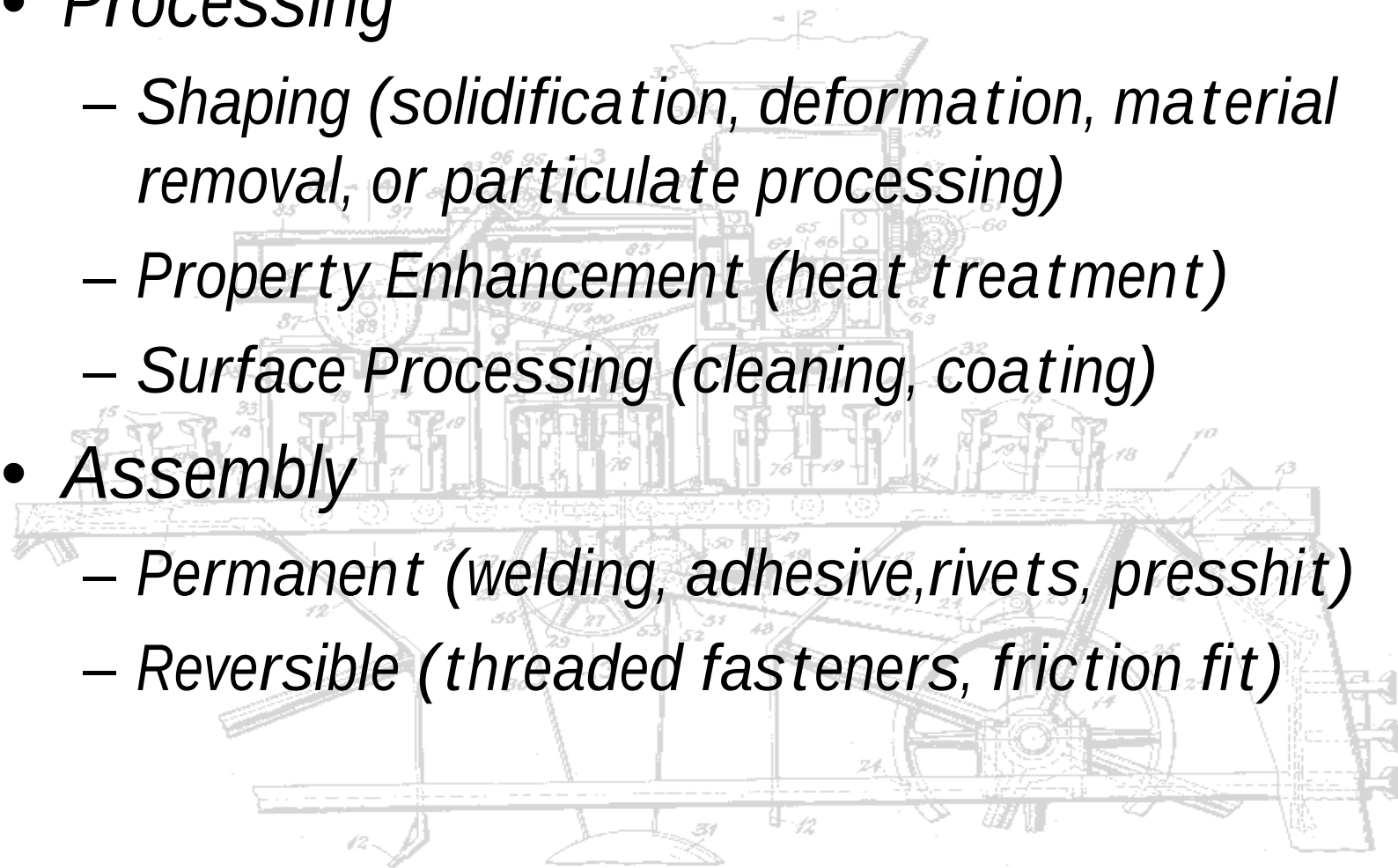
ENGR480 Manufacturing Systems

Spring 2006

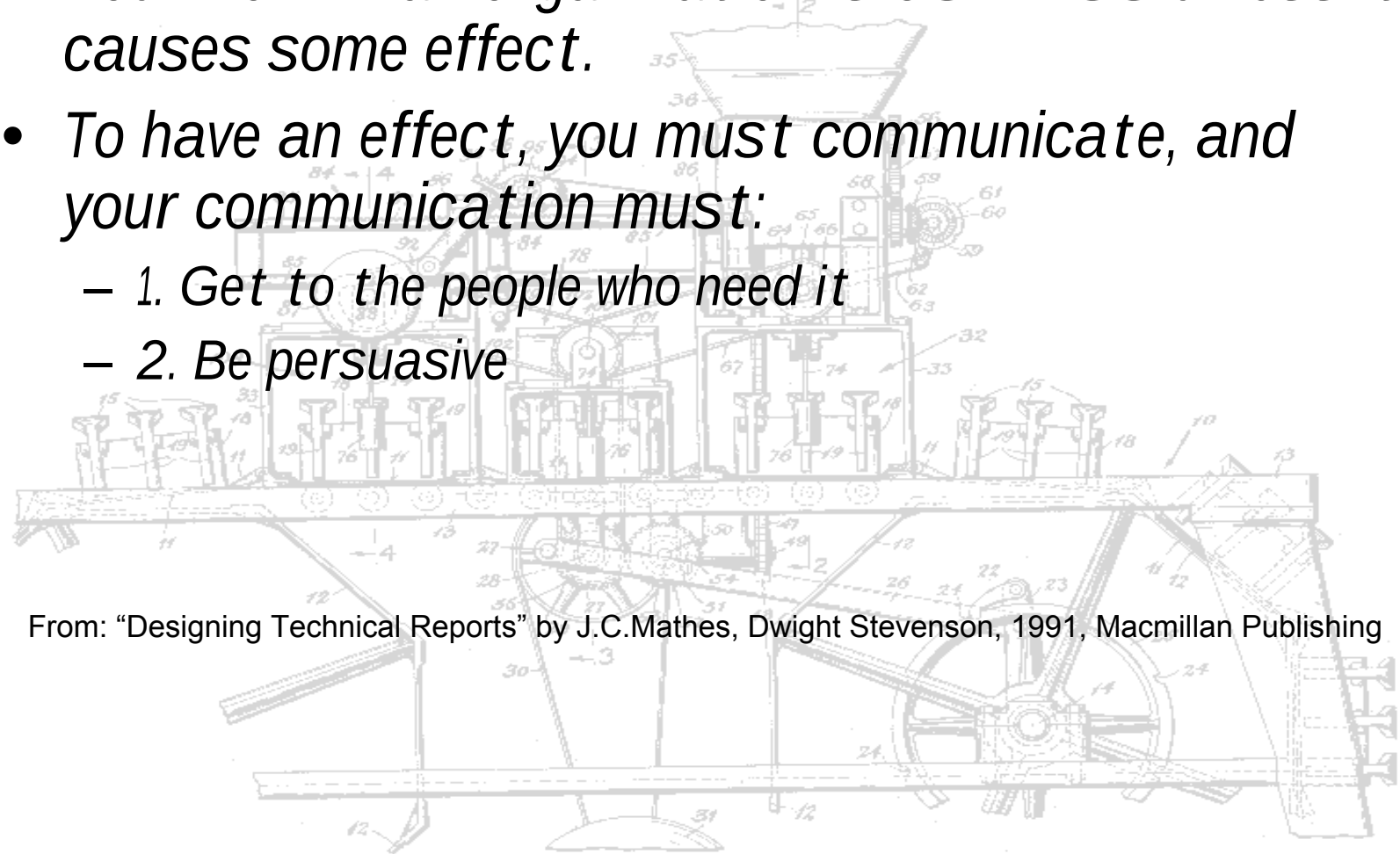
Manufacturing Operations

- *Processing*
  - *Shaping (solidification, deformation, material removal, or particulate processing)*
  - *Property Enhancement (heat treatment)*
  - *Surface Processing (cleaning, coating)*
- *Assembly*
  - *Permanent (welding, adhesive,rivets, presshit)*
  - *Reversible (threaded fasteners, friction fit)*



Designing Technical Reports

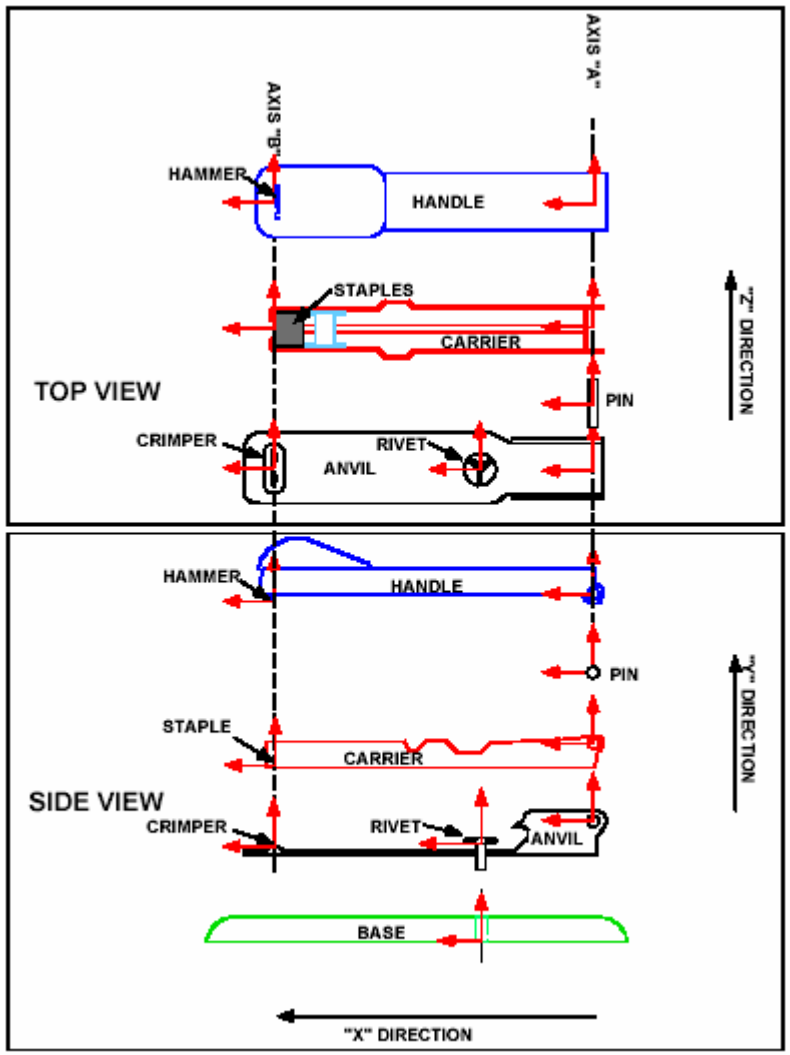
- *Your work in an organization is USELESS unless it causes some effect.*
- *To have an effect, you must communicate, and your communication must:*
  - *1. Get to the people who need it*
  - *2. Be persuasive*



From: “Designing Technical Reports” by J.C.Mathes, Dwight Stevenson, 1991, Macmillan Publishing

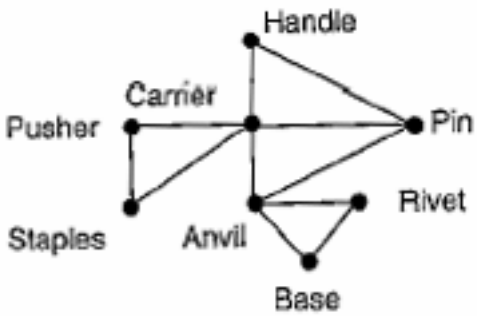
Analyzing the Product

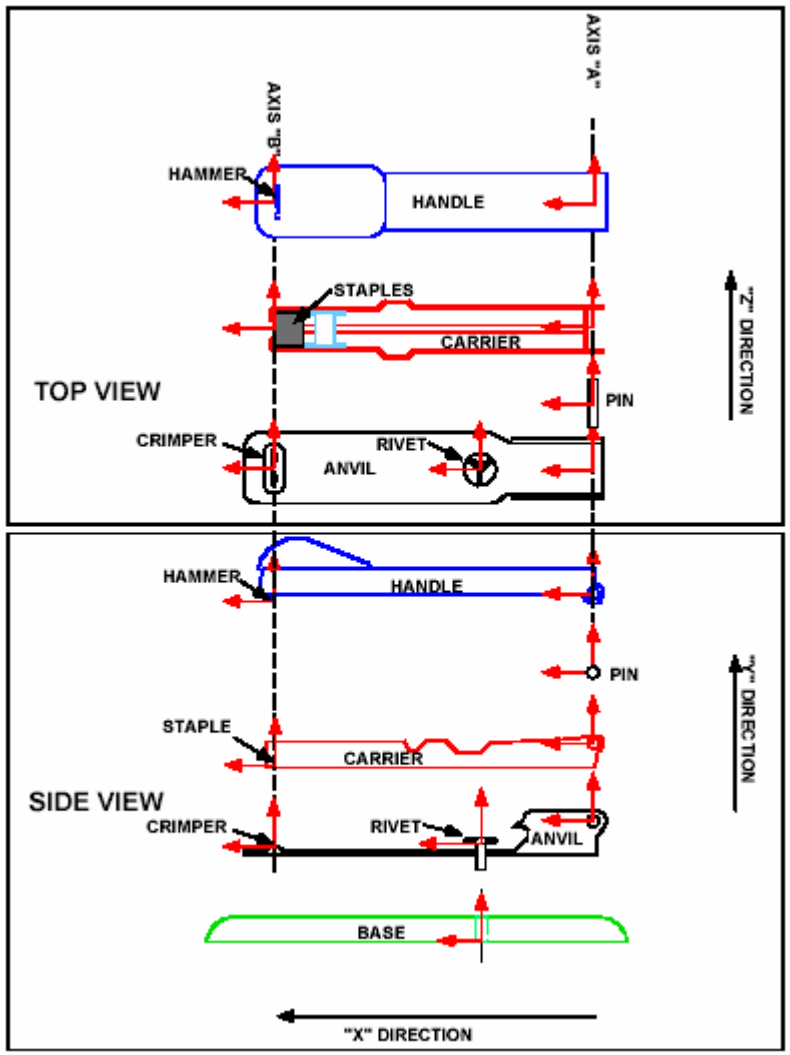
- *Stapler example:*



Analyzing the Stapler

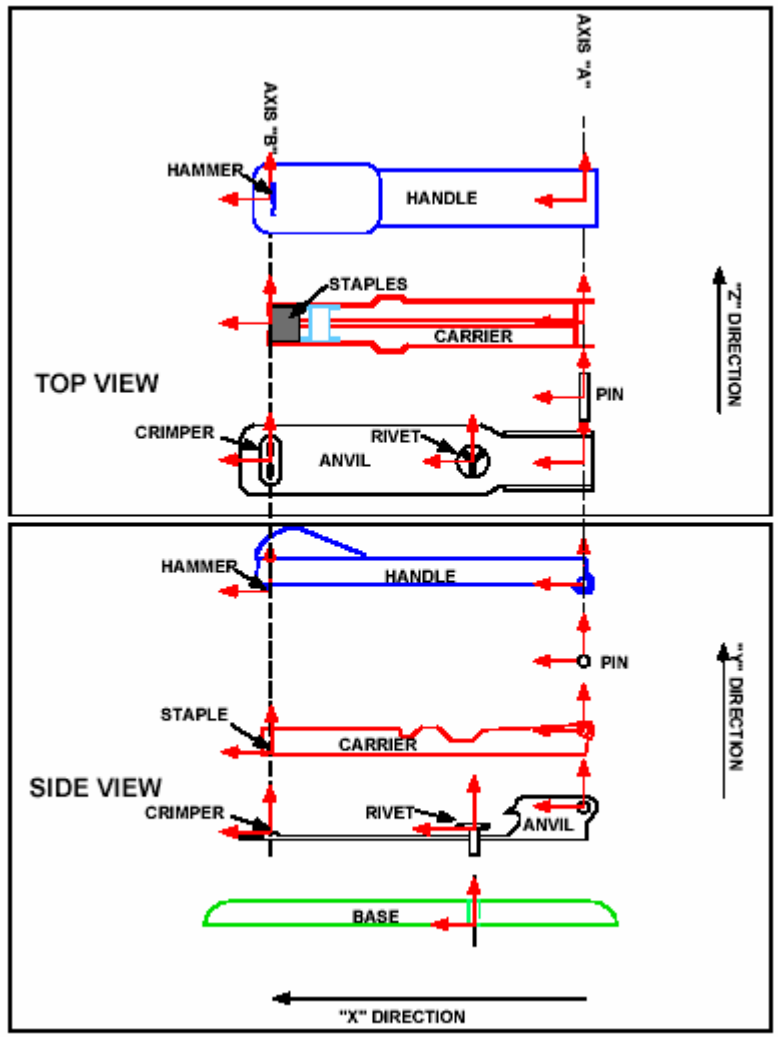
- *What would cause the stapler not to work?*
- *What is the "architecture" of the stapler? (how parts are laid out, functions, arrangement in space)*
- *Liaison Diagram (p.4)*



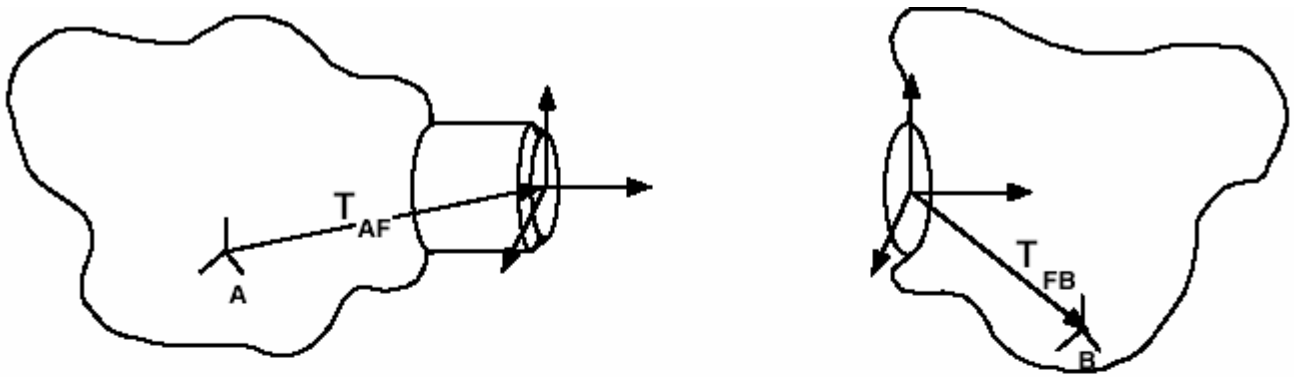


Mathematical Modeling of Assembly

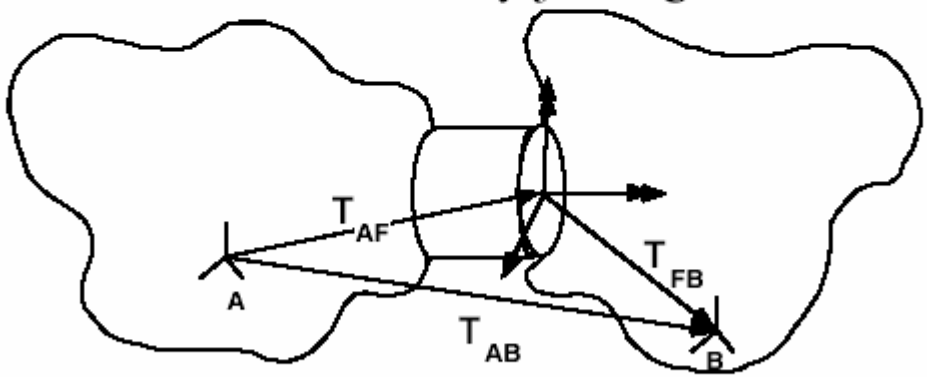
- *Coordinate frames*
  - *each part has a base coordinate frame*
- *Relationships between parts are expressed as 4x4 matrix transforms*



