Previous class notes

Addition of 2 bytes

Carry	1011111
	11011011
	+ 11001111
	110101010

- You might well have to add 3 bits together

Addition of 3 bits

a	b	c	carry	sum
1	1	1	1	1
1	1	0	1	0
1	0	1	1	0
1	0	0	0	1
0	1	1	1	0
0	1	0	0	1
0	0	1	0	1
0	0	0	0	0

The sum takes up a value of 1 if

A and B and C are all 1
Or A is 1 and B is 0 and C is 0
Or A is 0 and B is 1 and C is 0
Or A is 0 and B is 0 and C is 1

Hence, **sum** $= A.B.C + A.B'.C' + A'.B.C' + A'.B'.C$

And **carry** $= A.B.C + A.B.C' + A.B'.C + A'.B.C$

Sum of the product terms

The value of carry

$$Carry = A.B.C + A.B.C' + A'.B.C + A.B'.C$$

$$= A.B.C + A.B.C' + A.B.C + A'.B.C + A.B.C + A.B'.C$$

$$= A.B.(C+C') + B.C.(A+A') + A.C.(B+B')$$

$$= A.B + B.C + A.C$$

The value of Sum

$Sum = A.B.C + A.B'.C' + A'.B.C' + A'.B'.C = A\ .\ (B.C + B'.C') + A'.\ (B.C' + B'.C)$

Now, $B.C' + B'.C = B \oplus C$, *and*

$(B.C + B'.C')' = (B.C)'\ .\ (B'.C')' = (B' + C')\ .\ (B + C) = B.B' + B.C' + B'.C + C.C'$

$= B.C' + B'.C = (B \oplus C)'$

Hence,

$A\ .\ (B.C + B'.C') + A'.\ (B.C' + B'.C) = A.(B \oplus C)' + A'\ .\ (B \oplus C) = A \oplus B \oplus C$

Numerical problem 2.1

- There is a grinding machine in which coolant is to be applied automatically if
- The temperature $\geq 60^\circ$ C , surface speed $\geq$ 20 m/s & table feed $\leq$ 15 m/min
- The temperature $\geq 60^\circ$ C , surface speed < 20 m/s & table feed > 15 m/min
- The temperature $\geq 60^\circ$ C , surface speed $\geq$ 20 m/s & table feed > 15 m/min
- *If sensors are set up in such a way that the following variables*

A = 0 when temperature $< 60^\circ$ C

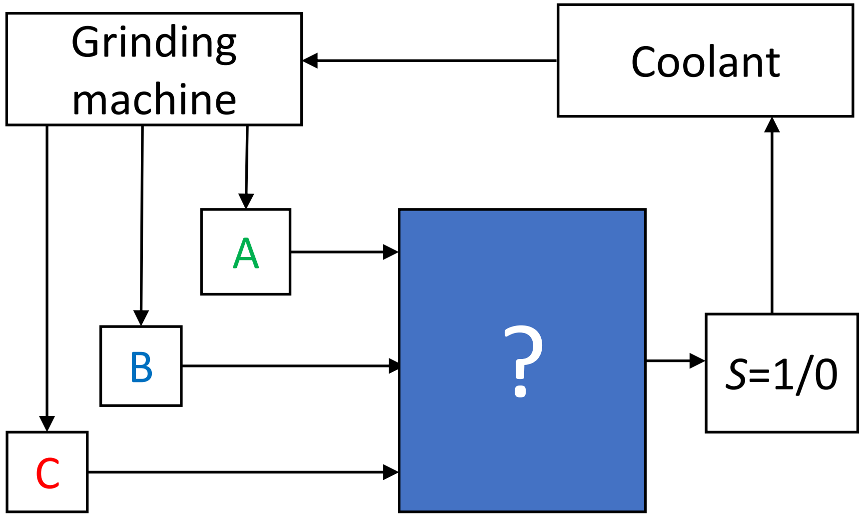
= 1 when temperature $\geq 60^\circ$ C

B = 0 when surface speed < 20 m/s

= 1 when surface speed $\geq$ 20 m/s

C = 0 when feed $\leq$ 15 m/min

= 1 when feed > 15 m/min



- **Make a circuit which would send an output signal S = 1 when coolant is supposed to be applied, otherwise 0.**

Solution to Prob 2.1

A	B	C	$signal$
1	1	1	1
1	1	0	1
1	0	1	1
1	0	0	0
0	1	1	1
0	1	0	0
0	0	1	0
0	0	0	0

- Applying sum of the product terms,

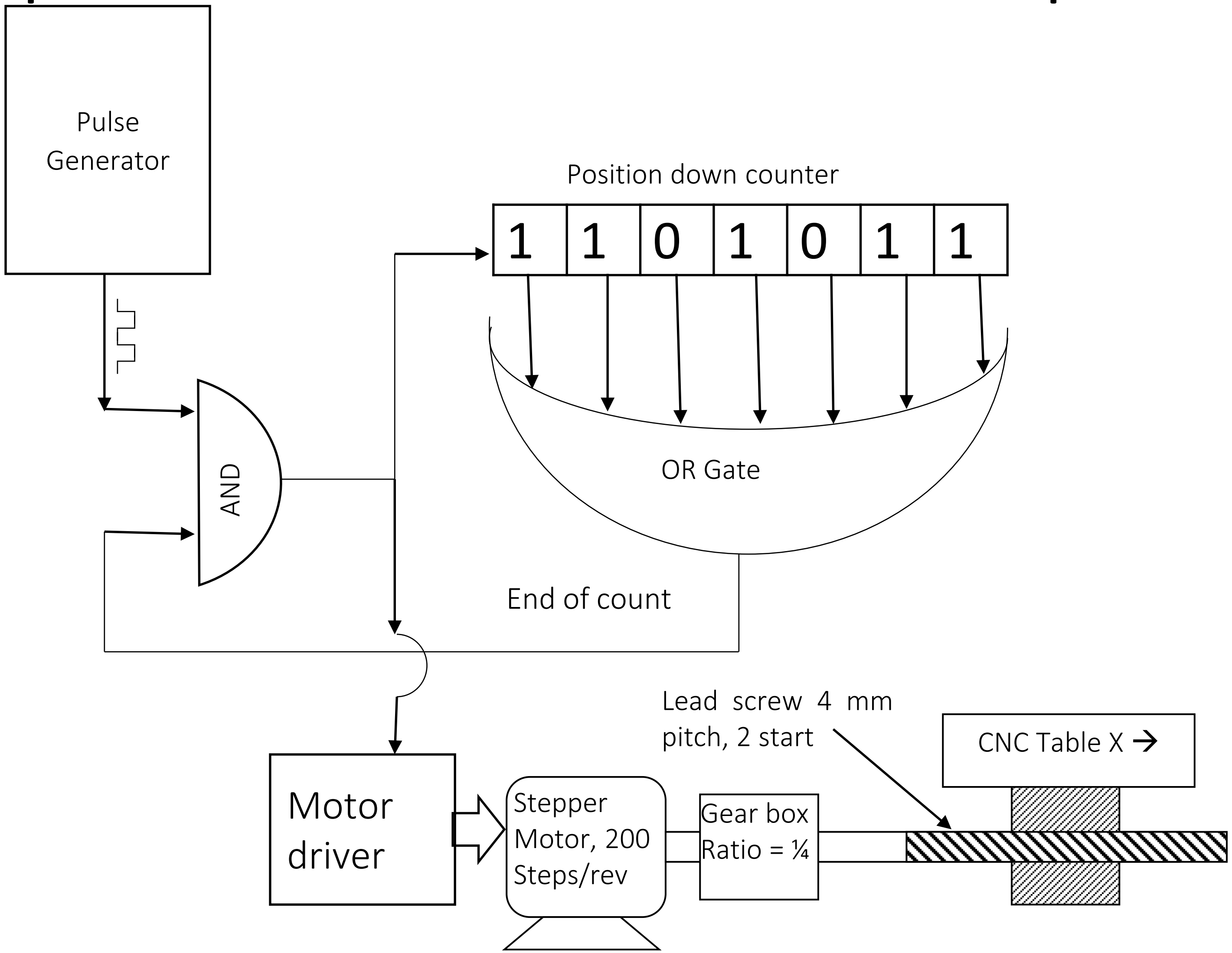
$$Signal = A.B.C + A.B'.C + A.B.C'$$

$$= \ A.B.C + A.B'.C + A.B.C' + A.B.C$$

$$= A.C.(B + B') + A.B.(C + C')$$

$$= \ A.C + A.B = \mathbf{A.(B + C)}$$

Point-to-point control – one example



Explanations to the control loop elements

- PDC = position down counter. It can be loaded with a binary number. A train of pulses input as shown will downcount the content of the counter, 1 bit for 1 pulse.
- End of count = All the bits of the PDC are input t the OR gate. The OR gate will output a 0 only when all the inputs are 0. Which means – the contents of the PDC have been counted down to 0, so it is called 'End of count'.
- Pulse generator = The pulse generator sends out pulses continuously at a definite frequency

Explanations – cotd.

