable tool needs where grippers are included as part of the tooling combination. See Figure 18.
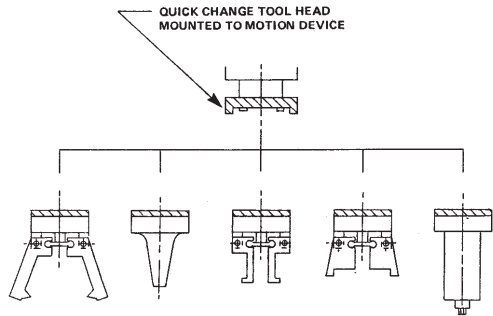
Figure 18

In addition to automatic connect-disconnect features, most quick change tool heads incorporate electrical, fluid power and other types of connections.

An example of effective use of interchangeable tool heads is to pick a housing from an intermittant conveyor, place it on a fixture, pick and place internal parts, dispense sealant at the flange, pick and place a coverplate, pick and place and drive fasteners followed by transfer of the completed unit to a test fixture. Inventory for end of arm tooling in this application includes several grippers, a sealant dispenser and nut driver.

PNEUMATIC SYSTEMS:

Control of an air operated, double acting gripper is simplified when using a conventional four way valve plumbed to plant air. A source of plant air is available in all industrial locations and components for pneumatic systems are shelf items. A simple pneumatic system is shown in Figure 19.
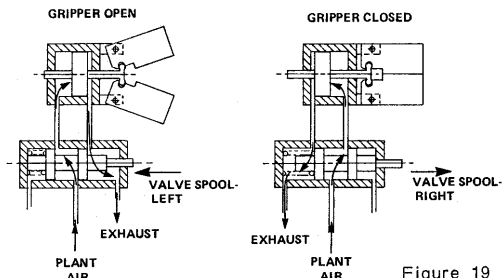
Figure 19

Selecting a solenoid operated, four way valve permits remote control of a pneumatic system and is inherently well suited for output from typical controllers and computer systems used in automation applications. See Figure 20.
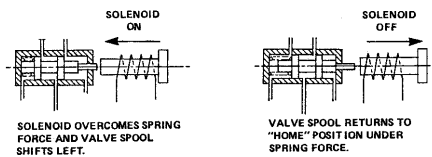
Figure 20

Figure 21 is a schematic of an air operated, double acting gripper as part of a combination of five non-servo automation components.
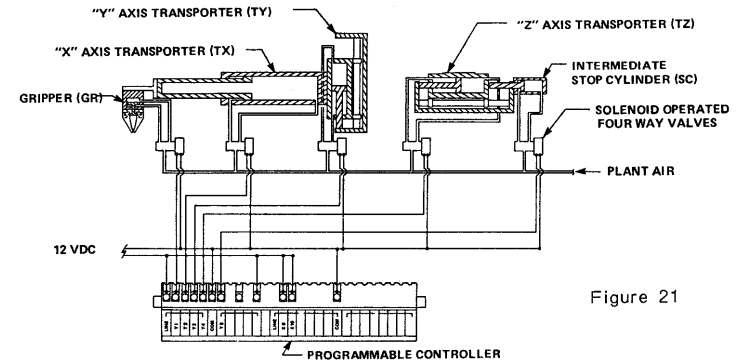
Figure 21

Structurally, this non-servo, pneumatic robot takes the form shown in Figure 22 and Picture 5 to perform a simple PICK-DIP-DROP sequence.

Typical of B·A·S·E® ROBOT COMPONENTS
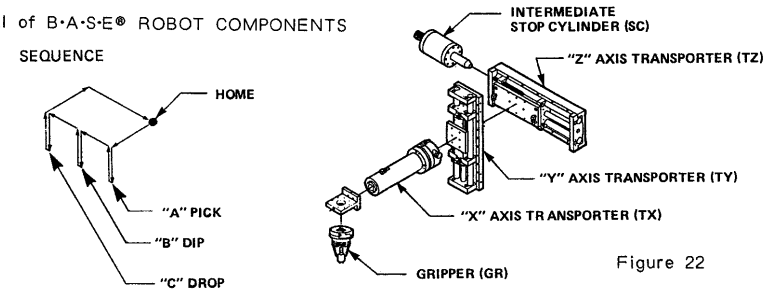
Figure 22

A part is "picked" from a parts feeder at "A", partially "dipped" in tinning solder at "B" and "dropped" onto an outboard conveyor at "C".