Nominal Mating of Parts

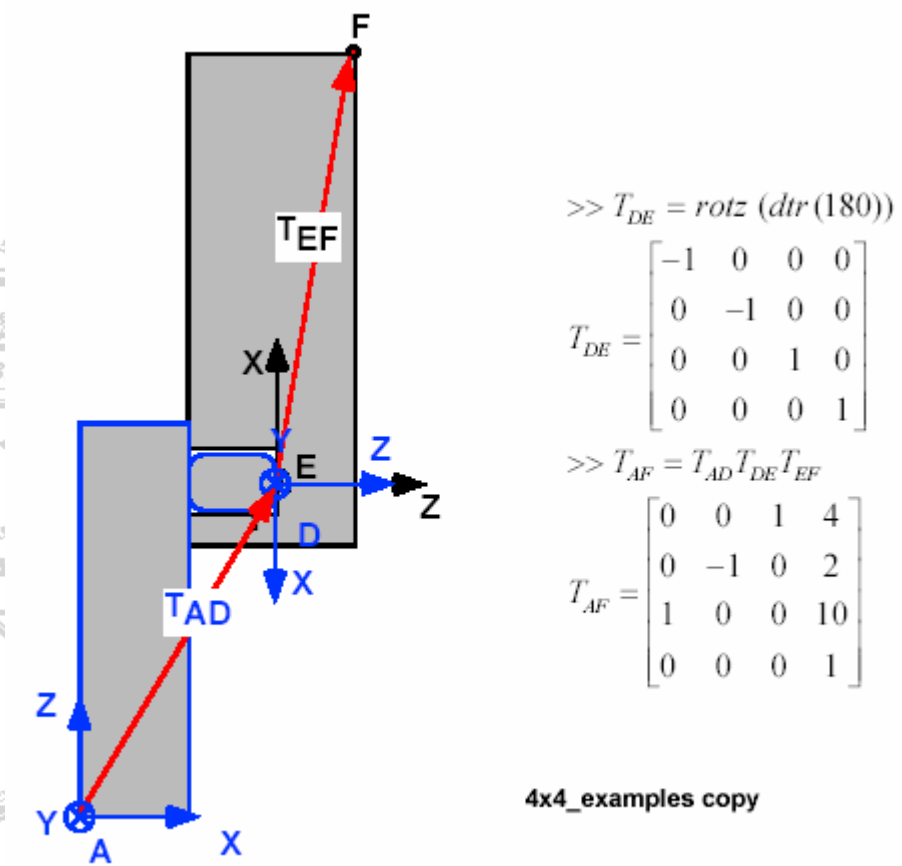


Parts A and B are mated by joining two features



The nominal location of part B can be calculated from the nominal location of part A using 4x4 transform math

Example - Pin & Hole Mating (Assembling two parts)



$$>> T_{DE} = rotz\ (dtr\,(180))$$

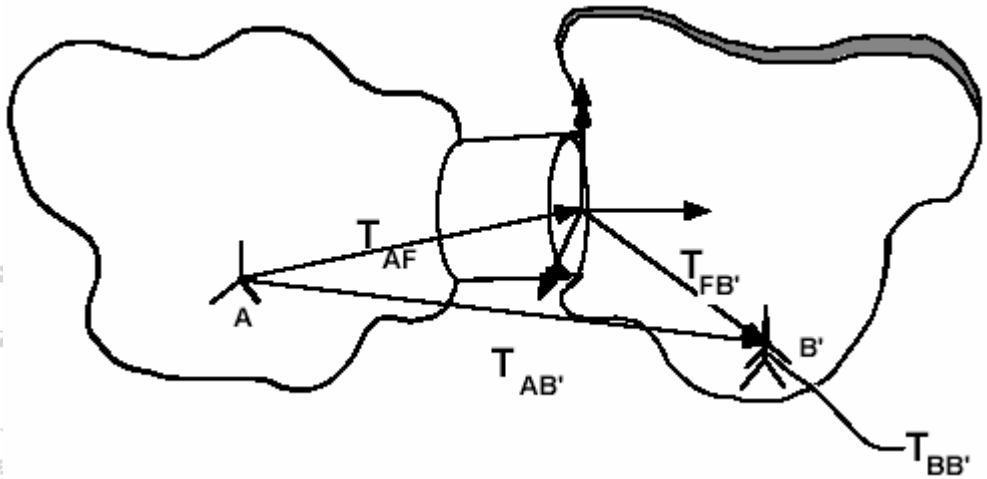
$$T_{DE} = \begin{bmatrix} -1 & 0 & 0 & 0 \\ 0 & -1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$>> T_{AF} = T_{AD} T_{DE} T_{EF}$$

$$T_{AF} = \begin{bmatrix} 0 & 0 & 1 & 4 \\ 0 & -1 & 0 & 2 \\ 1 & 0 & 0 & 10 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

4x4_examples copy

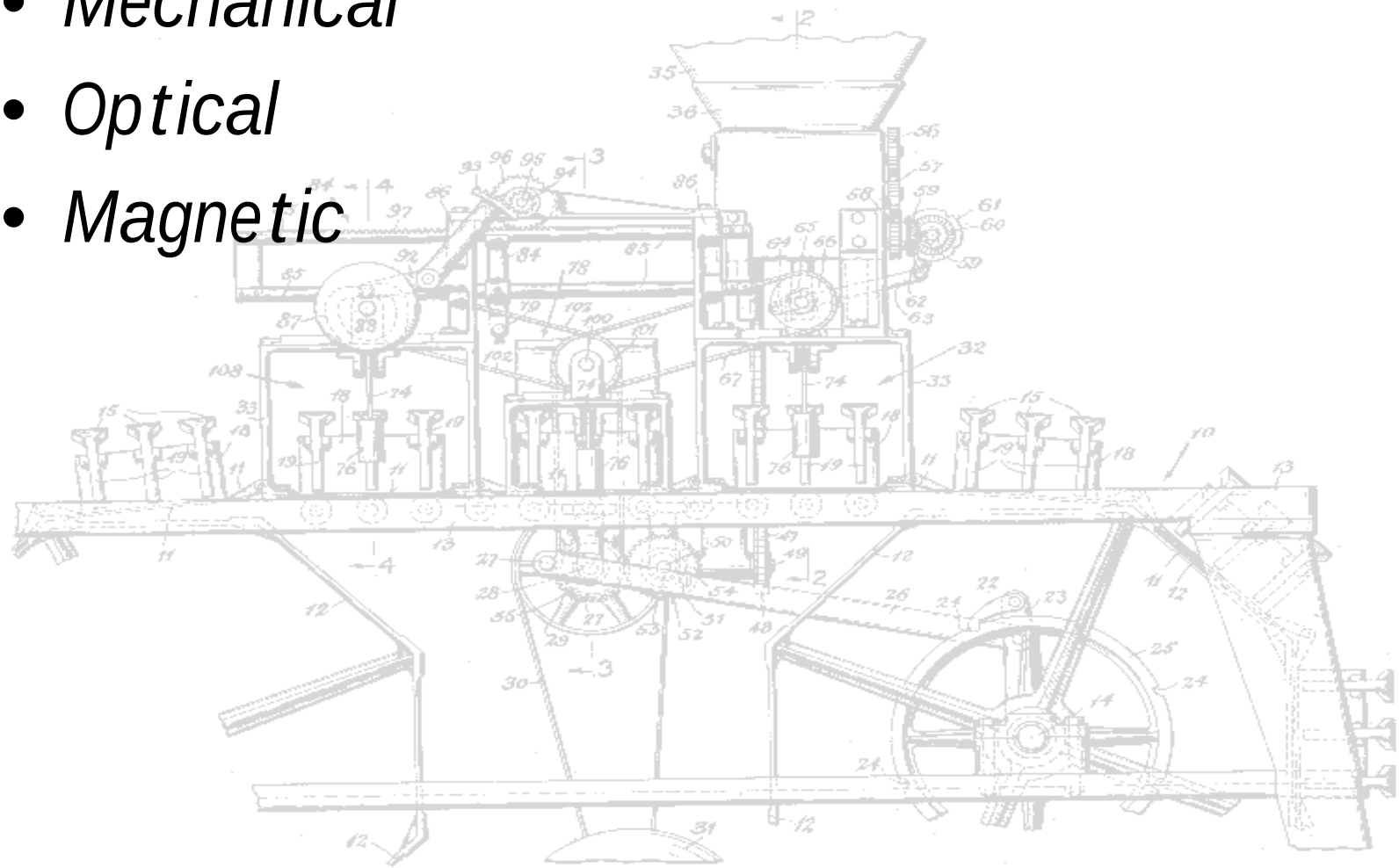
Part Location Variation



- *Varied location of Part B calculated from nominal location of Part A*
- *Uses same math as nominal model!*

Position Sensing

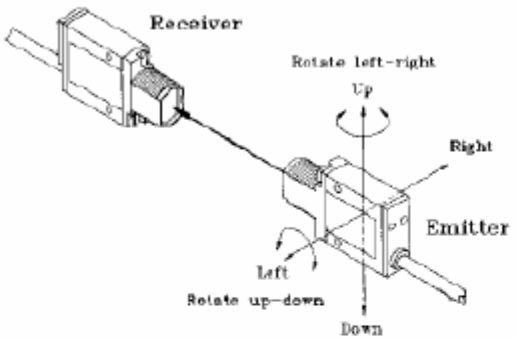
- *Mechanical*
- *Optical*
- *Magnetic*



Transmissive & Reflective Sensors

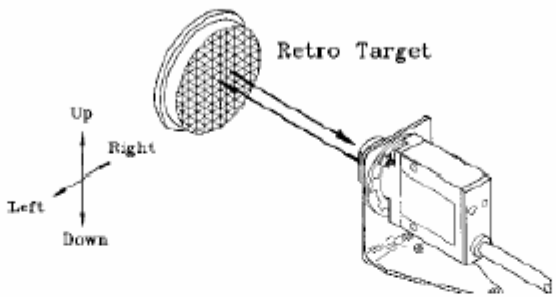
Opposed Mode Alignment

Opposed Mode Alignment: Move Emitter or Receiver Up-Down, Left-Right, and Rotate



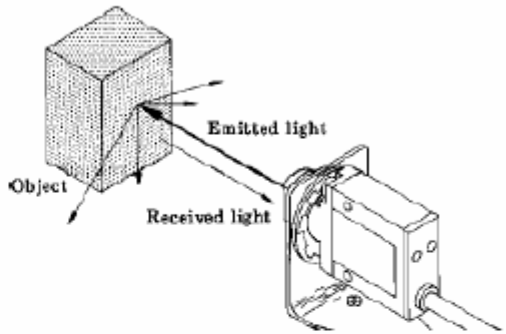
Retroreflective Mode Alignment

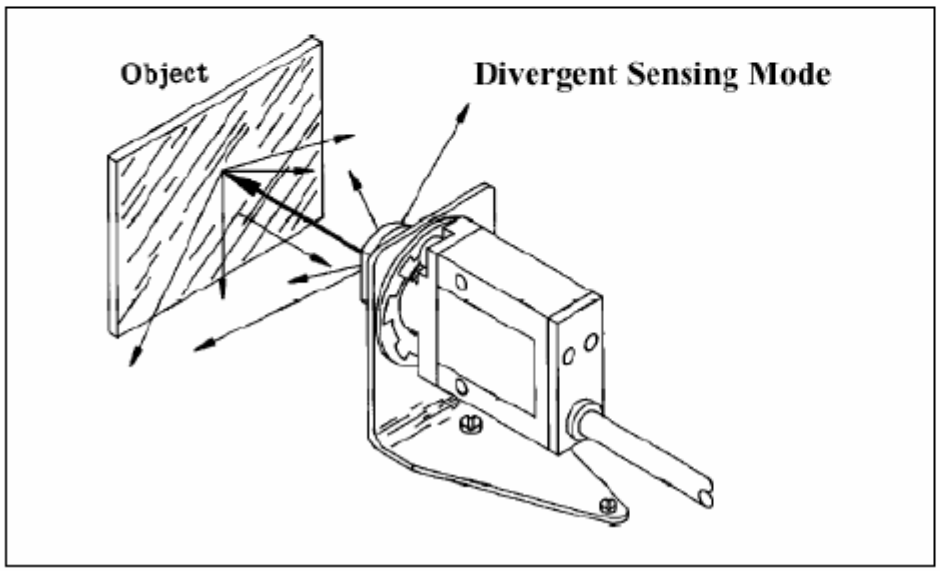
Retroreflective Mode Alignment:
Move Target Up-Down, Left-Right



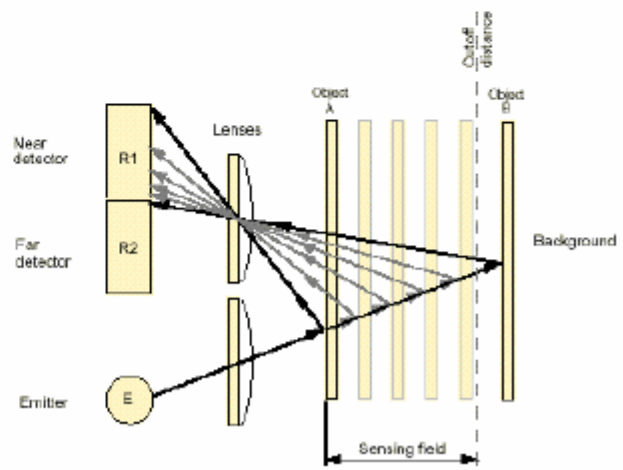
Proximity (Diffuse) Mode Alignment

Diffuse Mode Alignment:
Rotate Up-Down, Left-Right



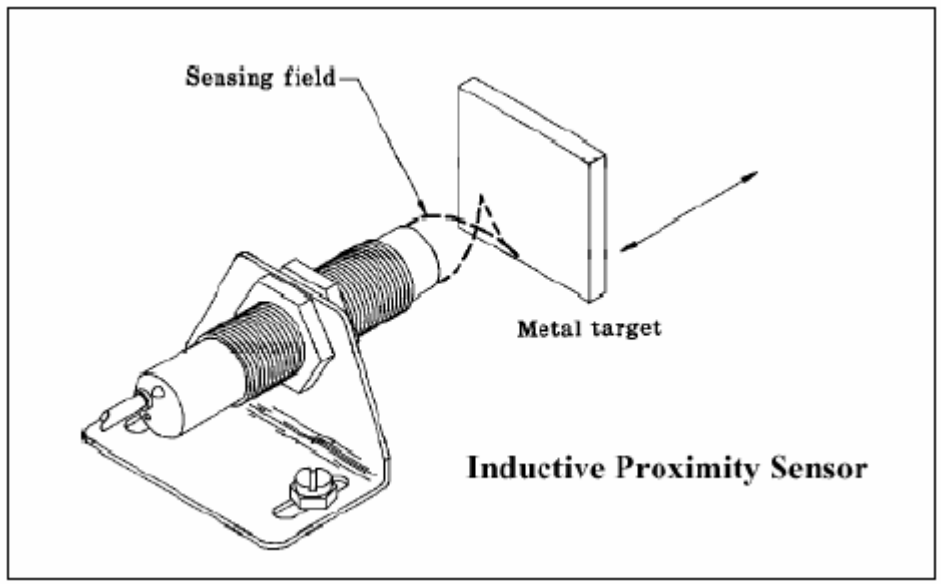


Fixed-field Diffuse Sensing

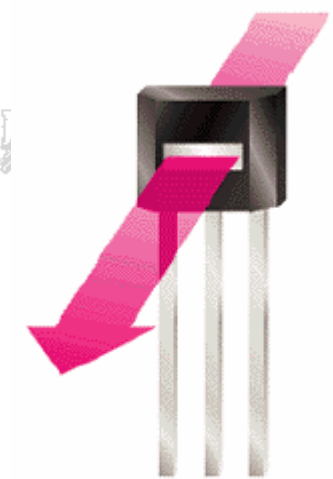


Object is sensed if amount of light at R1 is greater than the amount of light at R2

Inductive Proximity Sensor

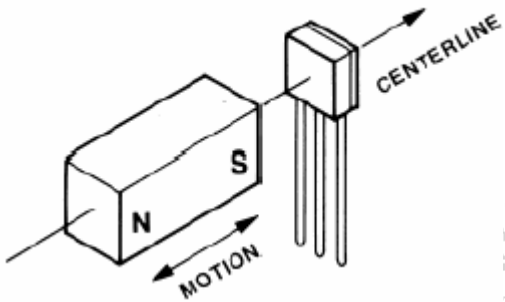


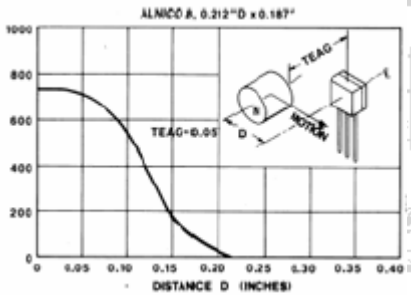
Hall Sensors



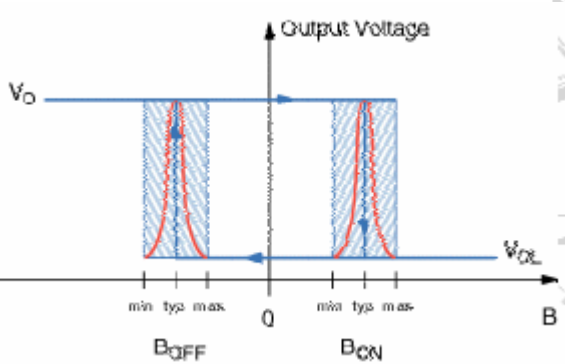
- *Hall effect:*
  - *constant voltage forces a constant current in semiconductor sheet*
  - *magnetic field flux lines perpendicular to current cause proportional voltage across sheet.*
  - *discovered by E.F.Hall in 1879*
- *Linear sensor needs voltage regulator and amplifier*
- *Switch also needs threshold circuit, with hysteresis*