- Gear Box – Normally, CNC machine tools do not employ gear boxes. However, they may be present as a fixed speed reducer for attaining a definite speed range. Gear ratio = Output RPM/Input RPM
- Lead screw – nut mechanism : For 1 rotation of lead screw, the nut rotates by $p \times n$ = lead, where p = pitch and n = number of starts of screw
- Stepper motor – is a motor which moves in discrete steps in response to voltage pulses as input

P-T-P control – another example

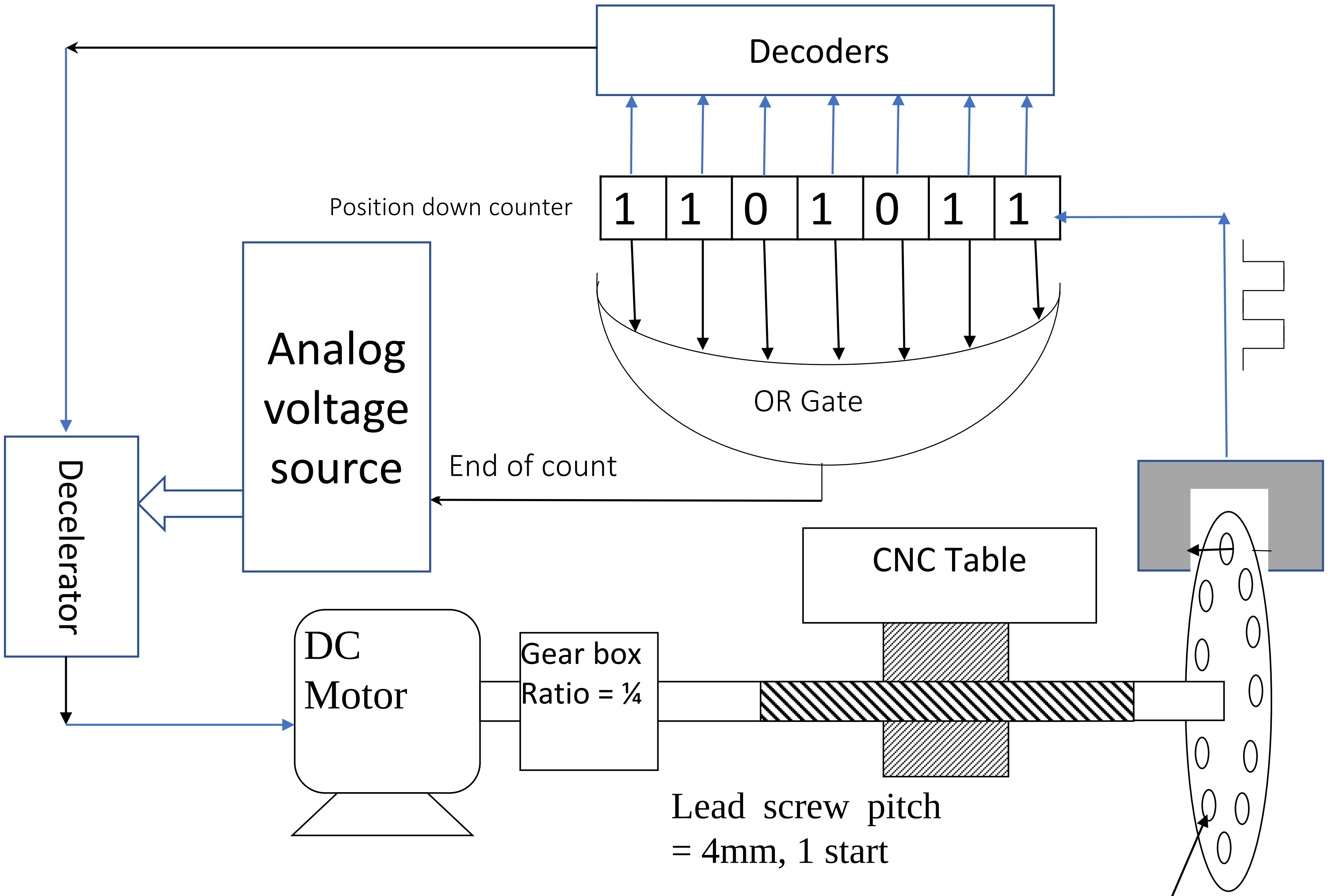


Fig. 1

Observations on the two P-T-P systems

- In both the examples – there is no velocity control of the table movements.
- The position down counter is present in both as it is associated with position control.
- In one case – there is internal feedback while in the other – there is external feedback.

MCQ on P-T-P machines

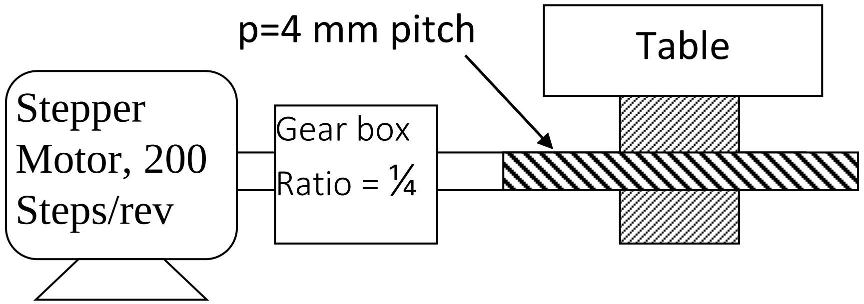
1.The basic length unit (BLU) of the following drive is

a. 5 microns

b. 50 microns

c. 10 microns

d. None of the others



When to use open loop

- Open loop is employed when the prime mover can reliably move through the extent of motion programmed.
- For example – the stepper motor can reliably move through discrete steps and stop exactly at a pre-defined location.
- In the previous control loop shown – there is indeed a feedback loop – but it is internal

P-T-P closed loop

- The DC motor cannot be relied upon to stop at a definite pre-defined location. Hence, an external check is necessary, together with deceleration applied towards the end of motion and mechanical brakes at the end of motion.
- The typical feedback device used in this case is the encoder. The encoder, together with an LED-photoreceptor-pulse emitter circuit, is capable of sending feedback pulses which keep count of the extent of rotation of the lead screw.

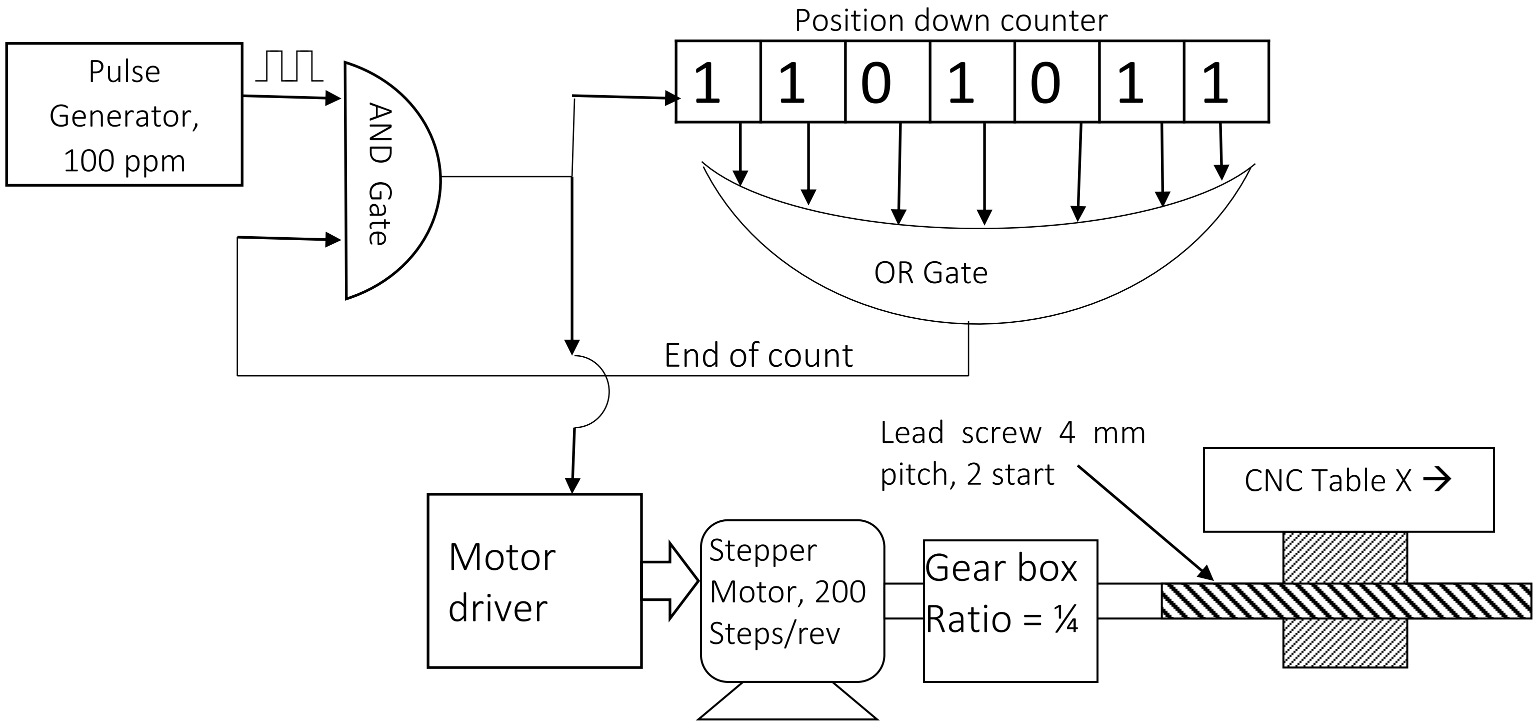
1. In a PTP open loop CNC drilling machine, a stepper motor drives the table in X direction. The stepper motor shaft is connected to a gear box with ratio (=output rpm/input rpm) ¼ which is in turn connected to a lead screw of pitch = 4 mm and no. of starts = 2. The stepper motor covers 1 rotation in 200 equal steps and executes 1 step per pulse of pulse generator (100 pulses per minute, ppm) received by motor driver. The pulses output from AND gate, go to motor driver and also to a position down counter (PDC). These incoming pulses decrement the content of PDC (1 pulse comes in, PDC content does down by 1).