Each of the five components is plumbed through four way valves to shop air and hardwired to a programmable controller.

GRIPPER CONTROL WITH PROGRAMMABLE CONTROLLERS:

Pneumatic grippers require only a series of ON/OFF commands and solid state programmable controllers are almost ideal for direct programming and subsequent control of this class of non-servo component.

Controllers are easy to use, highly reliable, readily available at low cost and provide a broad range of control capability.

Learning to use a solid state controller is only slightly more complex than learning to use a hand calculator. Controllers are shipped with simple tutorial handbooks and programming can be self taught in a short time without understanding internal function.

Operating systems for various controllers may differ but key elements for simple programming will be available, i.e. step number, duration of step and a series of outputs for each step.

Basically, the whole process can be thought of in terms of loading outputs and specifying duration for each step on an electronic drum. See Figure 23.

STEP NO.	DURATION (msec)	OUTPUTS							
		A	B	C	D	E	F	G	H
1	1,000	OFF	ON	OFF	OFF	OFF			
2	1,000	OFF	ON	ON	OFF	OFF			
3	1,000	ON	ON	ON	OFF	OFF			

Figure 23
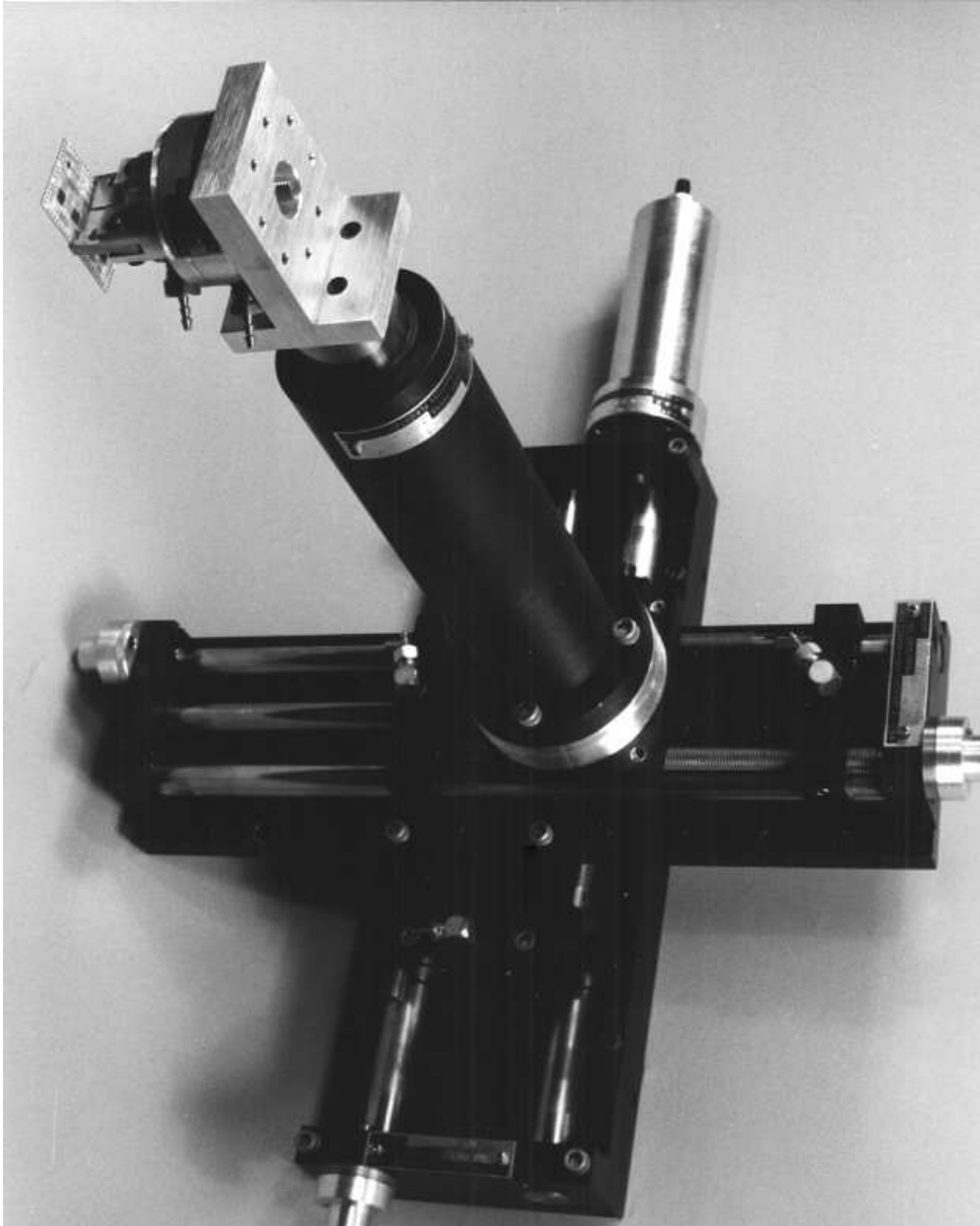
PICTURE 5

One output is committed to the gripper and is programmed with either an ON or OFF command at each stop in the sequence.

PROGRAMMING A SOLID STATE CONTROLLER:

The PICK-DIP-DROP sequence of Figure 22 is used for an example of programming and is shown in Figure 24 as a MOTION PATTERN with numbers assigned to each motion.
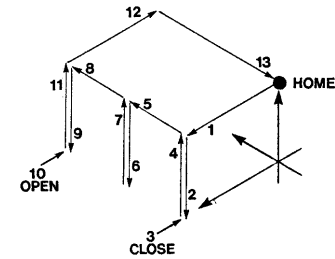
Figure 24

As stated earlier, an object is picked from a parts feeder at station 2, processed at station 6, dropped to a conveyor at station 9 and then returns HOME.

HOME position is arbitrary, but usually represents a location for "parking" at the end of a sequence.