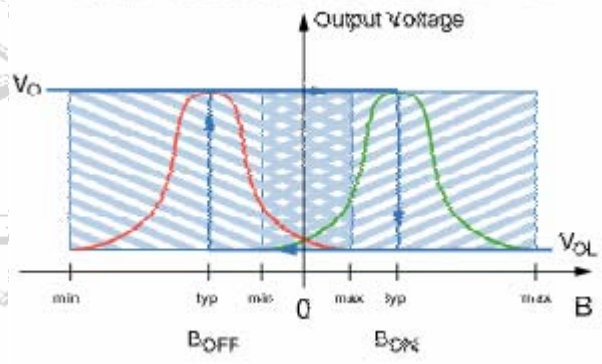
Hall Switch

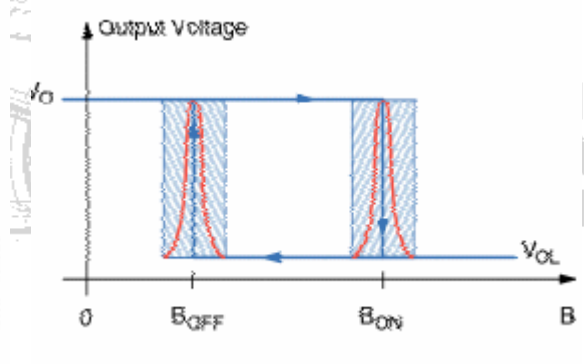




- *Magnet motion*
  - *head-on*
  - *bypass or slide-by*
- *Total effective air gap (TEAG)*
- *Sensitivity, Hysteresis, & Temperature*

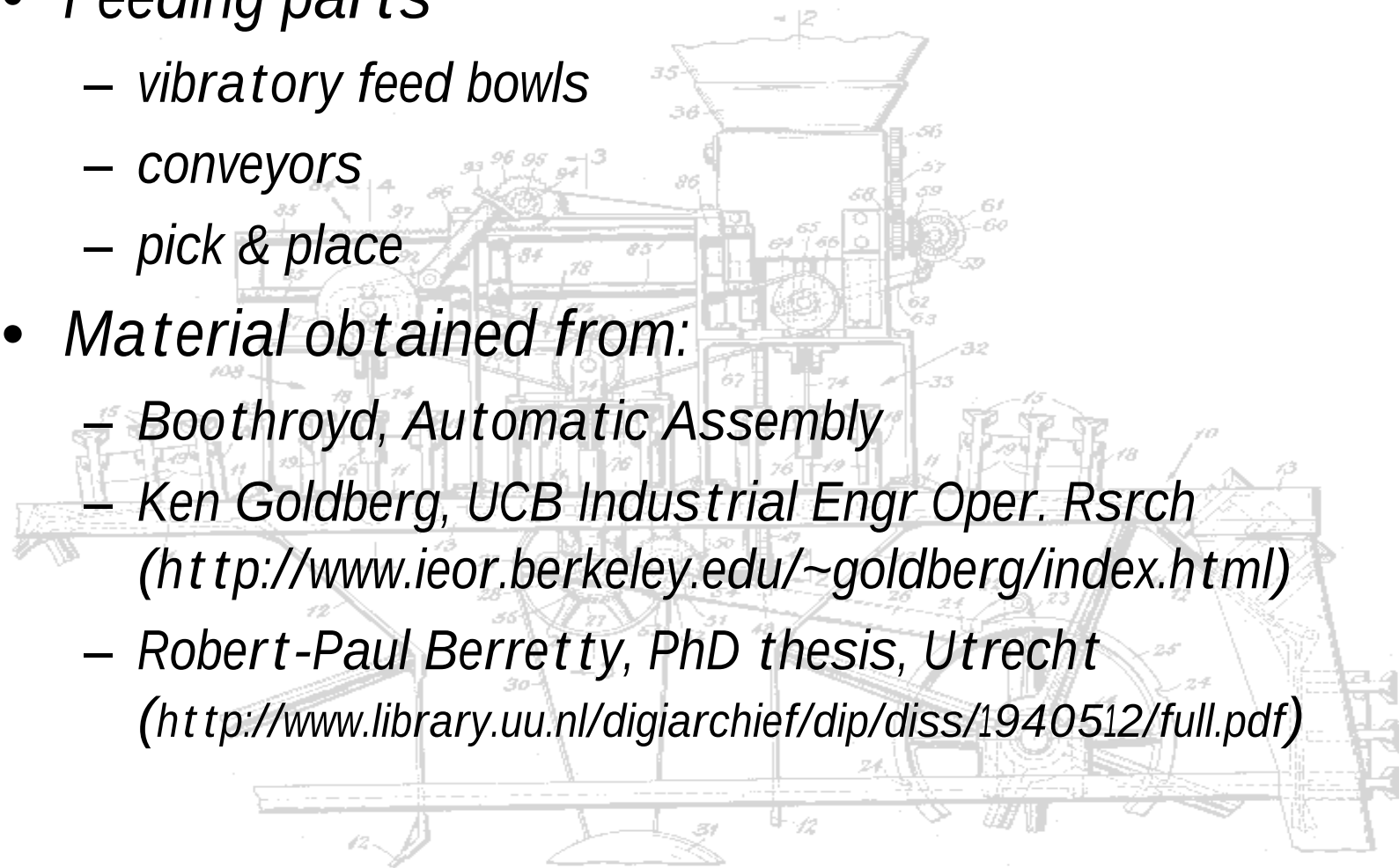






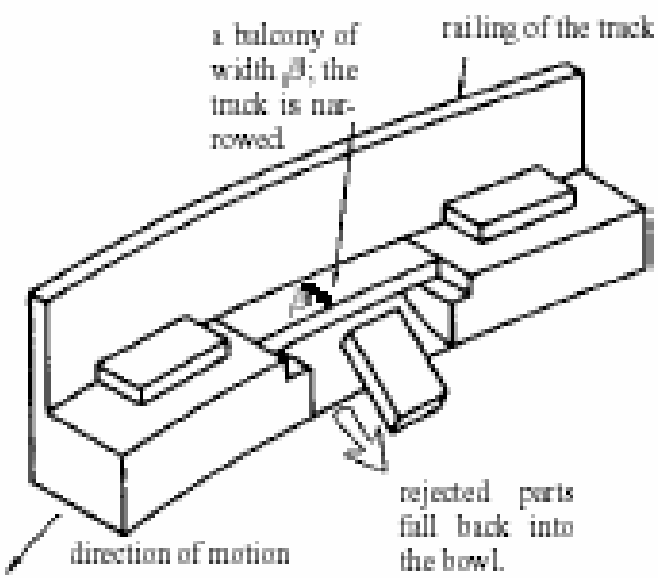
Care & Feeding of Machines

- *Feeding parts*
  - *vibratory feed bowls*
  - *conveyors*
  - *pick & place*
- *Material obtained from:*
  - *Boothroyd, Automatic Assembly*
  - *Ken Goldberg, UCB Industrial Engr Oper. Rsrch (http://www.ieor.berkeley.edu/~goldberg/index.html)*
  - *Robert-Paul Berretty, PhD thesis, Utrecht (http://www.library.uu.nl/digiarchief/dip/diss/1940512/full.pdf)*



Bowl Feeders

Bowl Feeders - Trap Design



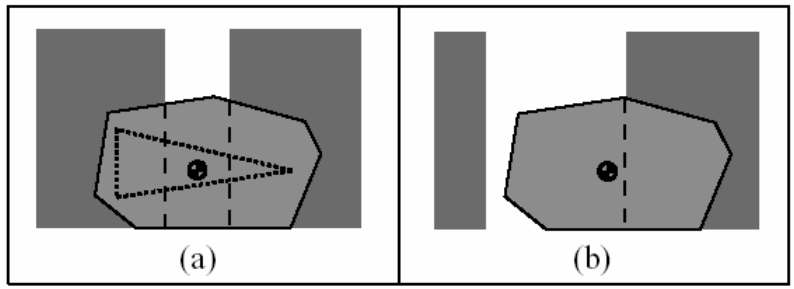


Figure 2: (a) A safe pose. The triangle is evidence of safeness. (b) An unsafe pose of the same part above a different trap.

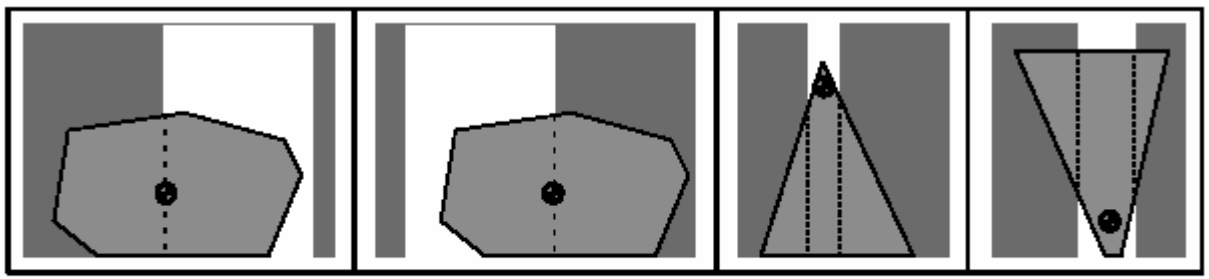


Figure 4: The types of rejected poses.

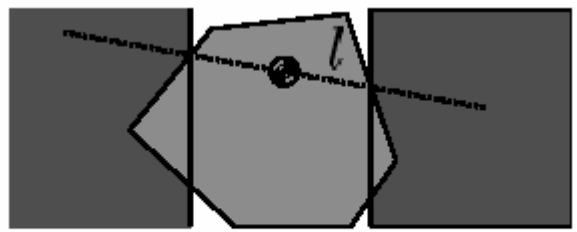
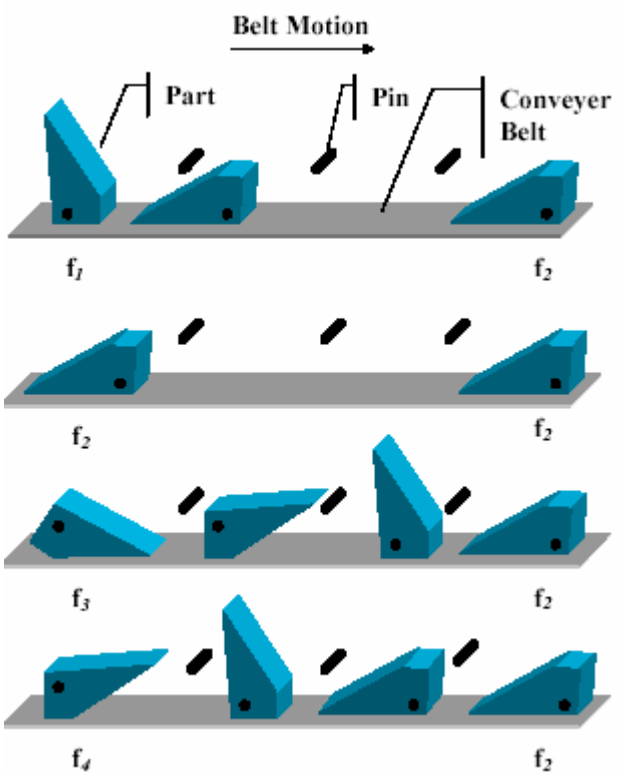
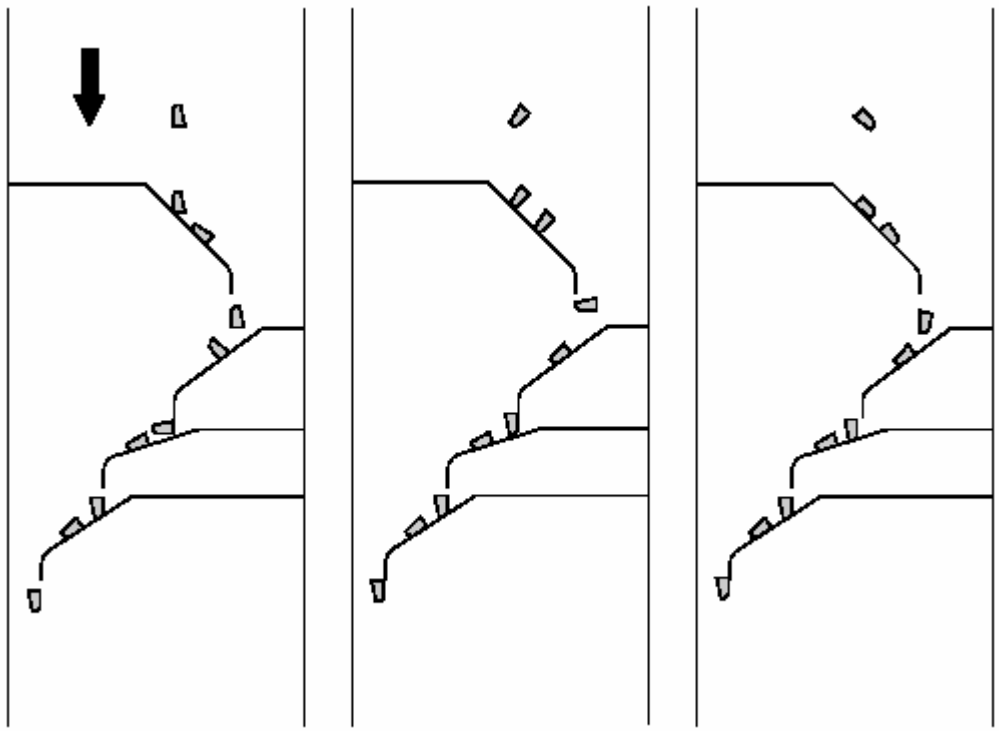


Figure 5: A critical pose.

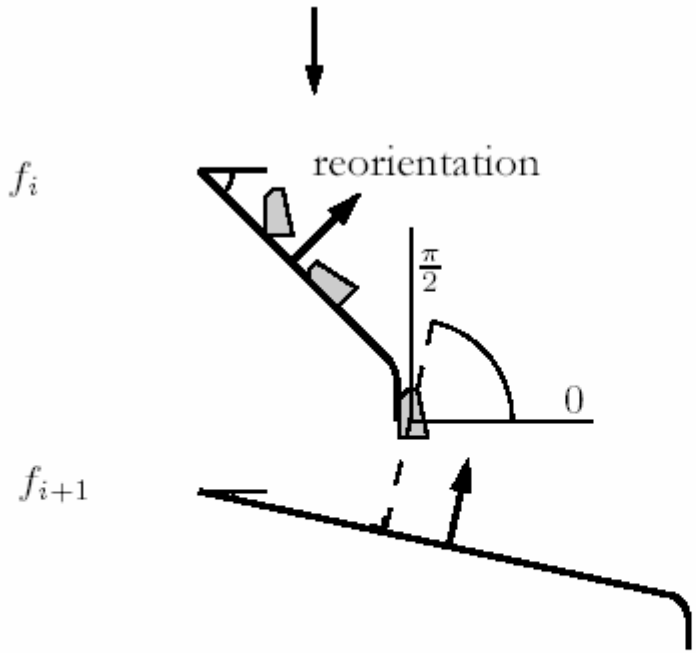
Conveyors





- *Orienting with pins or fences*

Conveyor part orientation - fences



(a)

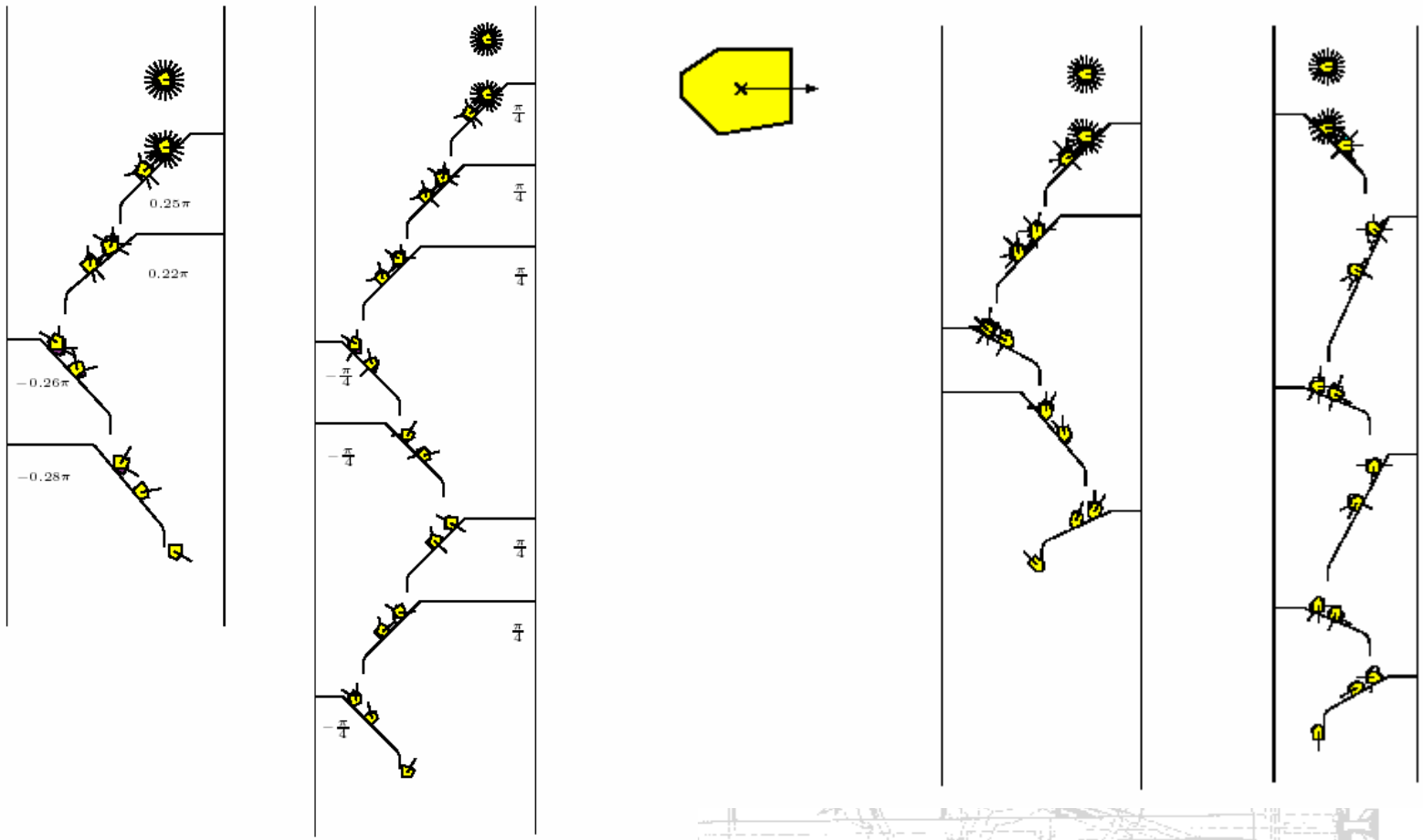
t_i	α_{i+1}	t_{i+1}
left	$(0, \pi/2)$	left
left	$(\pi/2, \pi)$	right
right	$(-\pi, -\pi/2)$	left
right	$(-\pi/2, 0)$	right

(b)

Figure 3.2 (a) For two successive left fences, the reorientation of the push direction lies in the range $(0, \pi/2)$. (b) The ranges op possible reorientations of the push direction for all pairs of fence types.