A. What are the BLU (basic length unit) and velocity of the table along x axis ?

Line 1 G00 G90 X20 Y30

Line 2 X25

B. What number in binary will the MCU put into PDC for executing line 2 of program above ?



Answer to problem

Ans :

- BLU = 8 mm/800 = 0.01 mm = 10 microns
- Velocity = BLU X PPM = 0.01 X 100 mm/min = 1 mm/min
- Number to be put in binary inside PDC = 5/0.01 = 500

Find BLU, velocity and number to be put inside PDC

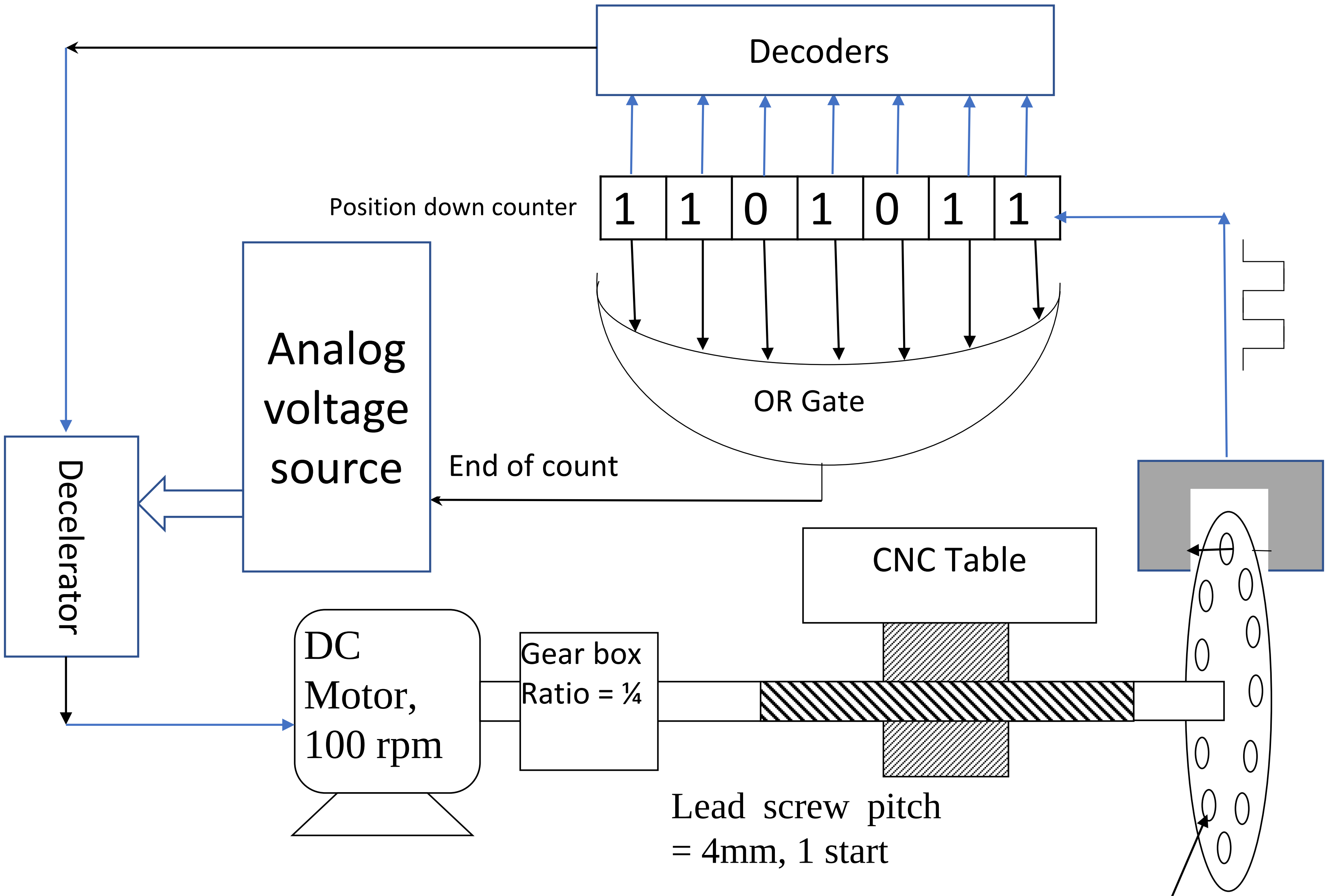


Fig. 1

Answer to previous problem

BLU = 4 mm/200 = 0.02 mm = 20 microns

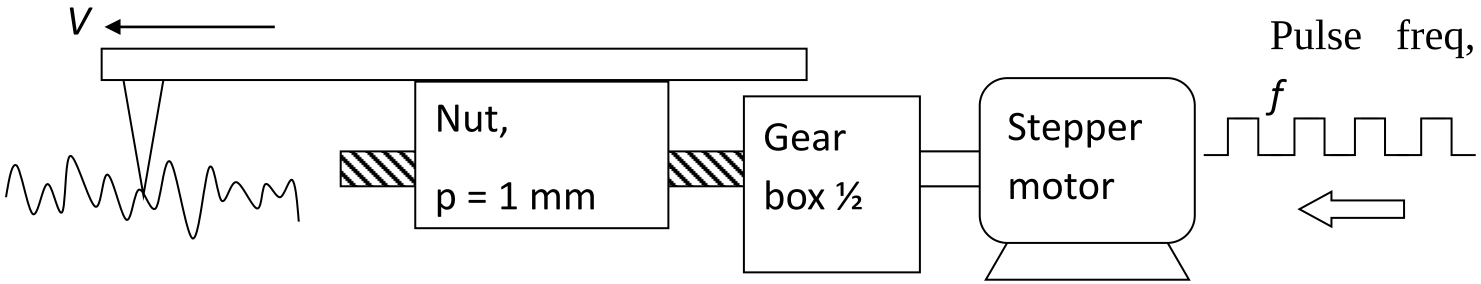
Velocity = 100 rpm X ¼ X 4 = 100 mm/minute

Number in binary to be put inside the PDC = 5 mm/BLU = 5 / 0.02 = 250

1. In a techno-fest for innovative designs – a student demonstrates a surface roughness tester he has developed. The stylus is moved with velocity V by a distance of 4 mm and it collects n number of profile data, one profile data for each step of the stepper motor. Stepper motor moves one step for each pulse and covers one rotation in 200 steps. The frequency of the pulses = f = 20 Hz. Pitch of lead screw = 1 mm.

(a) Find the value of n and V

(b) What is the distance covered by the stylus between two readings ?



- distance between successive readings = BLU = 1 mm/400 =0.0025 mm = 2.5 microns
- Number of readings in 4 mm sampling length = 4 mm/0.0025 = 1600
- Velocity = BLU X PPS = 0.0025 X 20 = 0.05 mm/s = 3 mm/min

Numerical Problem 3.1

A company publishes a tender inviting quotations for a CNC PTP control table which moves only in one axis. The Basic length unit (BLU) is to be 5 microns and the axis velocity is to be 100 mm/min.