In this case, HOME position is defined by the MOTION PATTERN as having the following status for each of five components.

HOME POSITION

COMPONENT	STATUS
GRIPPER	OPEN
"X" TRANSPORTER	RETRACTED
"Y" TRANSPORTER	UP
"Z" TRANSPORTER	RIGHT
INT. STOP CYL.	RETRACTED

Presetting the pneumatic system to a HOME position is easily accomplished by leaving power off to solenoids and turning air on to valves. REVERSE air lines to any component which is not HOME.

Presetting HOME position with solenoids in the OFF mode is important and serves as a reference for setting ON/OFF commands. For example, the gripper is open in the HOME position with a OFF command, therefore, an ON command will close it.

Presetting to the HOME position with power off has another advantage. In case of power failure, the robot drops everything, returns to HOME position and stays there unless progrmmed otherwise. On resumption of power, it can be programmed to start from the beginning, return to the interrupted motion or remain parked until reset by the attendant.

A table assigning ON/OFF commands to all five components can now be made using HOME position with valves OFF as reference.

COMMAND ASSIGNMENT

ROBOT COMPONENTS	STATUS OFF	ON
GRIPPER (GR)	OPEN	CLOSE
"X" TRANSPORTER (TX)	RETRACT	EXTEND
"Y" TRANSPORTER (TY)	UP	DOWN
"Z" TRANSPORTER (TZ)	RIGHT	LEFT
STOP CYLINDER (SC)	RETRACT	EXTEND

Step number 1 of the MOTION PATTERN calls for movement from HOME to a point over the parts feeder. An On command to TX is all that is required. All remaining components hold their respective positions with OFF commands.

Step number 2 calls for lowering an open gripper over the part. Maintaining an ON command to TX and introducing an ON command to TY lowers the gripper. The gripper is already open.

Step number 3 calls for closing a gripper onto a part with an ON command. All other components held the commands given in Step 2 to maintain the position over the parts feeder.

There are thirteen steps in this MOTION PATTERN with the last step being HOME.