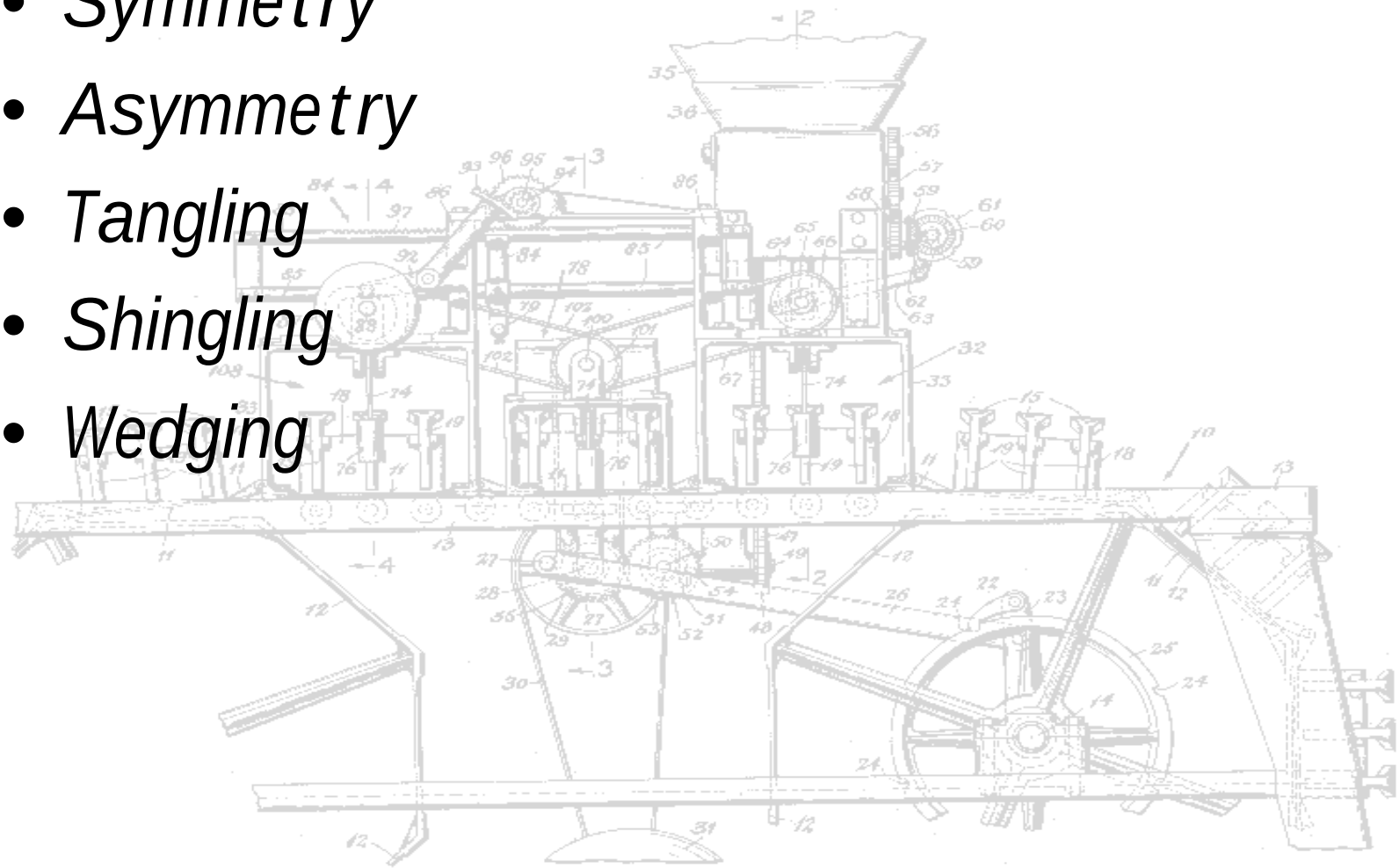
- *Any polygonal part can be oriented up to symmetry by a fence design*

Conveyor part orientation - fences



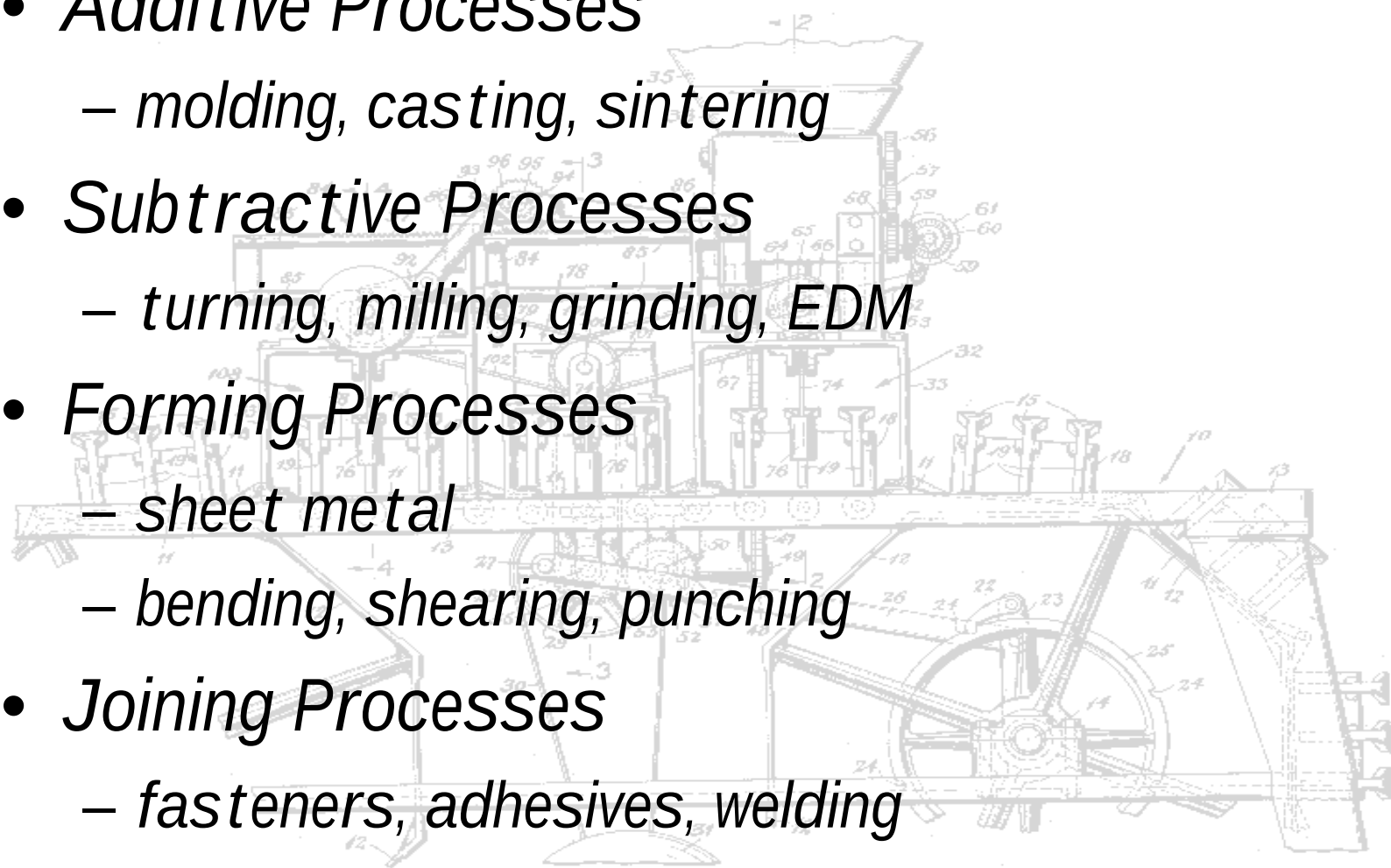
Designing Parts for Feeding

- *Symmetry*
- *Asymmetry*
- *Tangling*
- *Shingling*
- *Wedging*



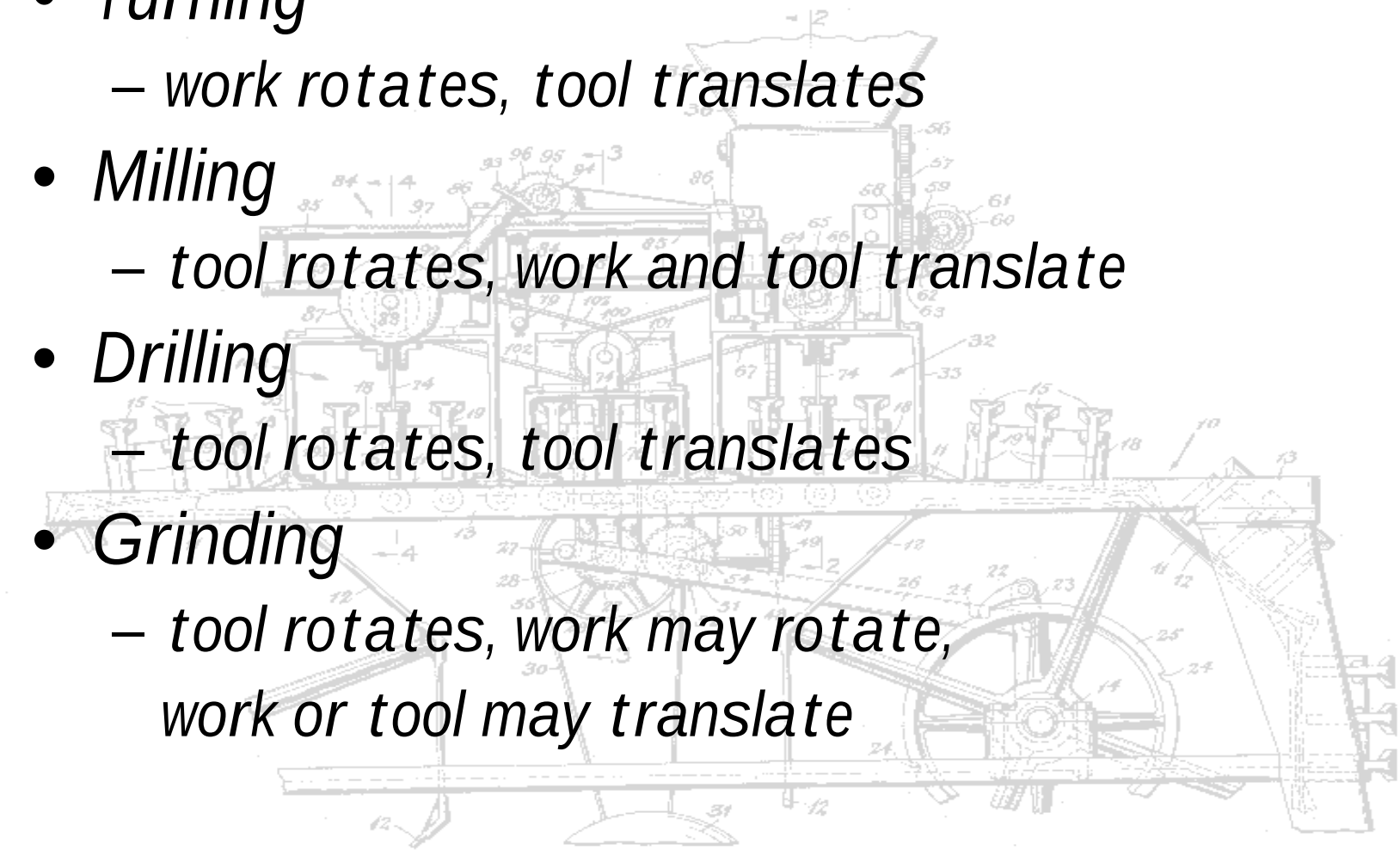
Part Fabrication

- *Additive Processes*
  - *molding, casting, sintering*
- *Subtractive Processes*
  - *turning, milling, grinding, EDM*
- *Forming Processes*
  - *sheet metal*
  - *bending, shearing, punching*
- *Joining Processes*
  - *fasteners, adhesives, welding*

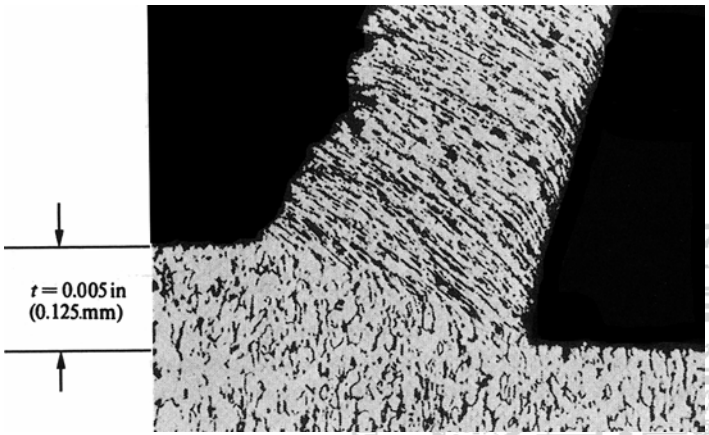


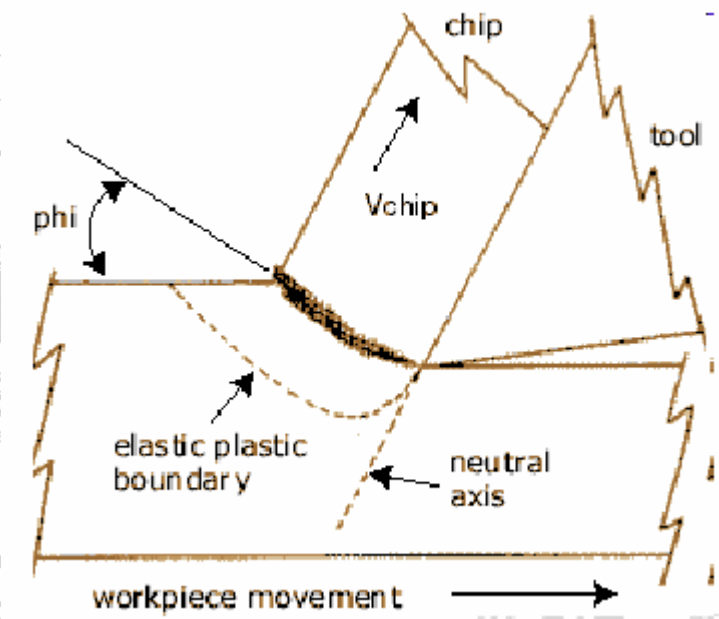
Material Removal Processes

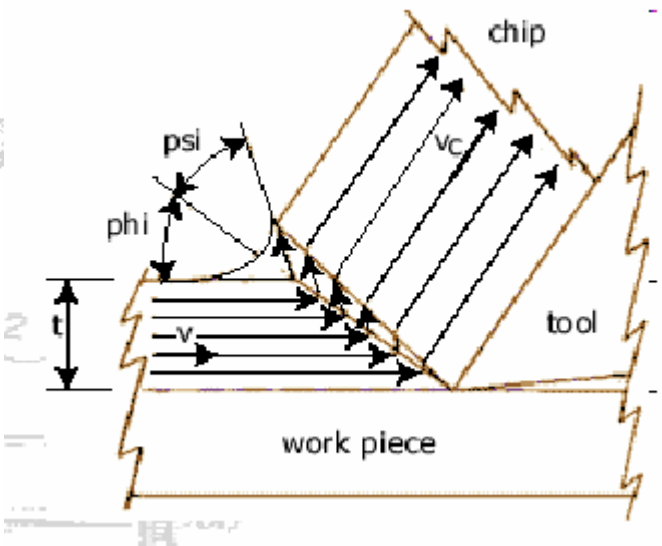
- *Turning*
  - *work rotates, tool translates*
- *Milling*
  - *tool rotates, work and tool translate*
- *Drilling*
  - *tool rotates, tool translates*
- *Grinding*
  - *tool rotates, work may rotate, work or tool may translate*