You represent another company which builds and sells machines by assembling different pieces of equipment (refer table 1).

Check whether you can build a machine to satisfy the above requirements [4] using 1 PG, stepper motor, 1 GB and 1 table.

Verify whether there is any chance that your quoted price (**assuming you want to make a profit of only Rs 1000 for the CNC PTP control table**) would be lowest, (refer table 2). [4]

Table 1. Your store has these pieces of equipment

Sl.	Equipment	Specification	Cost price
1	Pulse generator	22000 ppm	Rs 11,000
2	Pulse generator	20000 ppm	Rs 10,000
3	Stepper motor	1.8^0 steps, 1 step per pulse	Rs 7000
4	Gear Box	Gear ratio $= \frac{N_{out}}{N_{in}} = 1/4$	Rs 4000
5	Gear Box	Gear ratio $= \frac{N_{out}}{N_{in}} = 1/3$	Rs 3000
6	Table with Lead screw - nut	Pitch 4 mm	Rs 4000
7	Table with Lead screw-nut	Pitch 3 mm	Rs 3000

	Quoting company	Quoted price for CNC PTP control table
1	Lakshmi Brs pvt ltd	Rs 26,500/-
2	M/c builders Ltd	Rs 25,400/-
3.	CNC & Co.	Rs 24,300/-
4.	Nuts, Bolts & Comps	Rs 32,100/-
5.	Your company	?

- In a CNC machine with continuous control (the one where path velocity is also controlled), the following commands are executed :

N01 G90 G00 X100 Y200 Z 20

- N02 G01 X130 Y240 F50
- What is the feed velocity of the cutter in the X direction in line N02 ?

Incremental format, Feed Calculation

1. The feed (mm/min) along X axis corresponding to the program line G91G01X40Y30F100 is

a. 80

b. 100

c. 60

d. None of the others

(G91 – incremental)

A CNC user wants to remove a stepper motor from one axis of his CNC drilling machine table and replace it with a PMDC (Permanent magnet direct current) motor. The Stepper motor (1 rotation in 200 steps, 1 step for 1 pulse) received pulses from a pulse generator @ 5000 ppm and was driving a lead screw-nut pair (lead = 4 mm) directly. The PMDC motor rotates at a constant speed of 100 rpm and after fitting, ***should produce same BLU and axis speed as before***. The user may employ *any 1 lead screw-nut pair & 1 gear box & 1 encoder combination from inventory listed below*. No equipment other than these is permitted. Encoder, if used, should be mounted on lead screw.

encoders
400 holes
300 holes
200 holes

Lead of Lead screw-nut pairs
4 mm
6 mm
8 mm

Gear boxes with ratio
½
¼
⅓

MCQ 5

1.A machine will be said to have CNC control if

(a)The dimensions of the work piece are measured by sensors while cutting goes on
(b)The tool motion is guided by drum cams and disc cams
(c)The loading and unloading of the work piece on and off the machine respectively, is made automatic
(d)Control is achieved by employment of alphanumeric data

(c) In Computer controlled machine tools terminology, a machining center is

(i) The origin of the machine coordinate system with respect to which the operator has to make his program

(ii) The center of the cutter which actually goes to the programmed point (when used without radius compensation)

(iii) A computer control machine tool capable of a variety of operations involving rotating cutters

(iv) None of the others

- a) In Computer controlled machine tools, tool movements are controlled by :

(i) Cam (ii) Machine Operator

(iii) Fool proof mechanism (iv) None of the others

MCQ 8

1. Holes are to be drilled on the circumference of a circle with regular angular spacing. If a CNC machine is used, it should essentially

(a) Have one indexing head mounted on the machine table

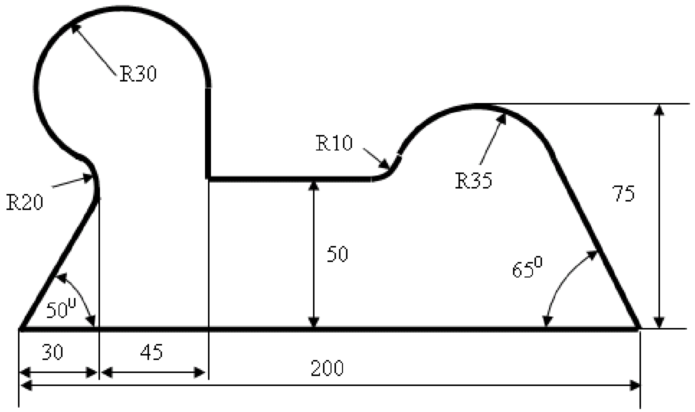
(b) Have a CNC rotary axis of motion to rotate the table about Z axis (in addition to X, Y and Z axes of motion)

(c) Be a CNC milling machine with contouring control

(d) None of the others

MCQ - 9

The following shape has to be cut on a CNC milling machine. The raw material is flat metal plate, 10 mm thick. In order to carry out CNC milling, we essentially require



(a) A 3-axis CNC milling machine with a copy-milling attachment
(b) A 3-axis CNC milling machine with a ball-end milling cutter
(c) A 5-axis CNC machine with a copy-milling attachment
(d) A 5-axis CNC machine with a ball-end milling cutter
(e) None of the above

(1) For milling a bi-laterally symmetrical 2-D profile on metal plate 10 mm thick, a CNC milling machine would require the following accessory / attachment

(a) Copy milling attachment
(b) Dividing head
(c) Reversing table
(d) Rotary table
(e) None of the above

- In order to produce a circular groove by milling in CNC machining centre
-

a. A Universal Dividing head is necessary
b. A planetary gear mechanism actuates table movement
c. A Rotary table is necessary
d. None of the above

(4)CNC is not applicable in

a. Drilling machine
b. Milling machine
c. Lathe
d. All of the above
e. None of the above

(4)A CNC machine tool has the following advantage over conventionally controlled machine tools

- (a)Surface finish of machined part is higher
(b)Cutting forces are less
(c)Cutting temperature is lower
(d)All of the above
(e)None of the above

1.The incremental encoder is capable of sensing

(a)Direction of movement of the table
(b)Direction of rotation of the lead screw
(c)Direction of rotation of the motor
(d)None of the others

- In a PTP machine feed axis employing a stepper motor as prime mover

a. An encoder for position feedback is a must
b. An interpolator is a must
c. A tachogenerator is a must
d. None of the others

- $A \oplus B$ is equal to

i. $A.B + A'. B'$
ii. $A'.B + A.B$
iii. $A'.B + B'. A$
iv. None of the others

6.CNC machines find the widest application in the field of

a. Mass production
b. Small lot and batch production
c. Non-conventional machining
d. None of the above

6. CNC machining has the following main advantage over conventional machining practice

a. Ability to employ higher cutting speeds, feeds and depths of cut
b. Flexibility
c. Feedback control
d. None of the others

- 9. On the CNC lathe
-

a. 2-D programming is sufficient
b. 3-D programming is necessary
c. 1-D programming is sufficient
d. None of the above

10. Interpolator is present in case of

a. PTP (Point to point) open loop system
b. PTP (Point to point) closed loop system
c. Continuous control system
d. None of the others

1. In a CNC turning center, threads of different pitches are cut by

•

a. Different settings of the Meander drive and Norton-tumbler gears

b. Different settings of the feed gear box

c. Different setting of the speed gear box

d. None of the others

- 5. A point-to-point (PTP) control CNC machine
-
- a. Does not have an interpolator
- b. Does not have a position down counter
- c. Never has DC motor as prime mover along any feed axis
- d. None of the others

- 2. In a CNC milling machine, a circular cut is always produced

  a. by operator's skill and experience
  b. by copy milling from a master circular shape
  c. By combined motion of feed axes
  d. None of the others

$a \oplus b$ (that is, a XOR b) is equal to

a. $\{(a' + b').(a + b)\}'$

b. $(a' + b')'.(a + b)$

c. $(a' + b').(a + b)'$

d. None of the others

1. In case of a CNC drilling machine, whenever there is table motion, the speed of X-Y table along X axis

a. Is always same

b. Can be different for different lines of program

c. Is always 0

d. None of the others

CNC machines have the ability to cut complex profiles as

a. They are equipped with tracer control
b. The accuracy of the axes movements is very high
c. They are equipped with high performance gear boxes
d. None of the above