STEP	MOTION	COMMAND STATUS				
		GR	TX	TY	TZ	SC
1	TX-OUT	OFF	ON	OFF	OFF	OFF
2	TY-DOWN	OFF	ON	ON	OFF	OFF
3	GR-CLOSE	ON	ON	ON	OFF	OFF
4	TY- UP	ON	ON	OFF	OFF	ON
5	TZ-LEFT	ON	ON	OFF	ON	ON
6	TY-DOWN	ON	ON	ON	ON	ON
7	TY-UP	ON	ON	OFF	ON	ON
8	TZ-LEFT	ON	ON	OFF	ON	OFF
9	TY-DOWN	ON	ON	ON	ON	OFF
10	GR-OPEN	OFF	ON	ON	ON	OFF
11	TY -UP	OFF	ON	OFF	ON	OFF
12	TX -IN	OFF	OFF	OFF	ON	OFF
13	TZ-RIGHT	OFF	OFF	OFF	OFF	OFF

In theory, programming non-servo, pneumatic components consists of adding time increments to each step in a LISTED MOTION PATTERN and wrapping the list around the drum. In practice, the process is almost as simple.

Good programming technique dictates a slow stepping rate during "set up". One step per second (or longer) allows for verification of motions and assures full travel for slower components. Decreasing cycle time is a refinement for later and is achieved by reducing time allocated for fast acting components such as closing a gripper. A gripper night close and develop full pinch force in 100 msec. while a slide mechanism might require a full second (1000 msec.) to complete its motion.

Modifying the LISTED MOTION PATTERN for programming at "set up" speed is shown in Fifure 25. ON/OFF commands have been changed to digits to expedite key pad entry.

DRUM TIMER PROGRAMMING FORM

PROGRAM NAME: ___PICK-DIP-DROP___   PROGRAM NUMBER: __SETUP__
PREPARED BY: _____
DATE: _____

STEP NO.	DURATION OF STEP (msec.)	OUTPUTS							
		A	B	C	D	E	F	G	H
		GRIPPER	"X" AXIS	"Y" AXIS	"Z" AXIS	STOP CYL.			
1	1.000	0	1	0	0	0			
2	"	0	1	1	0	0			
3	"	1	1	1	0	0			
4	"	1	1	0	0	1			
5	"	1	1	0	1	1			
6	"	1	1	1	1	1			
7	"	1	1	0	1	1			
8	"	1	1	0	1	0			
9	"	1	1	1	1	0			
10	"	0	1	1	1	0			
11	"	0	1	0	1	0			
12	"	0	0	0	1	0			
13	"	0	0	0	0	0	HOME		
14									
15							Figure 25		
16									

Decreasing cycle time involves reducing the duration for each step to cover the slowest component in motion at that time.

For example--in Step 3, closing a gripper is the only component in motion end reducing duration to 100 msec. is practical for fast acting grippers.

Cycle time for this "set up" is thirteen seconds. A practical "running time" might be six seconds or so depending on time required at the processing station (station 6).

Figure 26 is typical of various sequences which can be programmed directly at the controller for the robot structure of Figure22. Re programming stop locations within the structure may be required if there are changes in the physical locations of the work station.
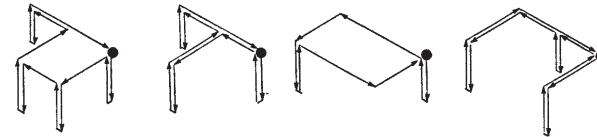

Figure 26

GRIPPER CONTROL WITH COMPUTERS:

At first thought, controlling a non-servo component with a computer appears to be overkill.

However, many sophisticated, servo-controlled automation systems incorporate non-servo components and a control link is provided in the form of an optically isolated, solid state relay.

Optical isolation protects computer circuits and a relay controls an external circuit. See Figure 27 and Picture 6.
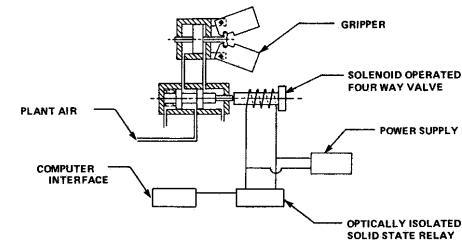

Figure 27

Programming is simply inserting an ON or OFF command at a specified time for a specified duration.

SUMMARY:

Two, three and four finger, angular closing, double acting pneumatic grippers fill a niche in many simple automation applications. This class of end effector is low cost, fast acting, reliable, easy to understand, has good accuracy, readily available, easy to reprogram by changing fingers and easy to mount.

PICTURE 6

For questions or to order direct.

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