Chip Formation

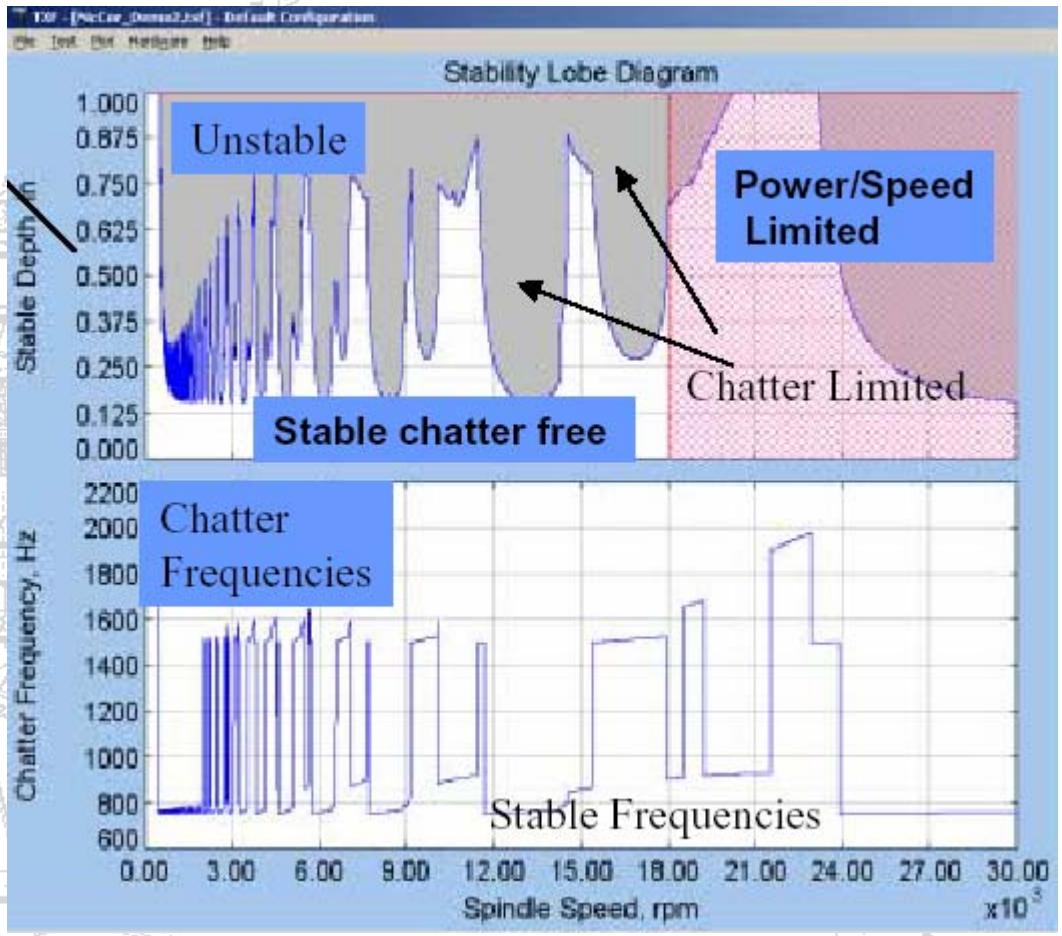






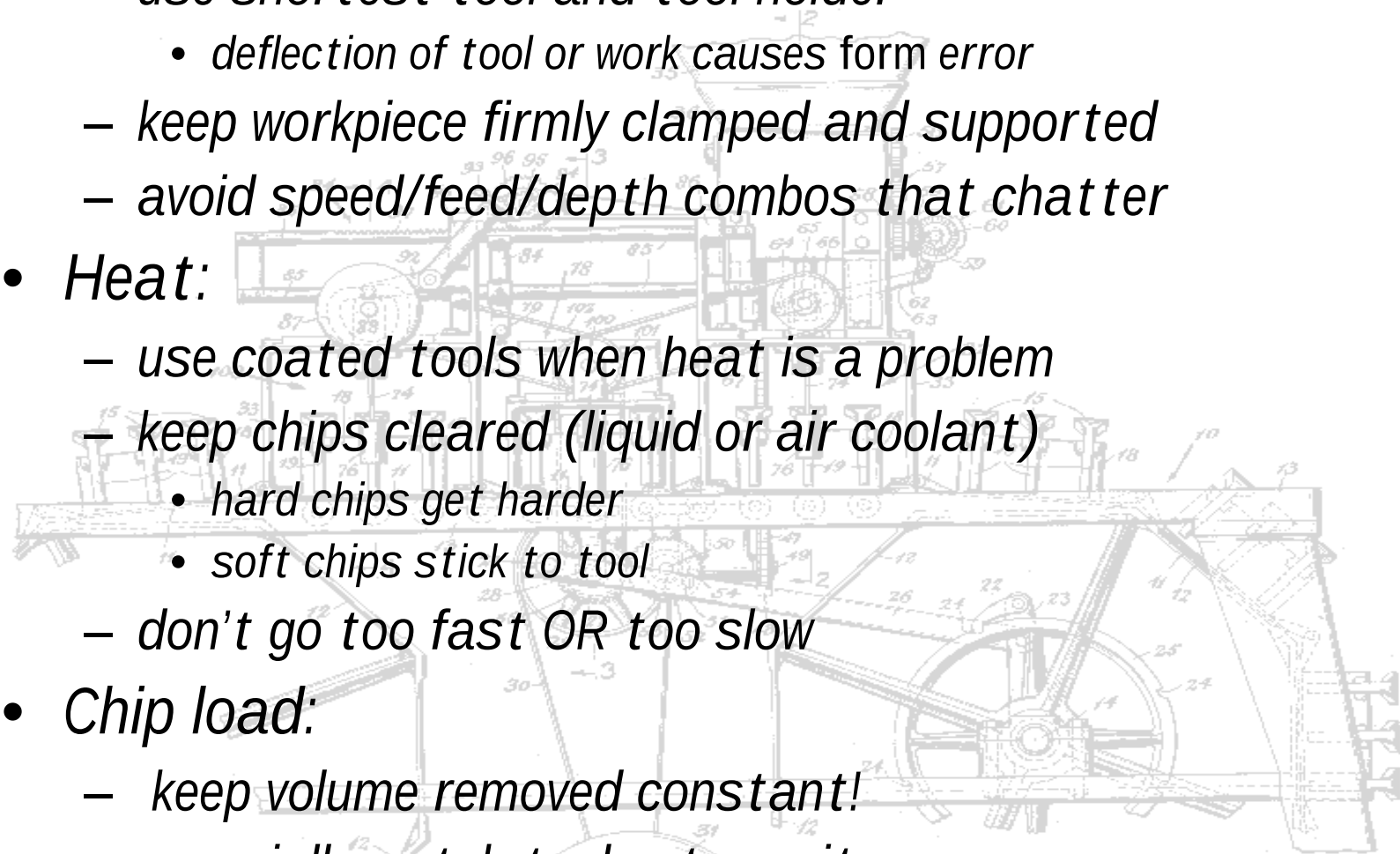
Vibration

- *For Max Material Removal Rate:*
  - *Choose highest spindle RPM*
  - *Tune tool length to stay in a stable lobe at top spindle RPM*



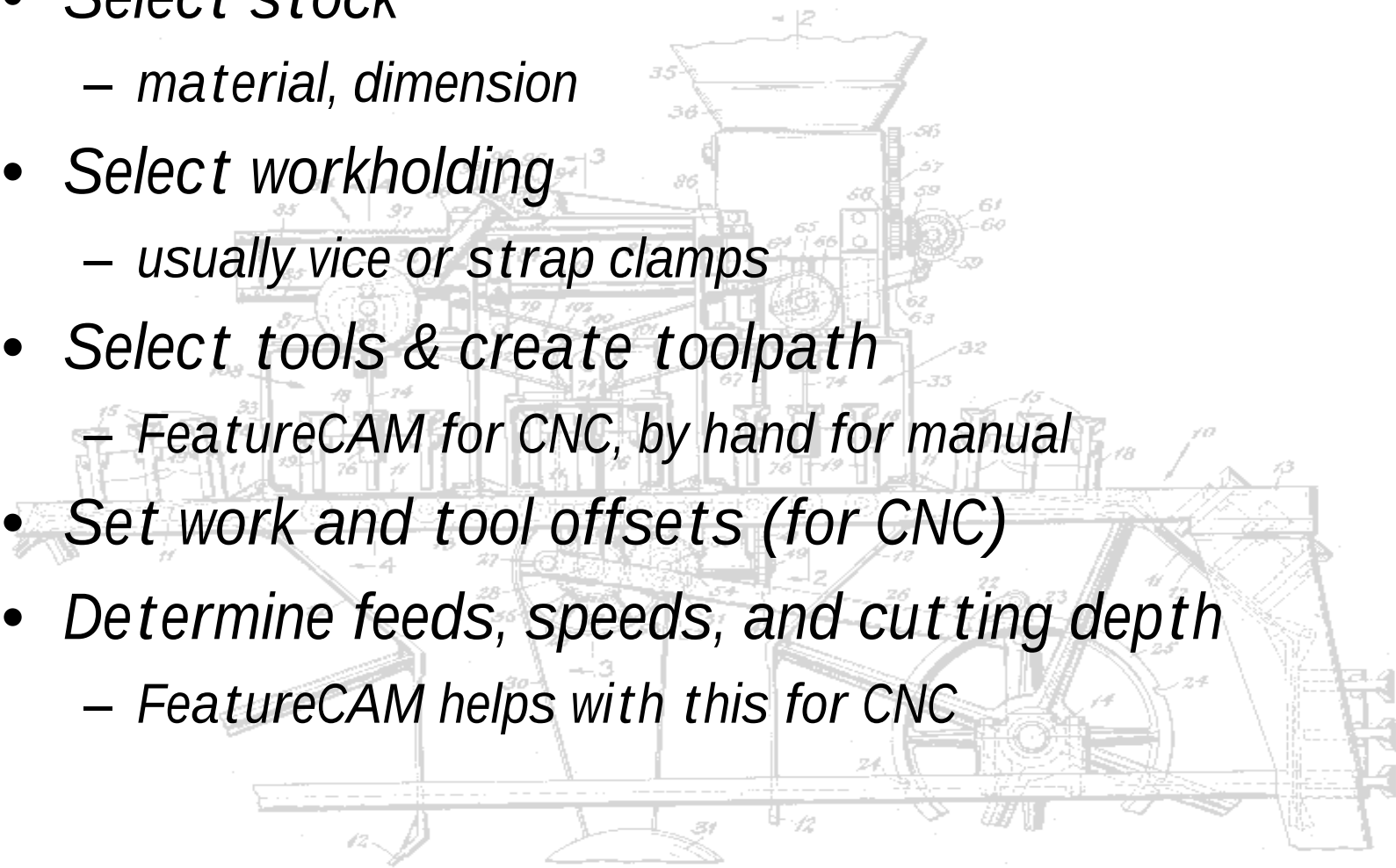
Process

- *Rigidity:*
  - *use shortest tool and tool holder*
    - *deflection of tool or work causes* form *error*
  - *keep workpiece firmly clamped and supported*
  - *avoid speed/feed/depth combos that chatter*
- *Heat:*
  - *use coated tools when heat is a problem*
  - *keep chips cleared (liquid or air coolant)*
    - *hard chips get harder*
    - *soft chips stick to tool*
  - *don't go too fast OR too slow*
- *Chip load:*
  - *keep volume removed constant!*
  - *especially watch tool entry, exit, corners*



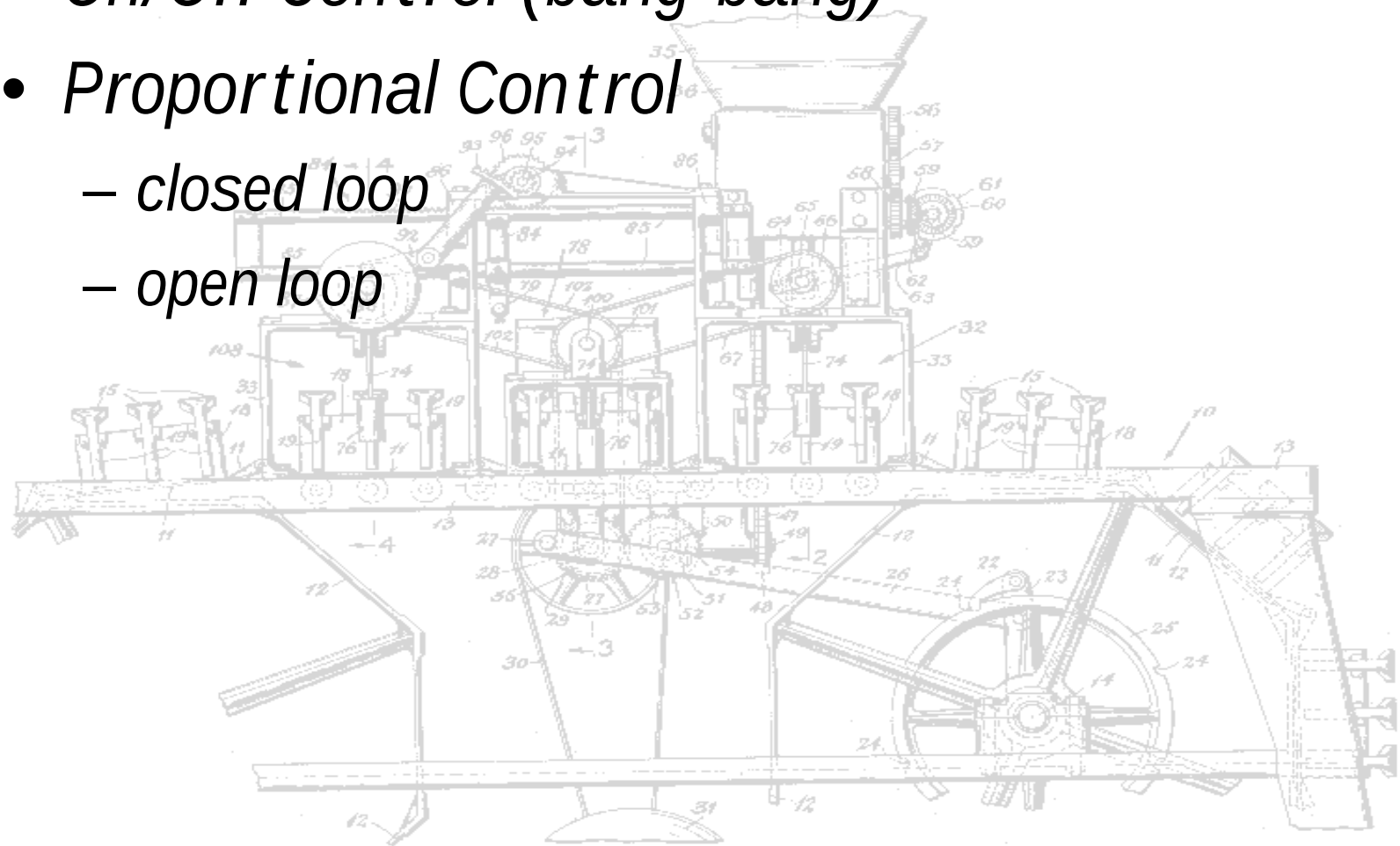
Doing Vertical Milling

- *Select stock*
  - *material, dimension*
- *Select workholding*
  - *usually vice or strap clamps*
- *Select tools & create toolpath*
  - *FeatureCAM for CNC, by hand for manual*
- *Set work and tool offsets (for CNC)*
- *Determine feeds, speeds, and cutting depth*
  - *FeatureCAM helps with this for CNC*



Control of Motion

- *On/Off Control (bang-bang)*
- *Proportional Control*
  - *closed loop*
  - *open loop*



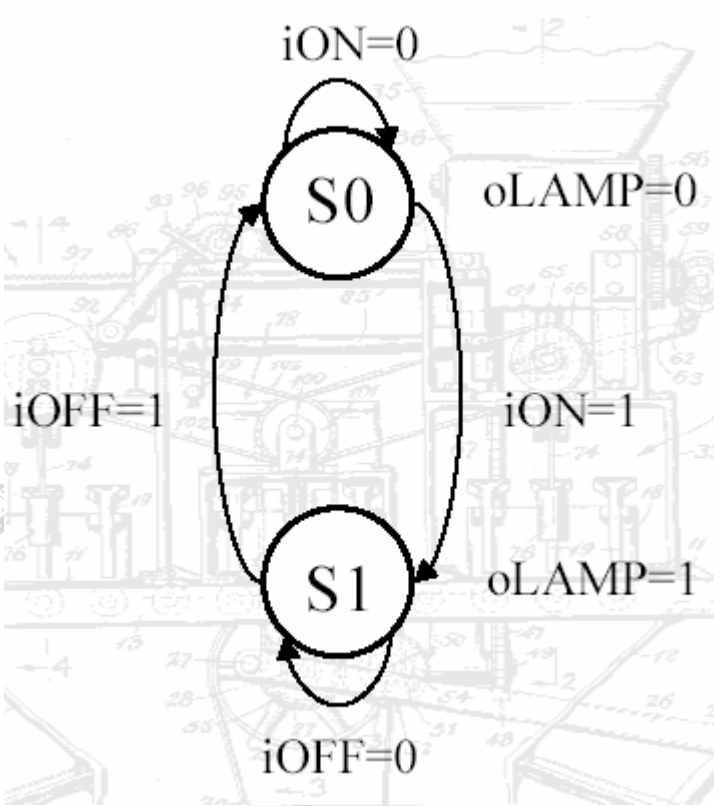
Digital Logic Expressions

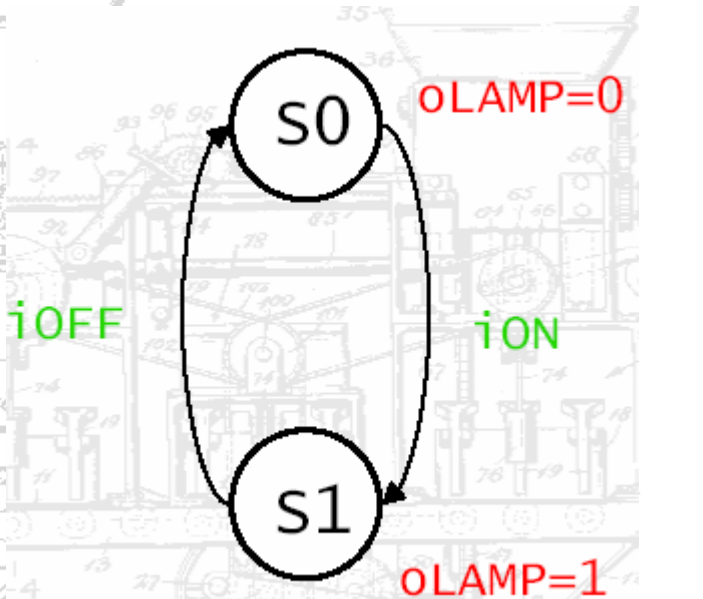
$$oCUT = (iPARTRDY \cdot iCYLRETRACT + oCUT \cdot /iCYLEXTEND) \cdot /iESTOP$$

$$oCUT = iPARTRDY \cdot iCYLRETRACT \cdot /iESTOP + oCUT \cdot /iCYLEXTEND \cdot /iESTOP$$

- *When part is ready, cylinder is retracted, and emergency stop is not on, then cut while cylinder is not fully extended and emergency stop is not on.*