1. PTP (Point to point) control of CNC machines is not applicable in case of

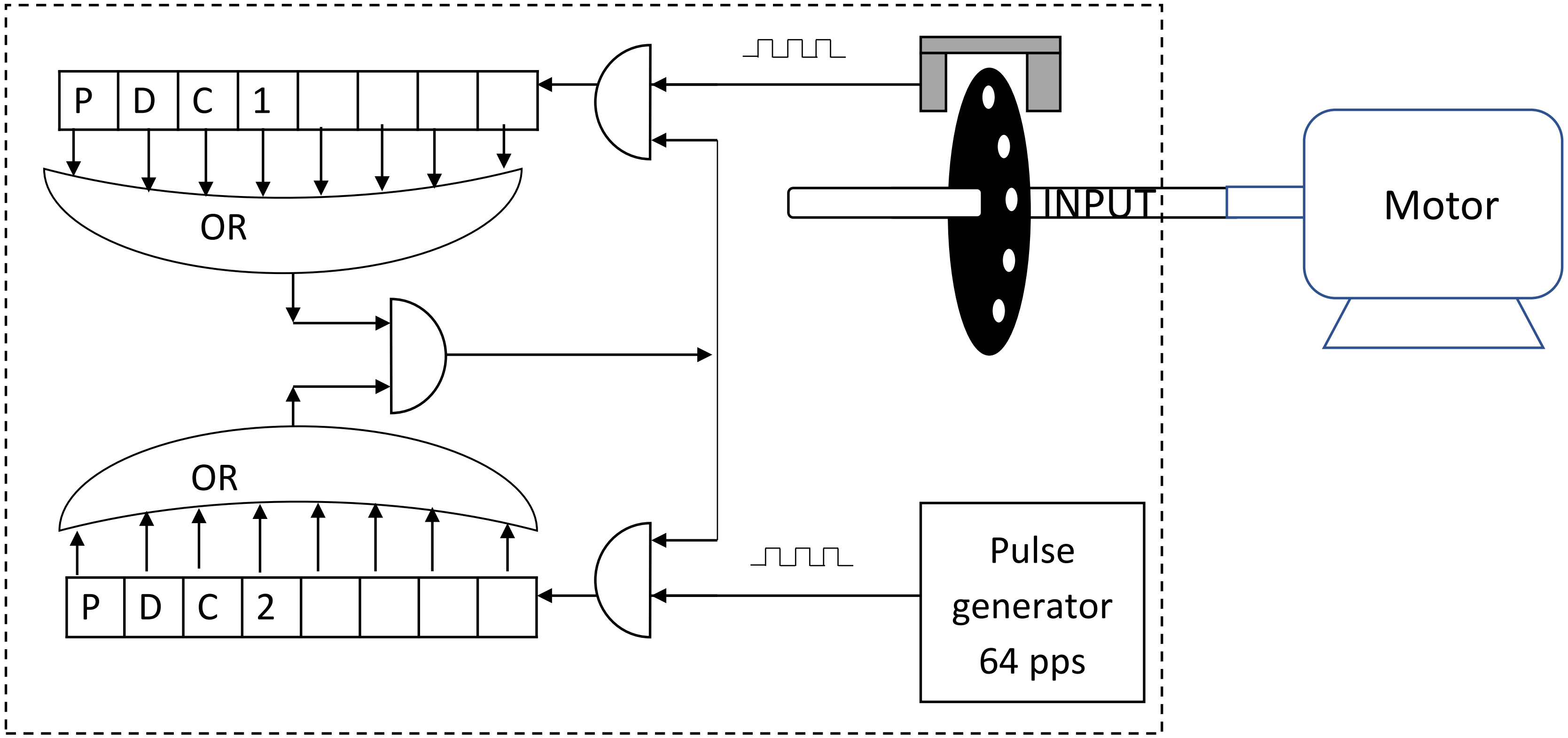
-

(a)Drilling of holes at the vertices of a triangle
(b)Drilling of 73 holes at regular angular intervals on the circumference of a circle
(c)Drilling of holes at intervals of 3 cm on any straight line on XY plane
(d)None of the others

1.In a CNC machine, complex profiles are cut with the help of

- Synchromesh gear boxes in every feed axes of machine
- A combination of axes velocities which are infinitely variable
- Cam control
- None of the others

An innovative student develops a tachometer (instrument which can measure rotational speeds of rotating shafts) by employing simple digital devices. The figure shows a motor shaft connected to the input shaft of the tachometer. When the motor rotates, it makes the input shaft rotate at the same speed. The input shaft has an encoder mounted on it with 64 holes. The 8-bit position down counters are down-counted by the pulses they receive, each pulse making 1 decrement. After connecting the input shaft to the rotating shaft of the motor (whose rpm is to be measured), the two PDCs are filled completely and instrument is started. If PDC1 = 0 and PDC2 = 204, whats the rpm of the motor?



- The rate at which pulses are coming from the motor encoder = 64*N (Where N = rps)
- Time required to empty PDC1 = 255/(64*N)
- Time required to reduce PDC2 to 204 = 51/64
- 255/(64*N)=51/64

How much is the speed of the motor shaft if instrument shows unchanging values of PDC1 = 0 and PDC2 = 204 after some time.
How much is the speed of the motor shaft if instrument shows unchanging values of PDC1 = 204 and PDC2 = 0 after some time.

- Let us suppose that the motor speed is N rps
- Hence, the pulse rate output from the encoder is

$= N \times 64$ pps

PDC1 contains 11111111 = 255 at the start, and that is decremented to 0 in t seconds.

So, $t = \frac{255}{64 \times N}$ and with same logic, from PDC2

$t = \frac{255-204}{64}$ from which, $\frac{255}{64 \times N} = \frac{255-204}{64} \rightarrow$ N = 5 rps = 300 rpm

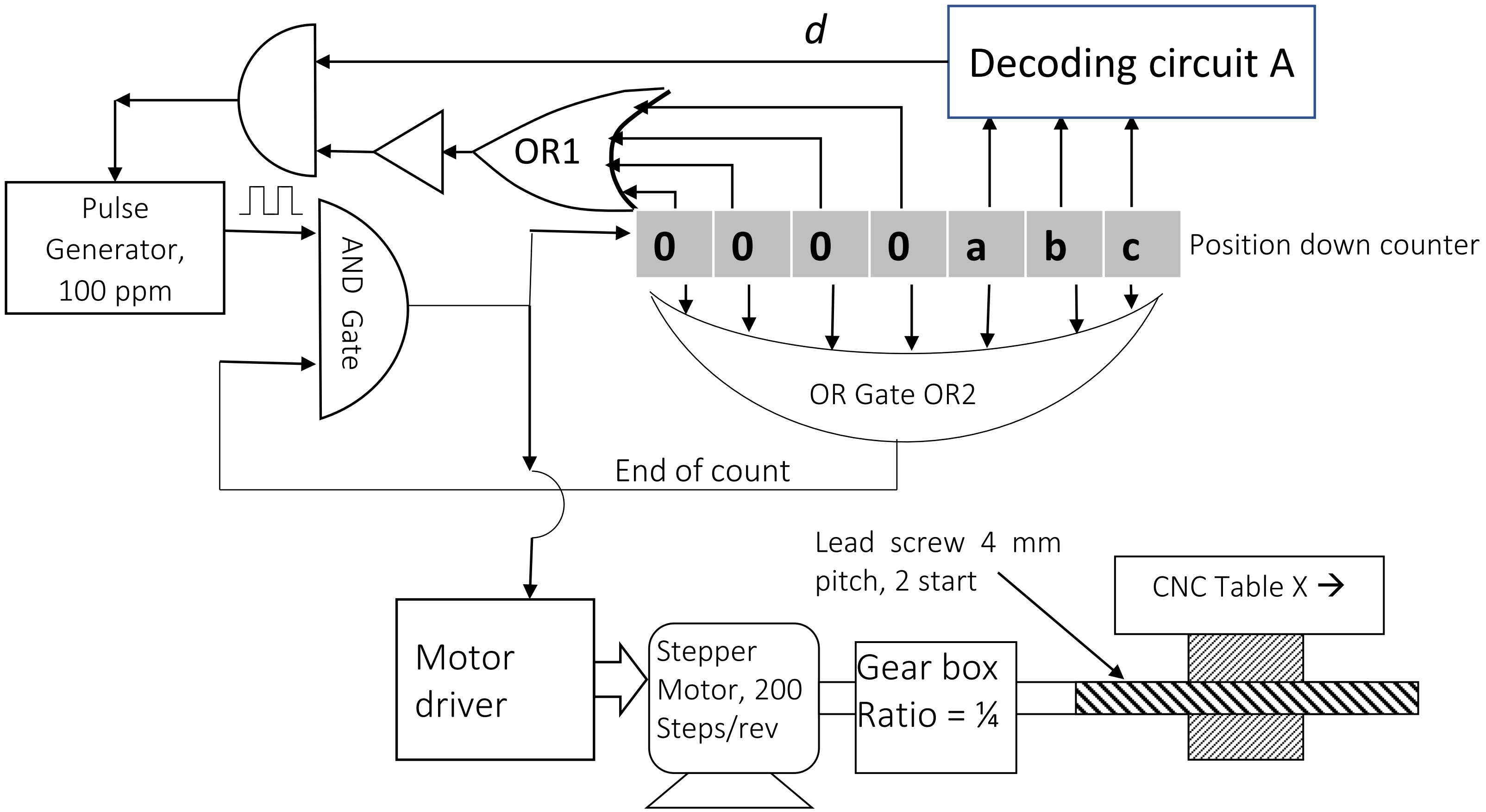
- In the same manner, for the next problem
- $\frac{255-204}{64N} = \frac{255}{64} \rightarrow$ N = 0.2 rps= 12 rpm

One problem on decoder

- In a workshop – an alarm system is incorporated such that the maintenance section is informed the moment any one or more of six machines are down. If a machine is up it emits 1 otherwise 0. The maintenance section wants a 1 as an alarm. In that case – what should be the circuit which will make this possible.

A Decoding circuit is to be designed which detects whether the CNC table is 5 BLU or less away from the target location. If so, it sends out a signal *d* = 1 to the pulse generator. Design this decoding circuit A.

Part of the required circuit is already provided. Unless the 4 most significant bits are zeros, the OR gate OR1 wont send out a 0. Now if the decoding circuit is to work , it should send out a 1 for 101, 100, 011, 010, 001 and 000. Contd. In next page….



Decoding circuit problem contd…

a	b	c	*d*
1	1	1	0
1	1	0	0
1	0	1	1
1	0	0	1
0	1	1	1
0	1	0	1
0	0	1	1
0	0	0	1

- But that would mean that from the truth table, we would get 6 terms (!!)

The method is called "Sum of Product terms"

$$d = a.b'.c + a.b'.c' + a'.b.c + a'.b.c' + a'.b'.c + a'.b'.c' = a' + b'$$

There is yet another method – the product of the sum terms → it involves less number of terms for this problem

$$d = (a' + b' + c').(a' + b' + c) = a' + b'$$

Hence the decoding circuit is $a' + b'$

a+a.b = a.1+a.b = a.(1+b) = a

- $d = a.b'.c + a.b'.c' + a'.b.c + a'.b.c'$+ $a'.b'.c + a'.b'.c'$ = a'+ b'
- =a.b'+a'.b+a'.b' = b'+a'.b = (b'+a').(b'+b) = a'+b'

$(a' + b' + c').(a' + b' + c)$= a'+b'

CNC programming : Computer numerical control programming 10th lecture

When a computer program, on being executed, successfully guides a machine tool through the sequence of motions and actions necessary for machining a part, or simulates such motions and actions on a graphic user interface, it is an example of computer numerical control programming or simply CNC programming.

G & M code programming

- G & M Code programming language is a coded language to intimate to the machine
  - The type of motion to be executed
  - The auxiliary operations to undertake

  through codes essentially preceded by G (preparatory function) or M (Miscellaneous function). Apart from such codes, parametric functions (E parametres) and three letter codes are also admissible.
- The G codes prepare the machine controls for the type of machine movements which are going to take place.
- M codes provide instructions to the machine about the auxiliary or non-cutting operations (like tool change, spindle start, coolant on etc.). They are sometimes referred to as managerial or auxiliary commands.

Types of programmed motions

- There are 4 basic types of motion for CNC machines.

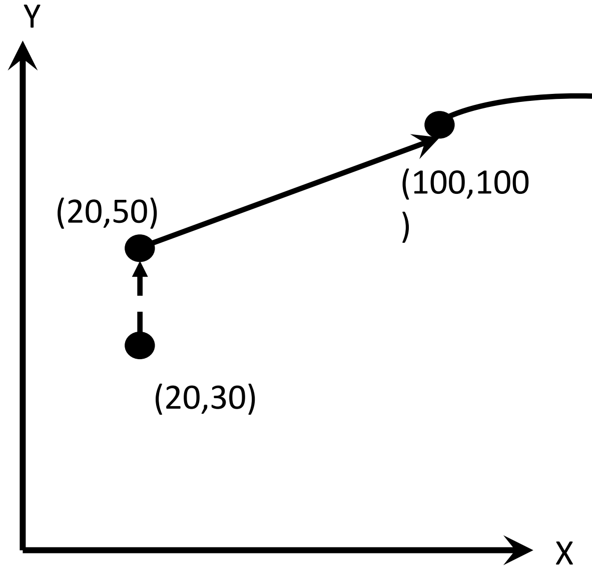
- The rapid traverse motion
- the linear motion (at controlled feedrate)
- the circular clockwise motion (at controlled feedrate)
- the circular counterclockwise motion (at controlled feedrate)

Description of the basic G codes for motion

Code	Explanation	Format
G 00	Rapid traverse	G00 X 200 Y300 Z 400
G 01	Linear motion at controlled feed	G01 X 220 Y 320 Z440 F 200
G 02	Circular clockwise motion	G02 X 250 Y 350 R 150 F200 or G02 X 250 Y 350 CX 270 CY 370 F200
G 03	Circular counter clockwise motion	G03 X 300 Y 370 R 130 F 200 or G02 X 250 Y 350 CX 270 CY 370 F200

Example of typical command blocks

- N006 G90 G00 X20 Y30
- N007 Y50
- N008 G01 X100 Y100 F200
- N009 G02 X140 R200
- N010 M30



Program – starting declarations

- Program may start with a number of declarations
- Whether we want an incremental or absolute system of reference
- Whether a number of options, if previously activated, are to be cancelled
- Whether there is a declaration on the type of coordinate system or offset from such a coordinate system
- Whether there is any declaration on tool / cutter and its length and diameter offsets

```
N001    G90 G40 G49 G80 G53 X0 Y0 ZO;
N002    M6 T12;
N003    G0 G90 G56 X-10 Y-10;
N004    M3 S2000;
N005    G43 H12 Z50;
```

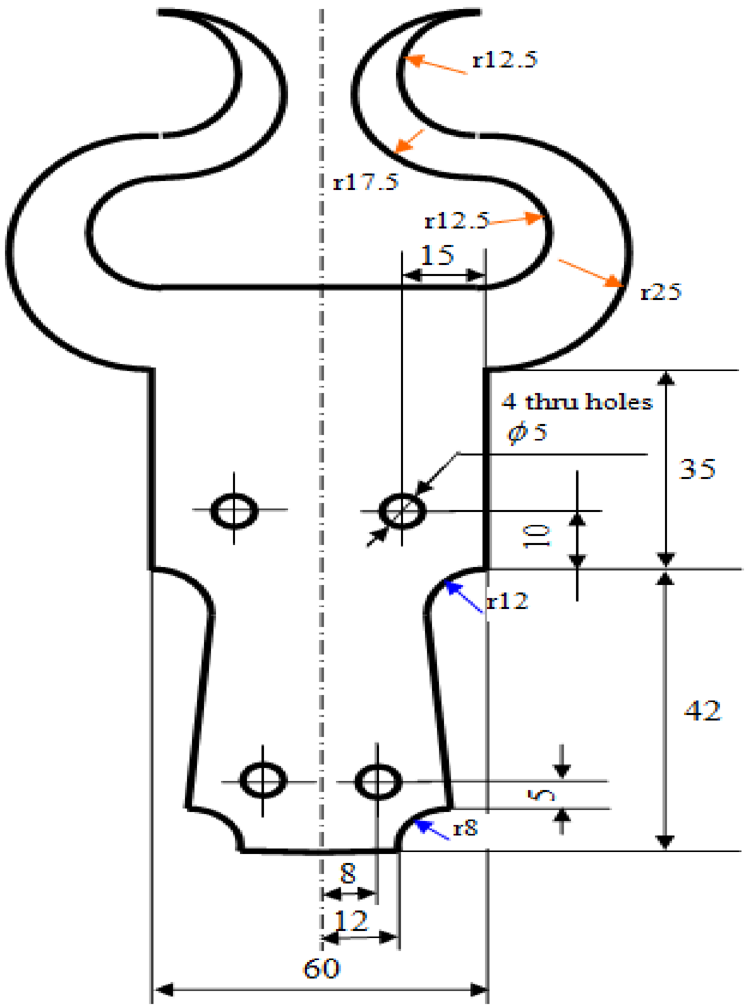
Program structure – main program

- The main body of the program may contain the various movements required
- Alternatively – it may contain calls to subroutines which in their turn – contain various motion commands
- A typical program may have a structure as follows

Mirror Imaging
Linear interpolation
Circular interpolation
Tool length offset
Tool diameter offset

Subroutine call
Canned drilling cycle
Repeat loop
Cutter diameter compensation
Cycle cancellation