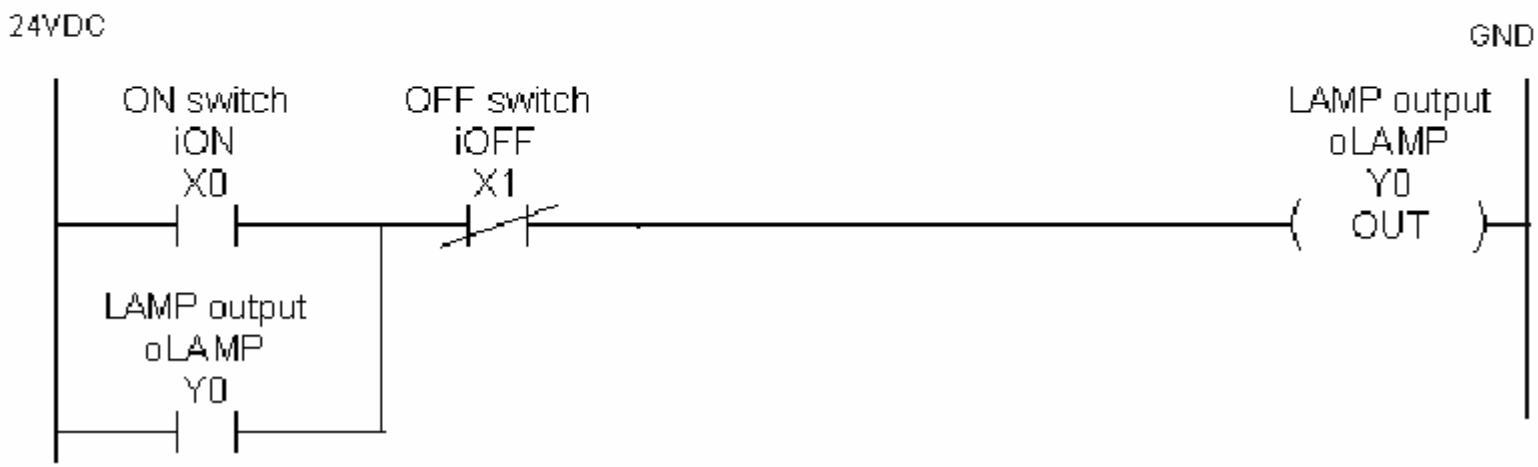
State Diagram



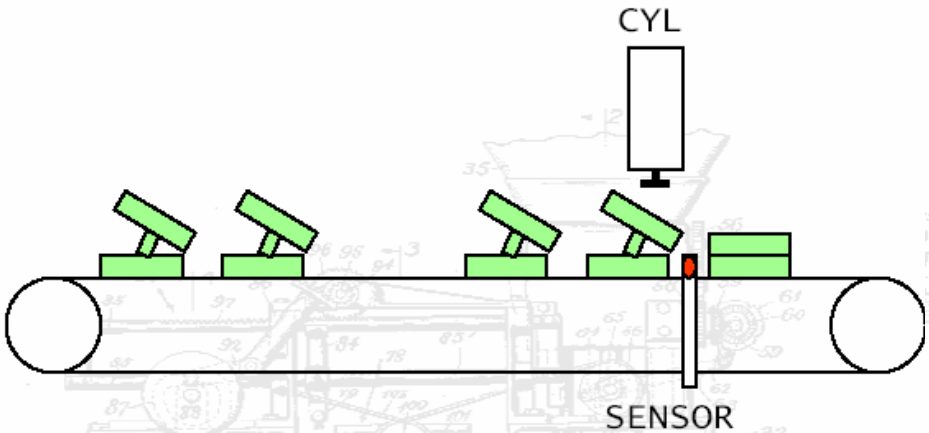


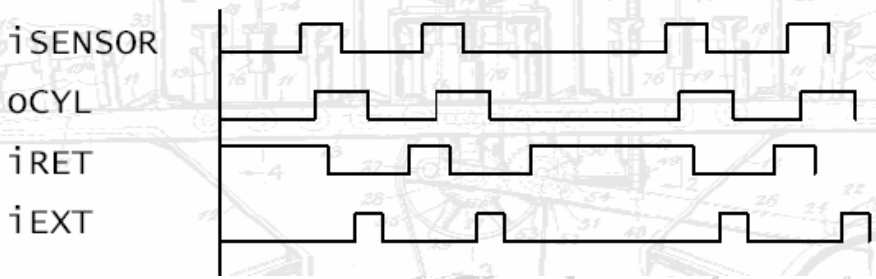
Logic Equation and Ladder Diagram

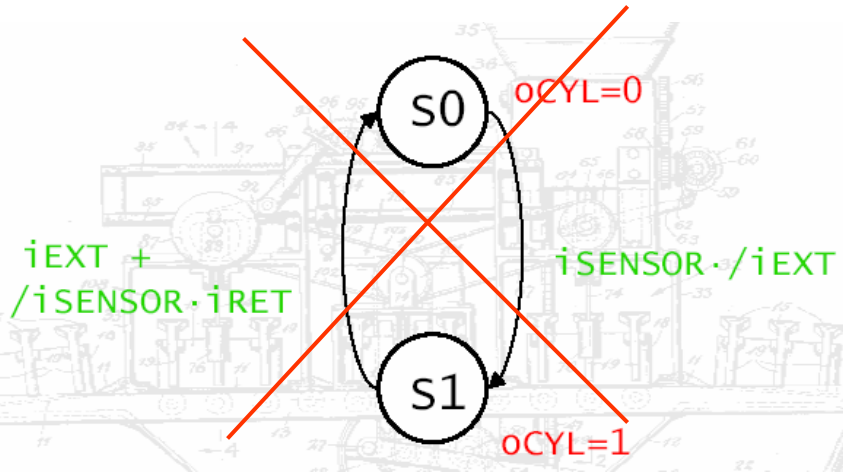
$$oLAMP = /iOFF \bullet (iON + oLAMP)$$

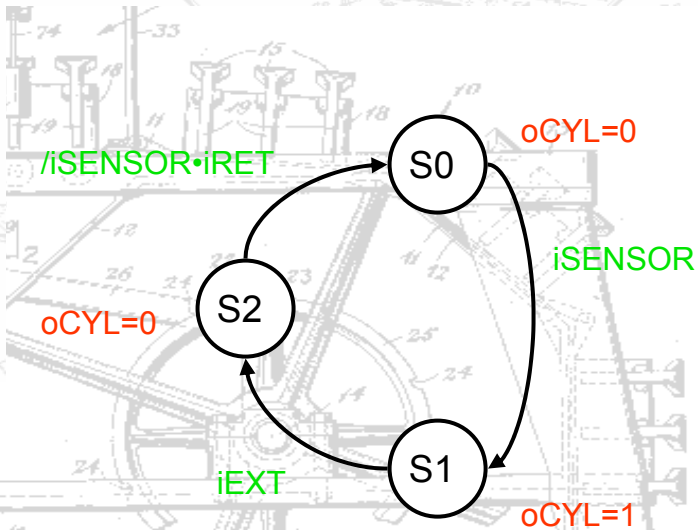


Second Example Revisited



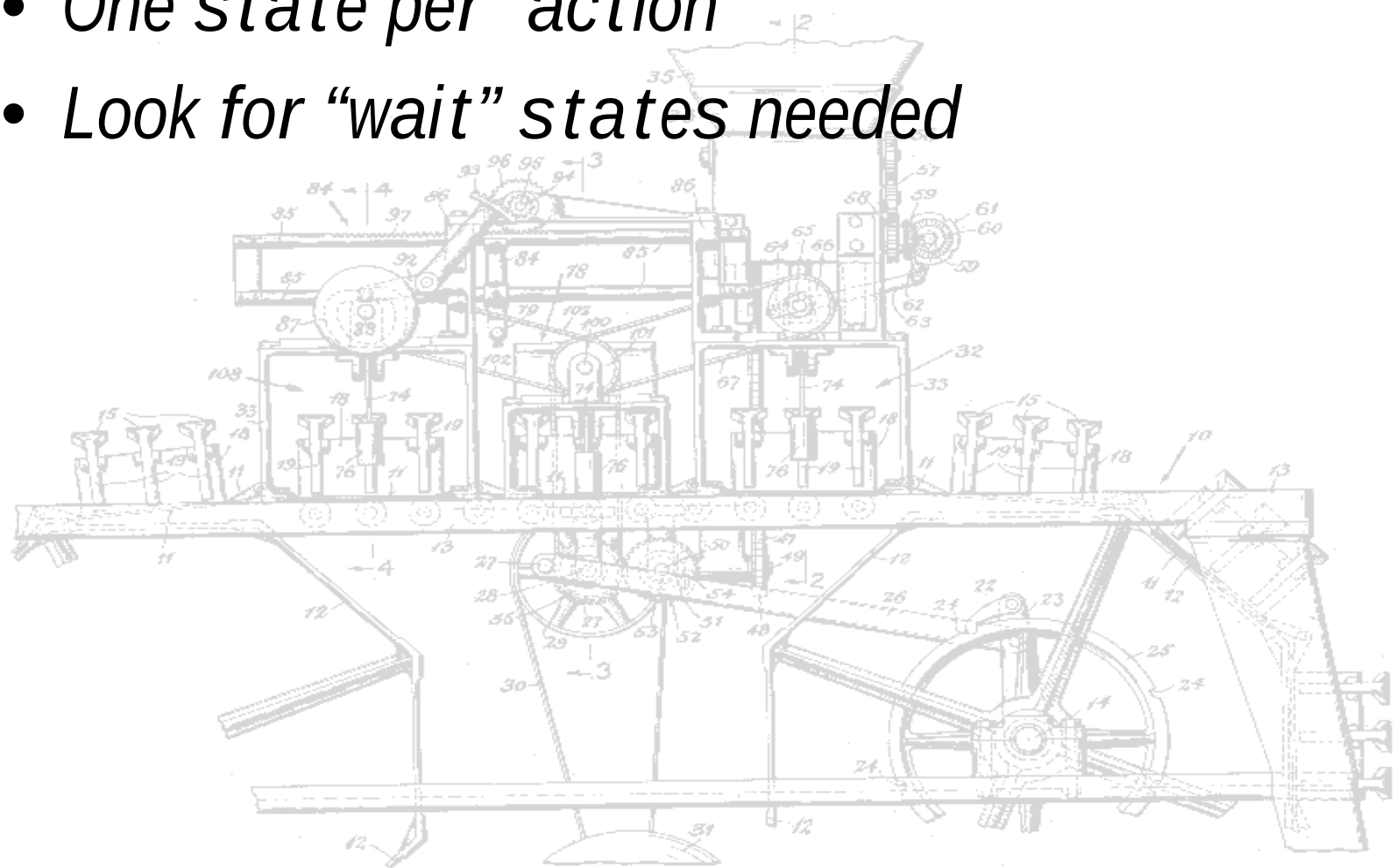




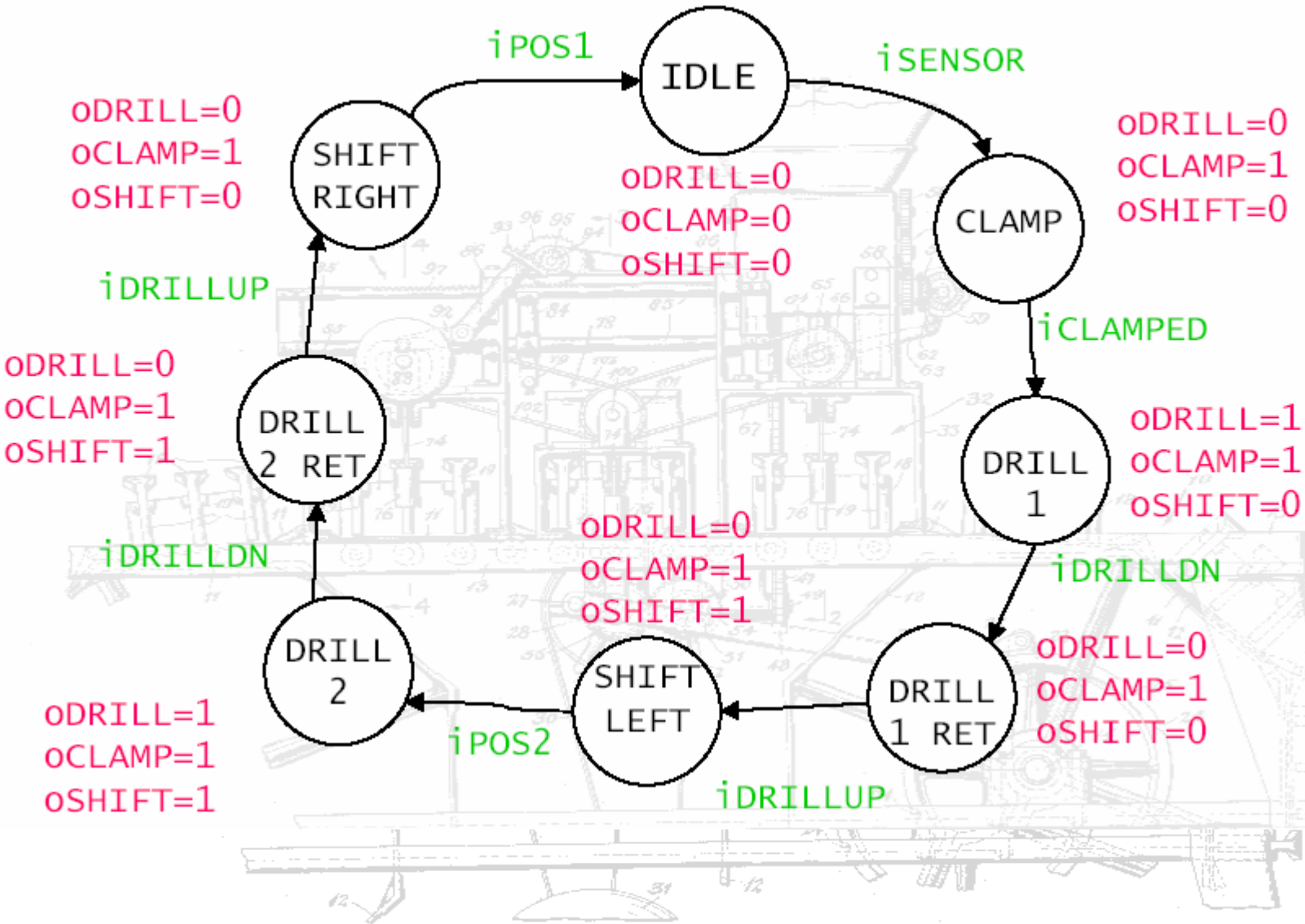


State Diagrams

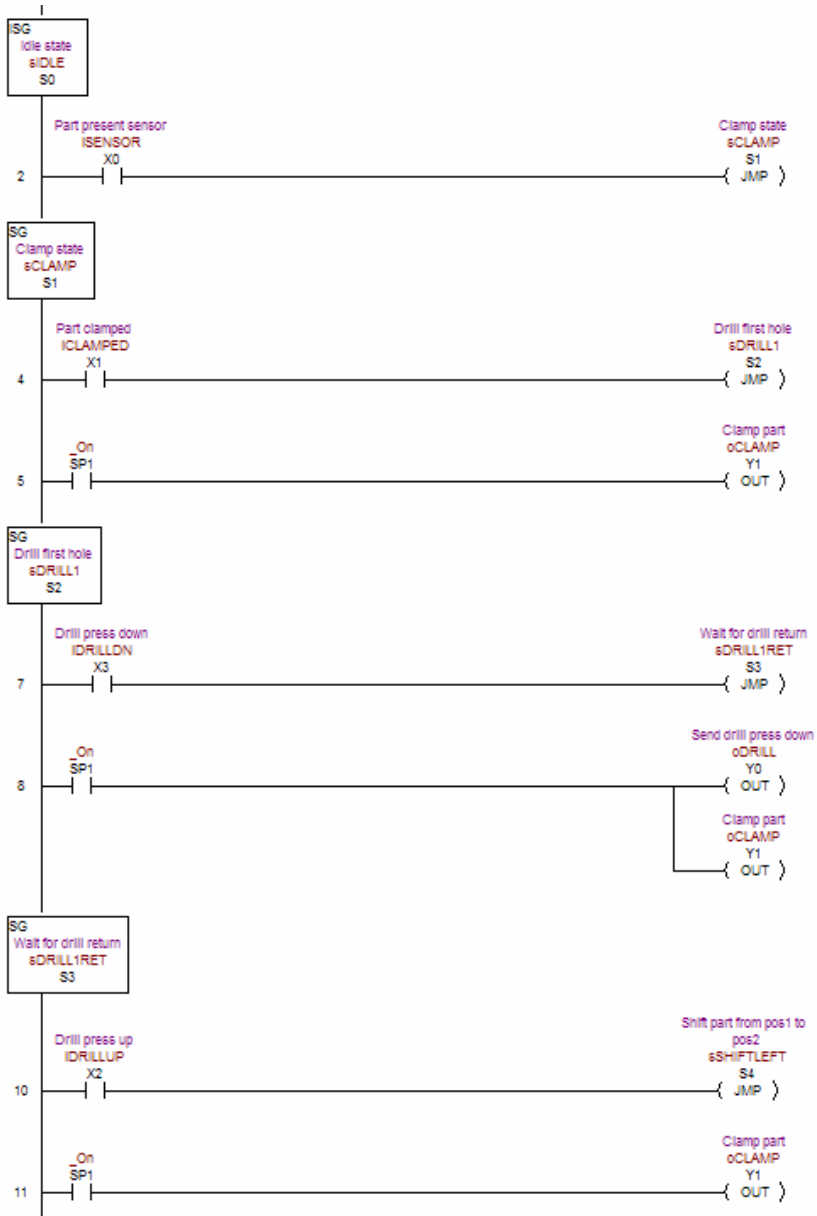
- *One state per "action"*
- *Look for "wait" states needed*