Example programs

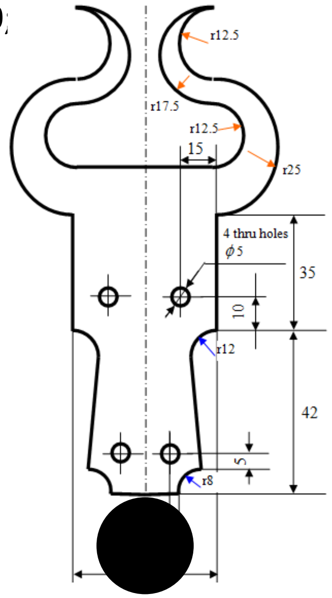


Mirror Imaging
Linear interpolation
Circular interpolation
Tool length offset
Tool diameter offset

Subroutine call
Canned drilling cycle
Repeat loop
Cutter compensation
Cycle cancellation

Program

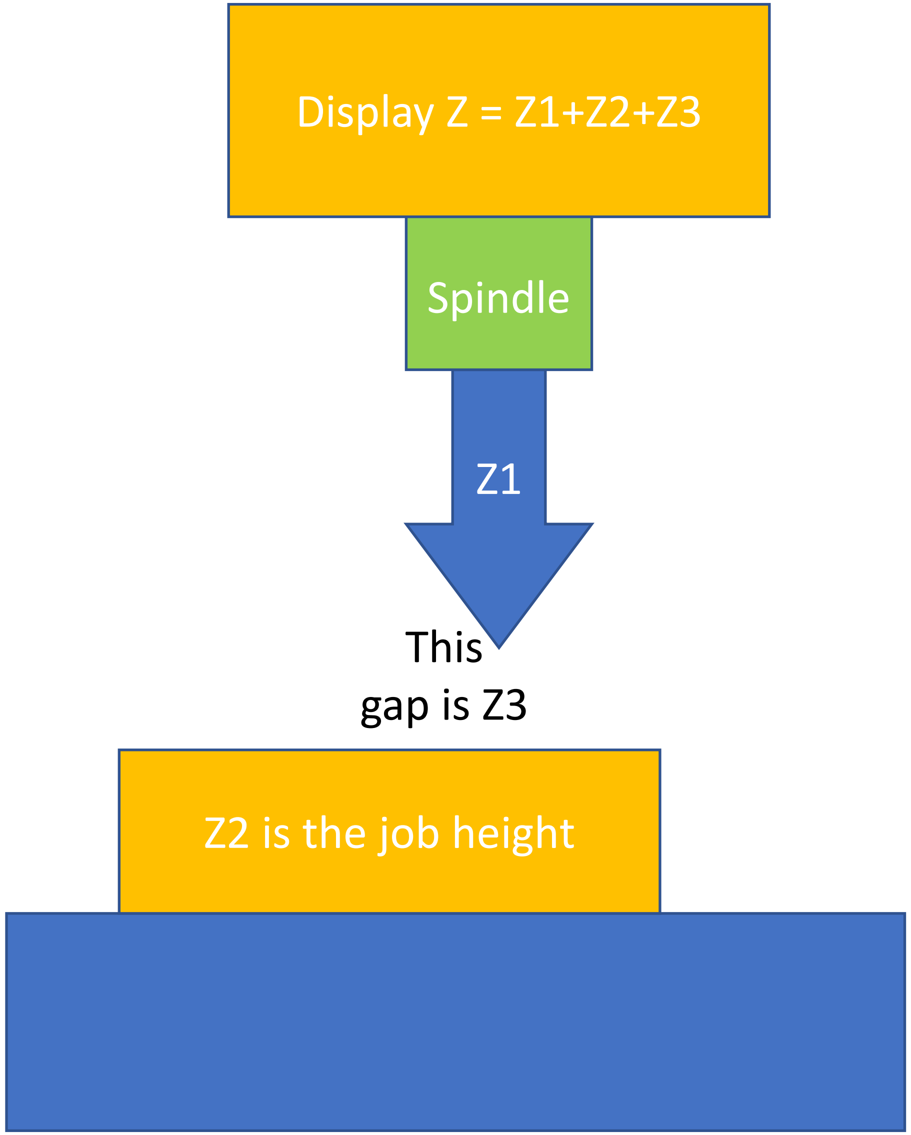
Main Programme: (P0036)
N100 G90 G0 G40 G49 G80 G53 X0 Y0 Z0;
N101 T12 M6;
N102 G90 G56 G17 X0 Y-10;
N103 G43 H12 Z50;
N104 M98 P0037;
N105 G51.1 X0;
N106 M98 P0037;
N107 G0 Z30;
N108 G50.1 X0;
N109 M98 P0038;
N110 M05;
N111 M02;
N112 M30;



- Milling subroutine
- N02 M03 S1200 F500;
- N03 G42 D03 G00 X0 Y0;
- N04 Z -2.0;
- N05 G01 X12 Y0;
- N06 G02 X20 Y8 R8;
- N07 G01 X18 Y30;
- N08 G02 X30 Y42 R12;
- N09 G01 X30 Y77;
- N10 G03 X30 Y127 R25;
- N11 G02 X30 Y152 R12.5;
- N12 G03 X30 Y117 R17.5;
- N13 G02 X30 Y92 R12.5;
- N14 G01 X0 Y92;
- N15 G01 Z30;
- N16 G40 Y-12;
- N17 M05;
- N1 99;

Drilling Subroutine: (P0038)

N50 G90 G40 G49 G80 G53 X0 Y0 Z0;
N51 M06 T04;
N52 M03 S1500;
N53 G56 G0 G90 X0 Y0;
N54 G43 H04 Z20;
N55 G81 G99 X8 Y13 Z-3.5 R15 F100;
N56 X-8 Y13;
N57 X-15 Y52;
N58 X15 Y52;
N59 G0 Z30;
N60 G0 X0 Y0;
N61 M05;
N62 M99;


Display Z = Z1+Z2+Z3
Spindle
Z1
This gap is Z3
Z2 is the job height

Program start
Call Milling
Mirror imaging
Call Milling
Cancel Mirror
Call drilling

- Milling subroutine

- Drilling subroutine

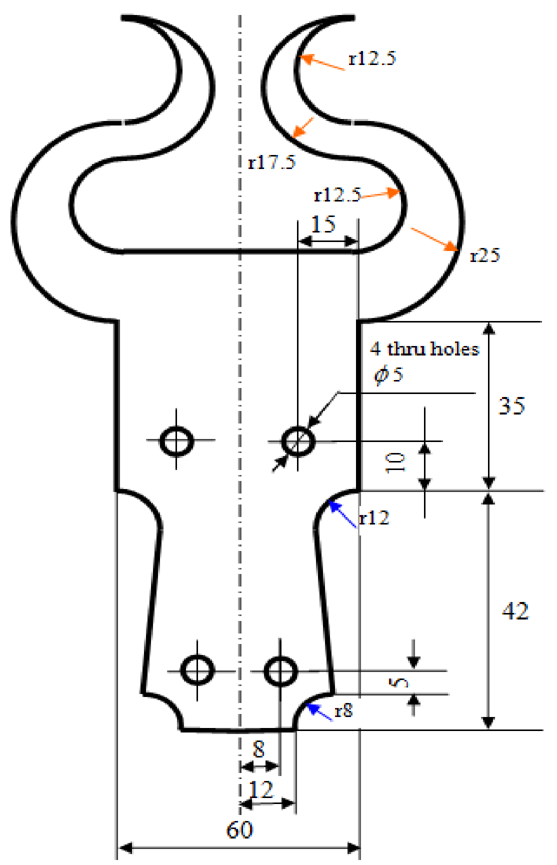
- G00 – Rapid traverse
- G01 – Linear
- G02 – Circular CW
- G03 – Circular CCW
- G20 – Cancel GTL
- G21 – Enable GTL
- G40 – Cancel cutter radius compensation
- G41 – Cutter radius compensation left
- G42 – Cutter radius compensation right
- G81 – Canned drilling cycle
- G90 – absolute programming
- G91 – Incremental programming

- M00 – program pause
- M03 – Spindle on
- M05 – Spindle off
- M06 – Tool change
- M08 – Coolant on
- M09 – Coolant off
-
- CLS – call subroutine
- RPT – Repeat
- URT – rotate coordinate system
- UOT – use temporary origin
- UAO – Use absolute origin
- ERP – End of Repeat