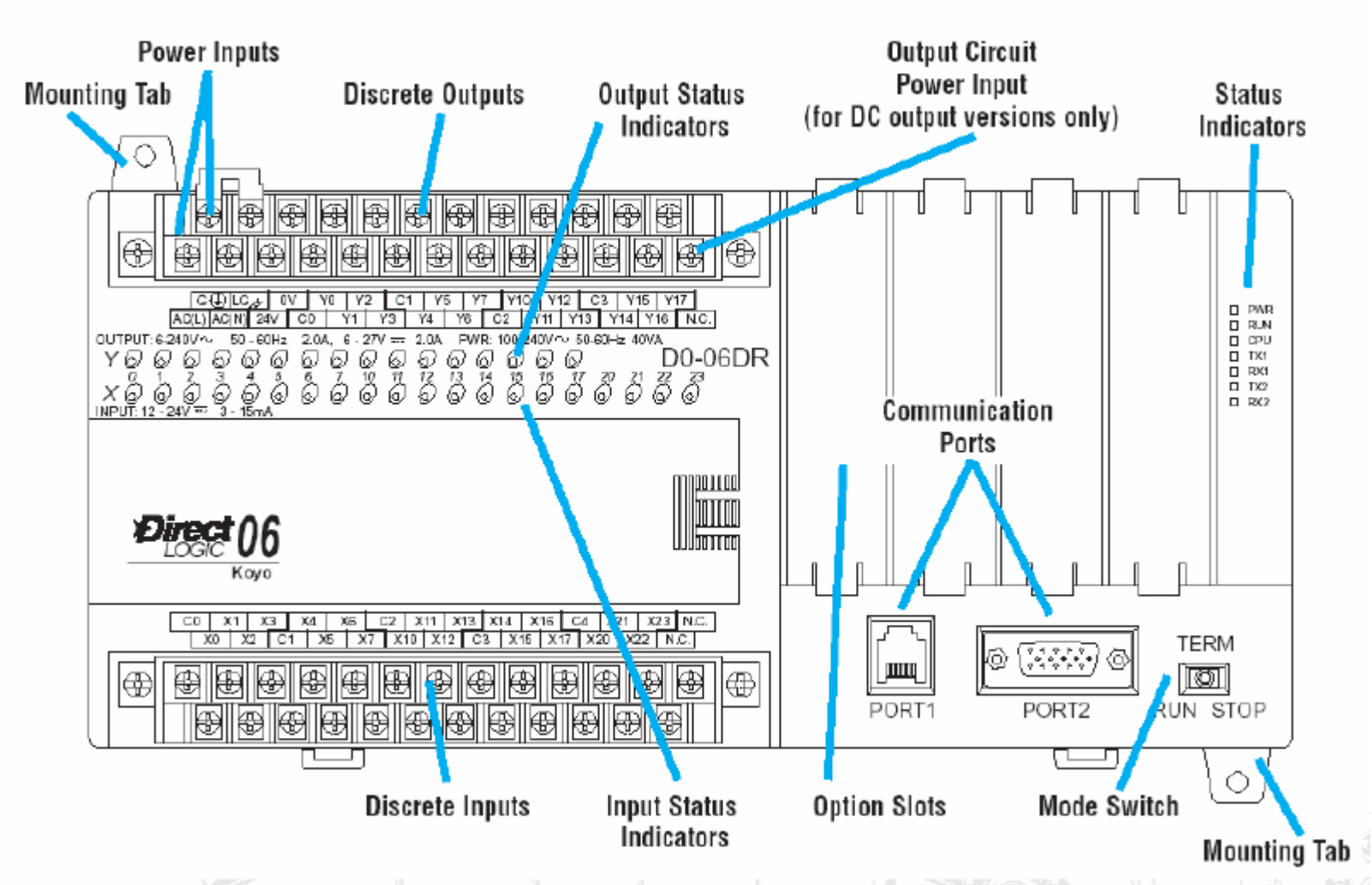
State Diagram



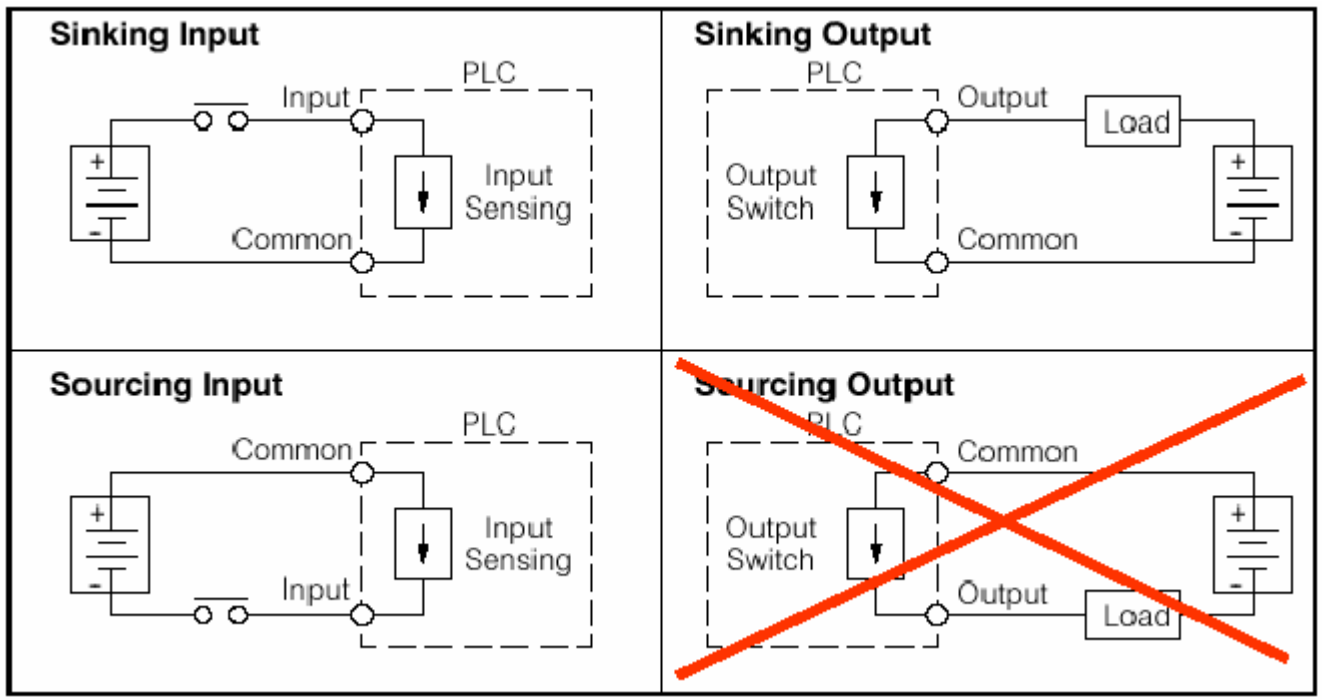
RLL-Plus


SG
Idle state
sIDLE
S0
Part present sensor
ISENSOR
X0
2
Clamp state
sCLAMP
S1
JMP
SG
Clamp state
sCLAMP
S1
Part clamped
ICLAMPED
X1
4
Drill first hole
sDRILL1
S2
JMP
_On
SP1
5
Clamp part
oCLAMP
Y1
OUT
SG
Drill first hole
sDRILL1
S2
Drill press down
IDRILLDN
X3
7
Wait for drill return
sDRILL1RET
S3
JMP
_On
SP1
8
Send drill press down
oDRILL
Y0
OUT
Clamp part
oCLAMP
Y1
OUT
SG
Wait for drill return
sDRILL1RET
S3
Drill press up
IDRILLUP
X2
10
Shift part from pos1 to pos2
sSHIFTLEFT
S4
JMP
_On
SP1
11
Clamp part
oCLAMP
Y1
OUT

PLC Front Panel

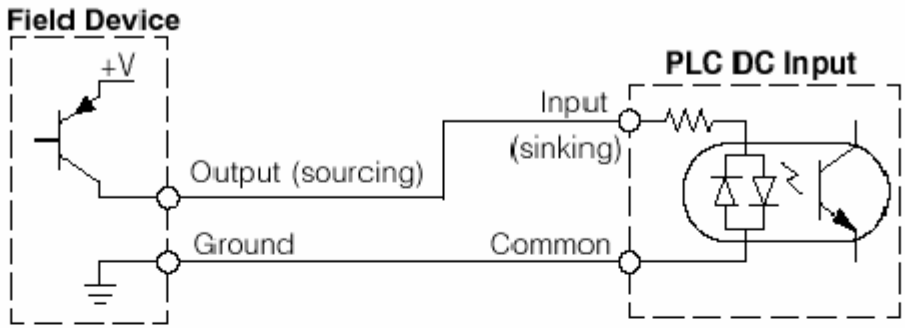


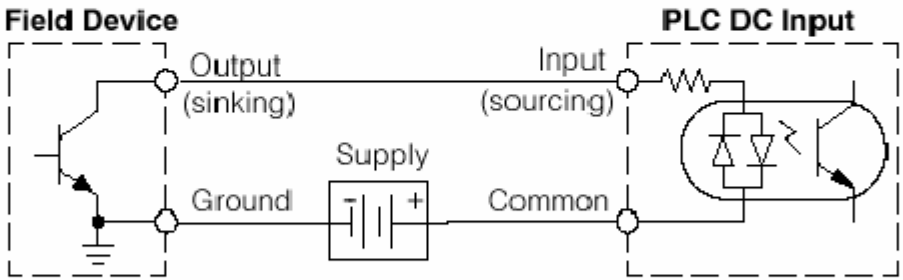
PLC Inputs and Outputs

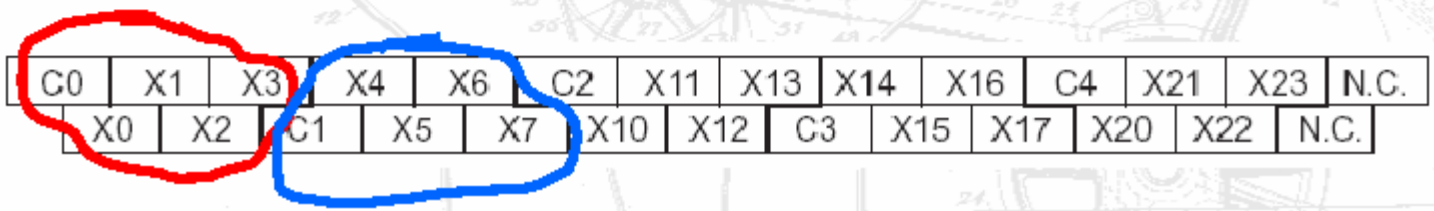


- *Sinking = drawing current*
- *Sourcing = supplying current*
- *Sinking output connects to sourcing input*
- *Sourcing output connects to sinking input*

DL06 Signal Inputs

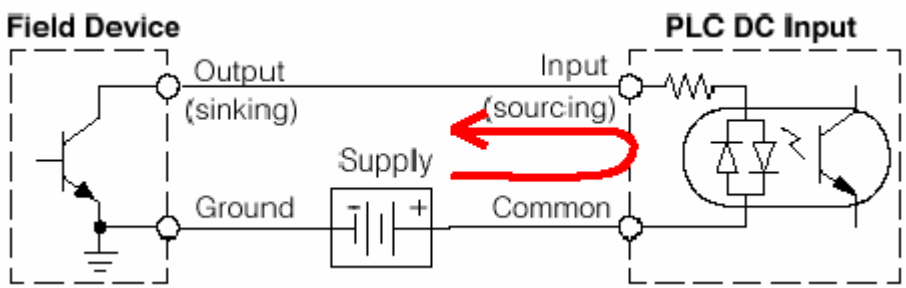


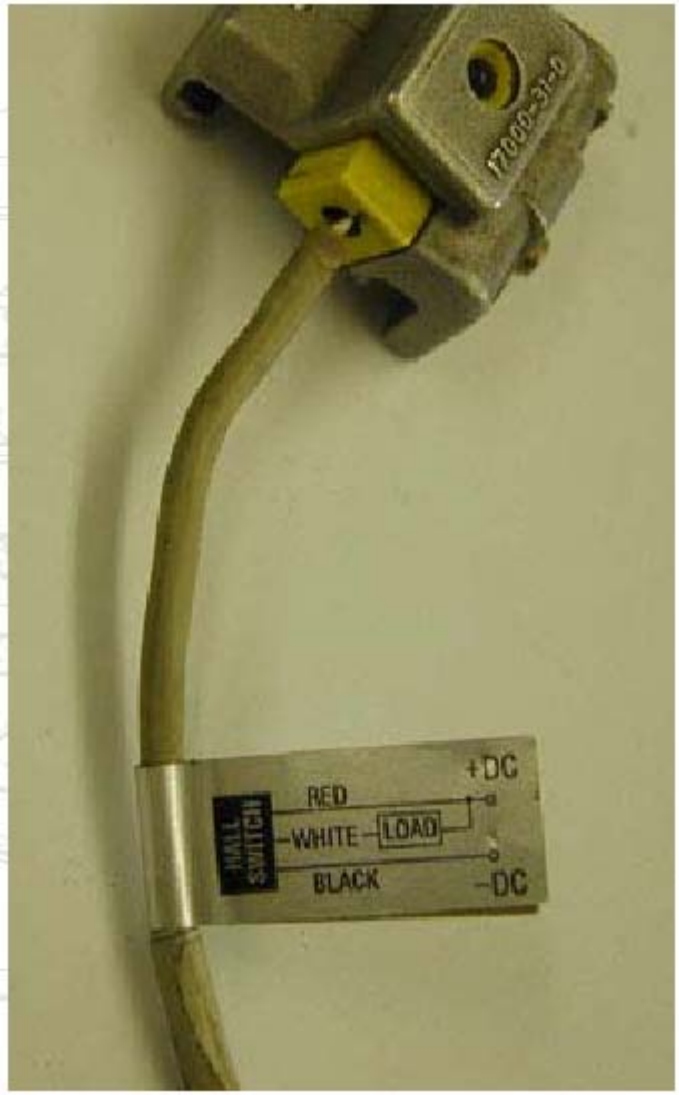




Typical Input Device

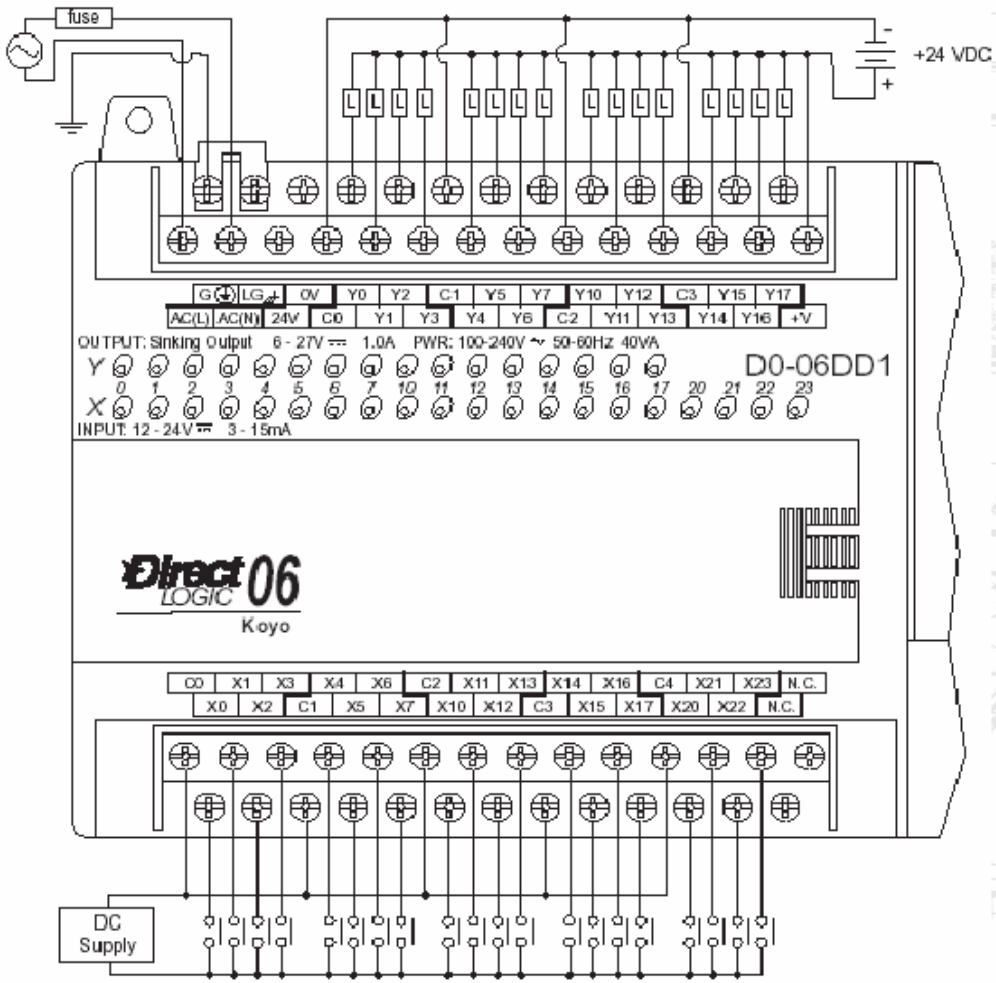
- *The tag indicates that the LOAD (PLC input has a +DC common*
  - *this is a sinking output*
  - *Sinking output => sourcing input*





DC Control Outputs

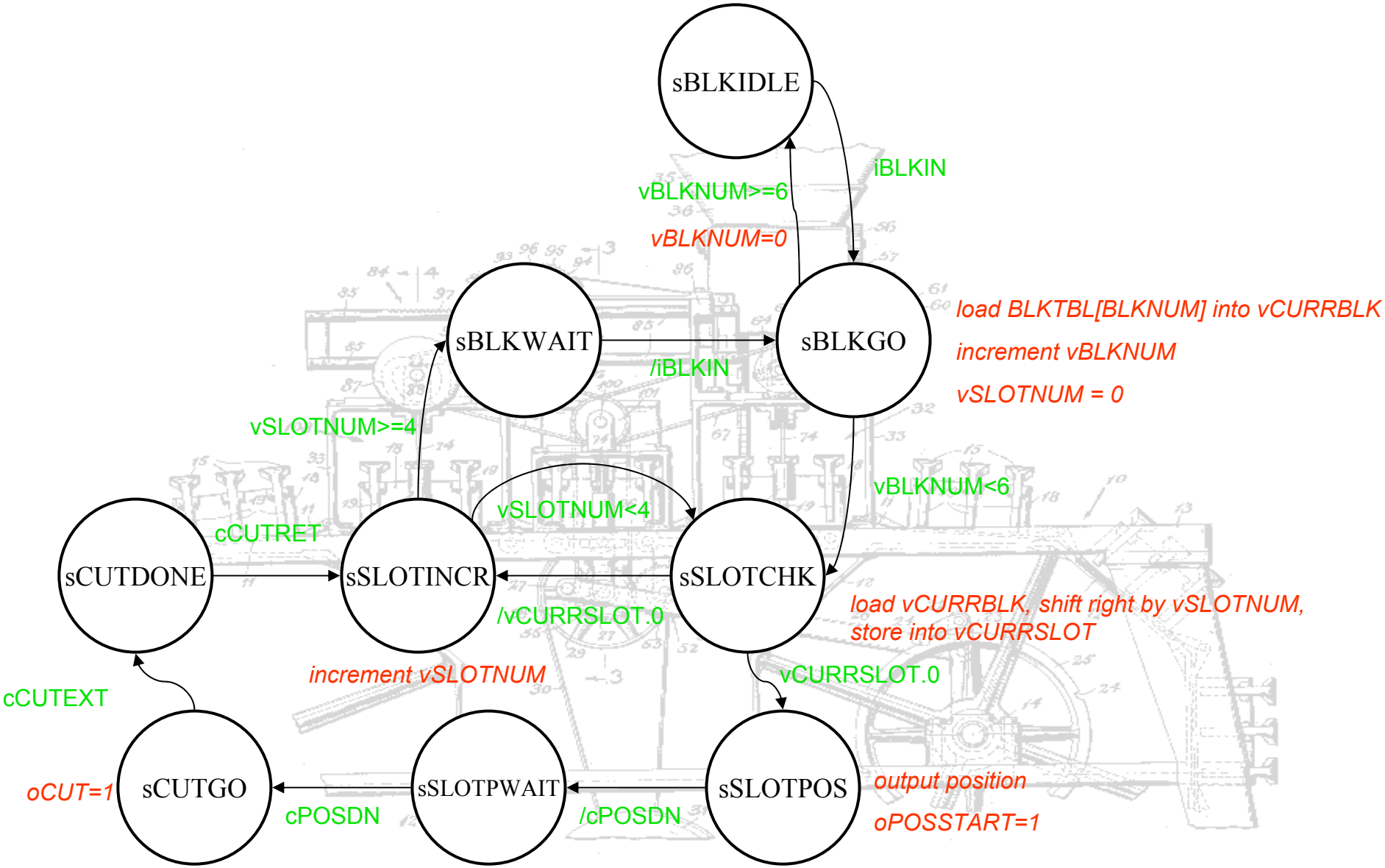
)V	Y0	Y2	C1	Y5	Y7	Y10	Y12	C3	Y15	Y17
C0	Y1	Y3	Y4	Y6	C2	Y11	Y13	Y14	Y16	+V



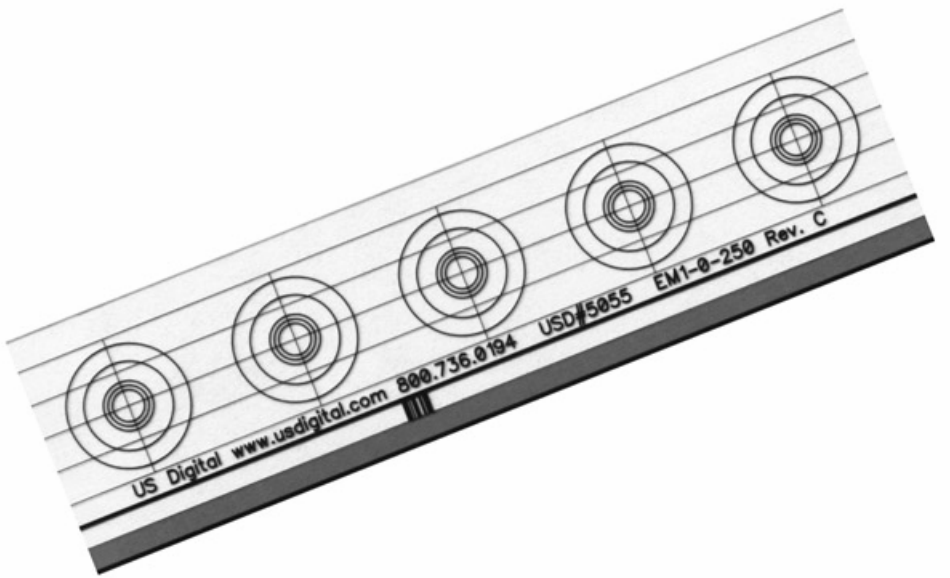
6-27VDC

1A/output

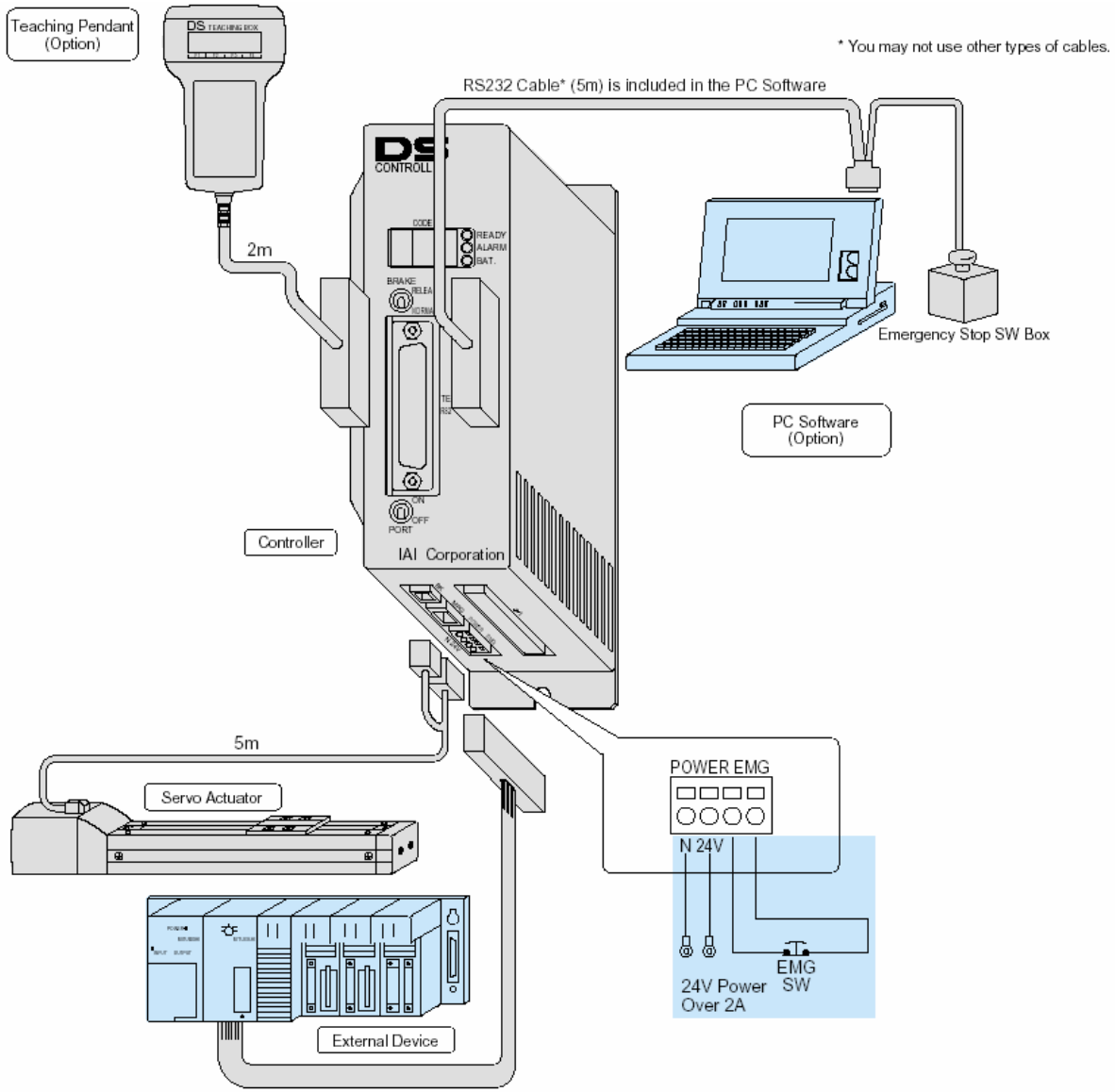
Big State Machine Example



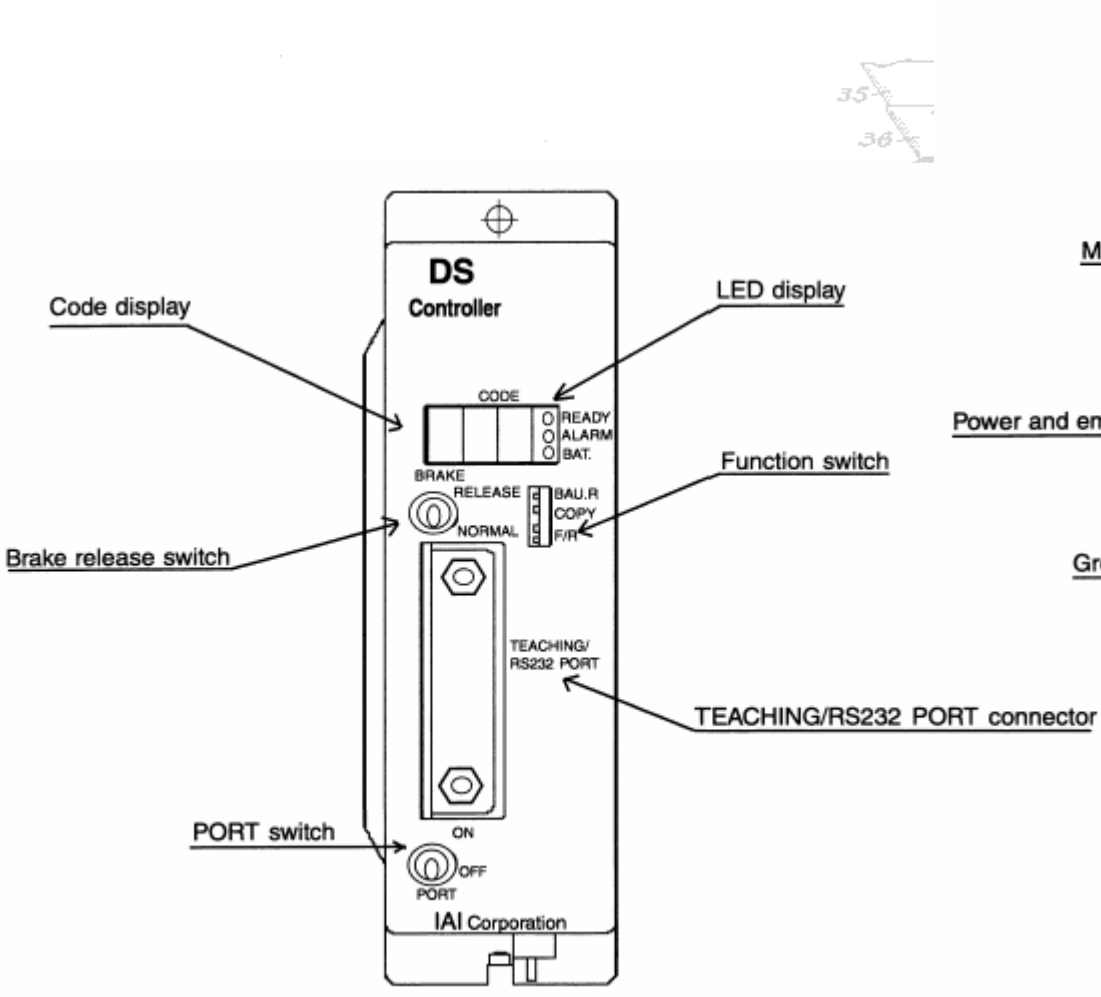
Incremental Encoders

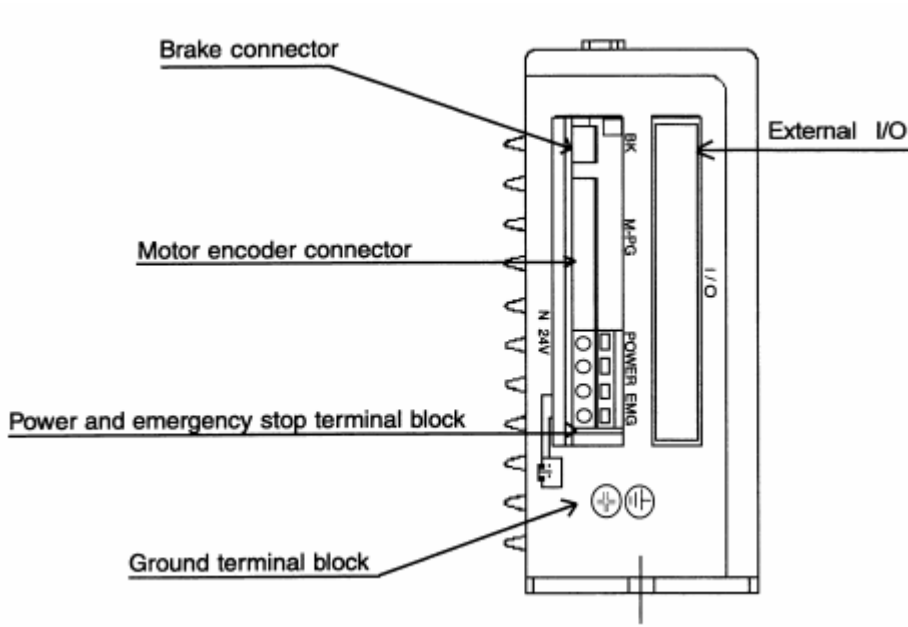


Intelligent Actuator Motion Ctrl

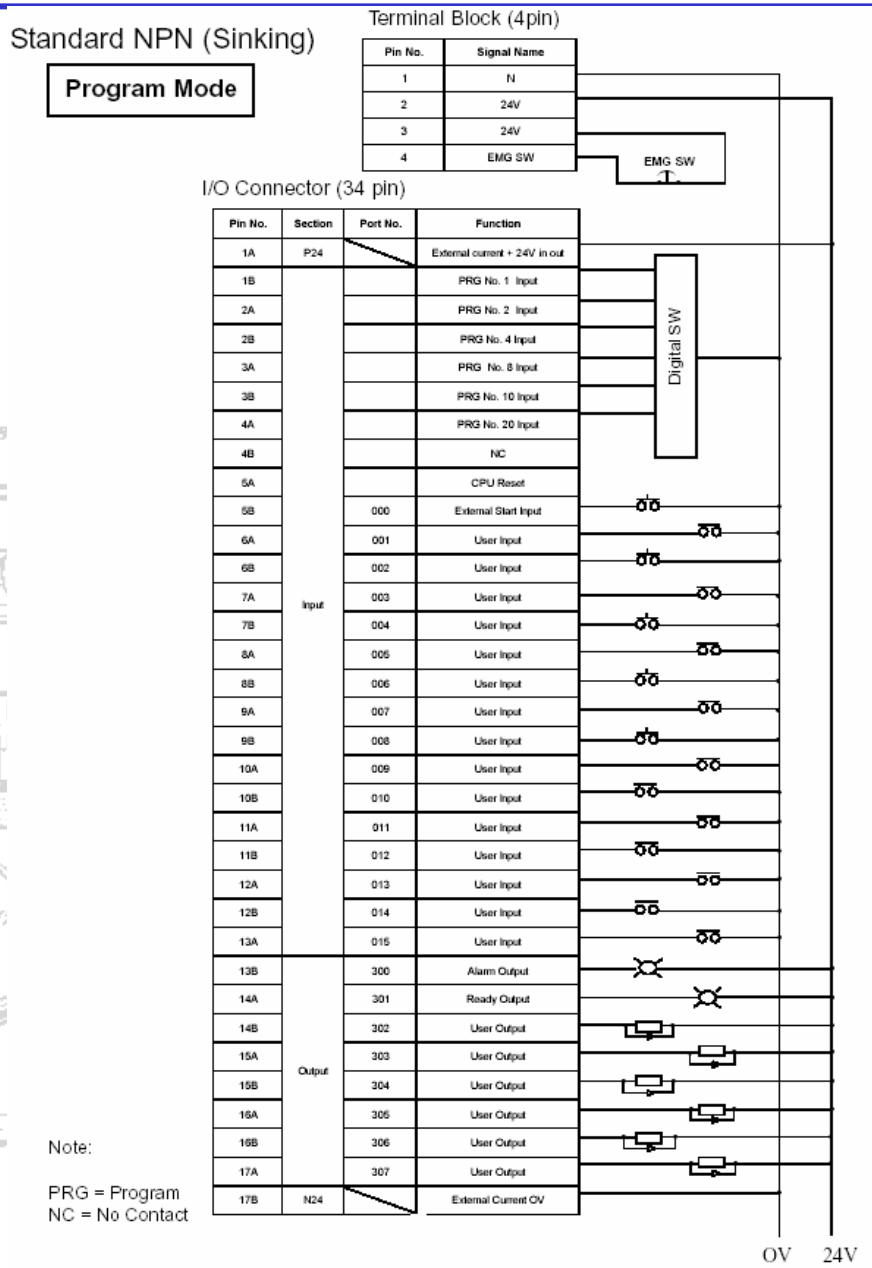


IAI DS Controller

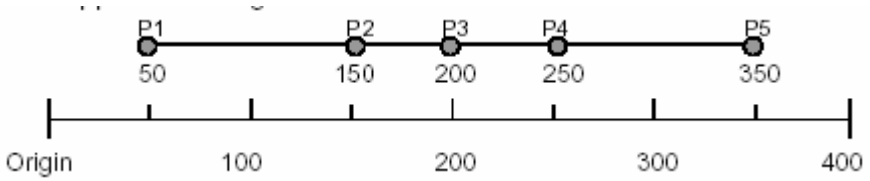




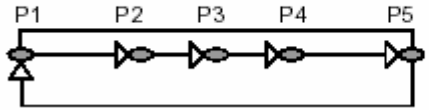
IAI DS Controller



IAI DS Controller



P1 → P2 → P3 → P4 → P5 → P1 (This path is repeated):



[Position Data]

Position No.	Position Data
0001	50.00
0002	150.00
0003	200.00
0004	250.00
0005	350.00

Step	Command		Explanation
1	SVON		Turns the Servo ON
2	HOME		Executes Homing
3	VEL	500	Sets the velocity to 500mm/sec
4	TAG	01	
5	MOVP	001	Moves to Position No. 1
6	MOVP	002	Moves to Position No. 2
7	MOVP	003	Moves to Position No. 3
8	MOVP	004	Moves to Position No. 4
9	MOVP	005	Moves to Position No. 5
10	GOTO	01	Jumps to TAG 01

IAI Example Program

K:\CLASS\ENGR\480\IAI\MASTER6.PRG

Step	E	N	Cnd	Cmnd	Operand1	Operand2	Pst	Comment
1				SVON	1			SERVOS ON
2				BTON	302			
3				HOME	1			HOME SERVO
4				ACC	0.9			SET ACCEL
5				VEL	1000			SET VELOCITY
6				MOVP	1			PICK UP POS.
7				TAG	1			
8				WTON	015			Wait for START
9				BTOF	302			Reset Move Done
10				IN	016	017		Load pos to 99
11				ADD	99	2		0 input -> Pos 2
12				MOVP	*99			Move to pos #
13				BTON	302			Move Done
14				WTOF	015			Wait for /START
15				GOTO	1			

No.	Acc	Vel	Position
1	0.5	200	100.000
2	0.50	200	120.000
3	0.50	200	140.000
4	0.50	200	160.000
5	0.50	200	180.000