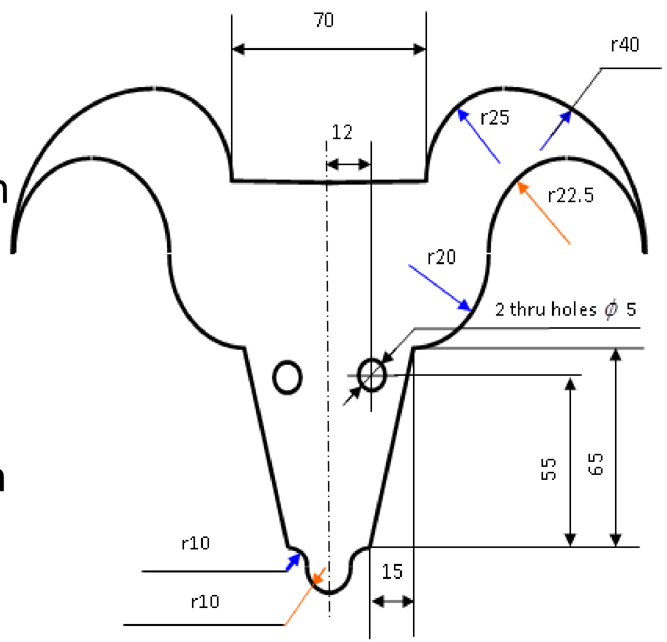
Programming practice - II

11th Lecture in the open online course “Computer Numerical Control (CNC) of Machine Tools and Processes

Example programs



Mirror Imaging
Linear interpolation
Circular interpolation
Tool length offset
Tool diameter offset
Subroutine call
Canned drilling cycle
Cutter compensation
Cycle cancellation



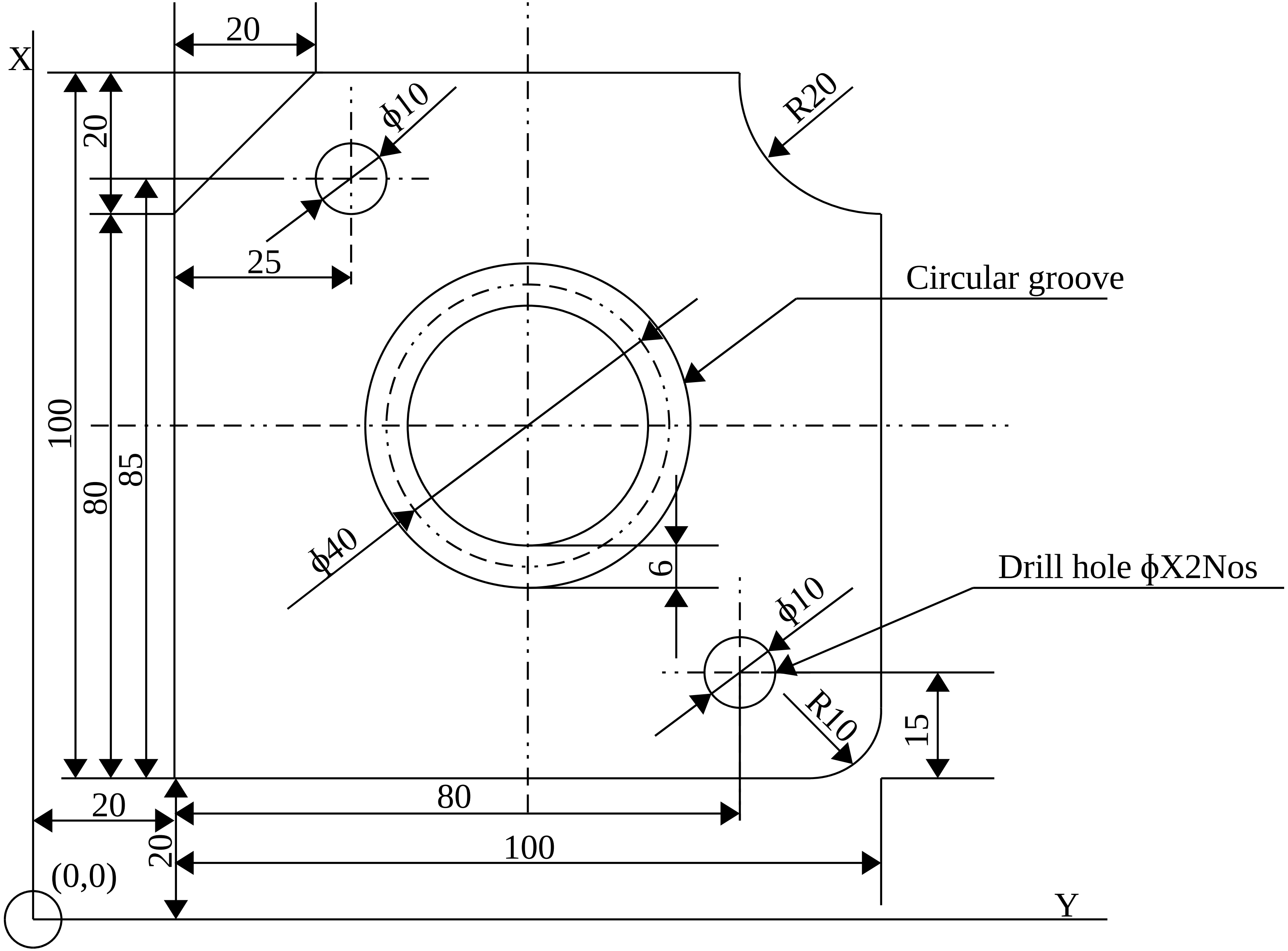
Program structure

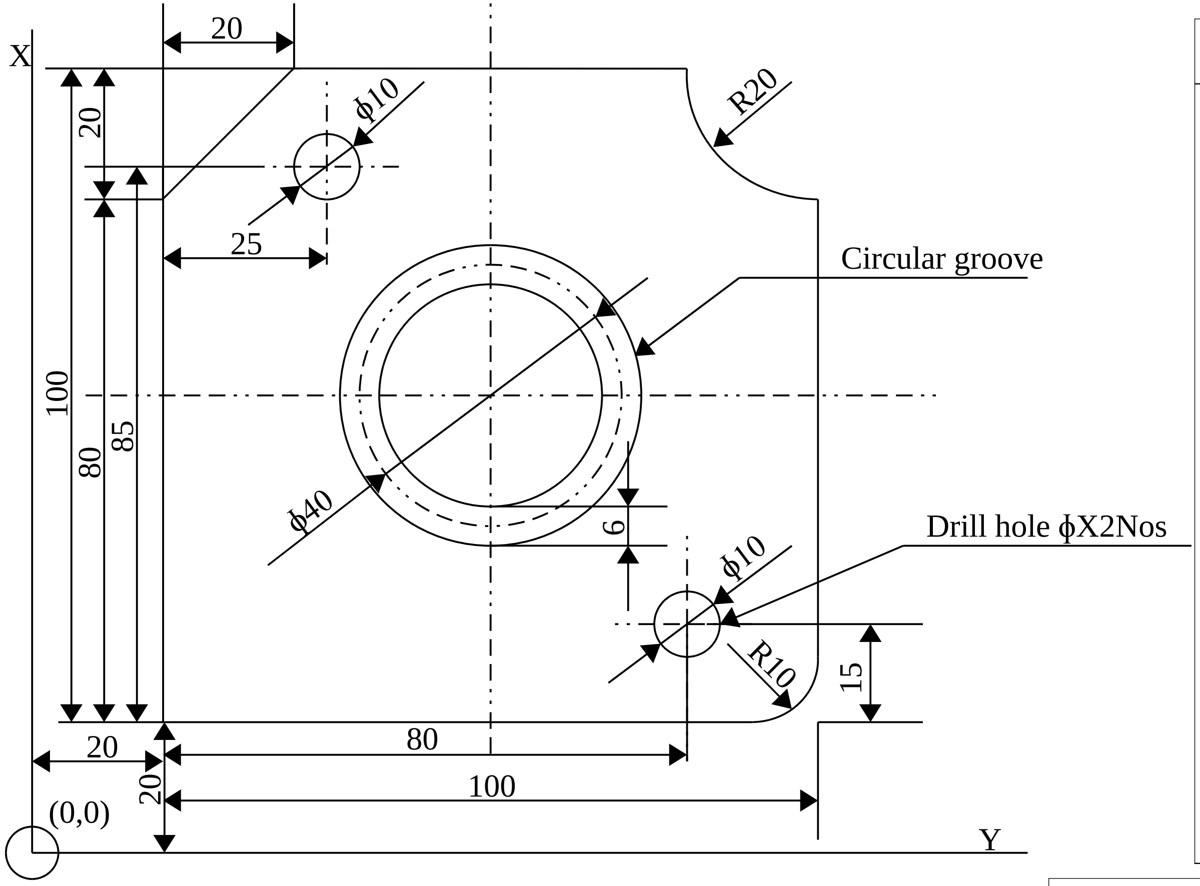
Program start
Call Milling
Mirror imaging
Call Milling
Cancel Mirror
Call drilling

- Milling subroutine

- Drilling subroutine

Job for Machining Centre





Program for machining centre job

```
G90 G0 G40 G49 G80 G53 X0 Y0 ZO;
T18 M06;
G0 G90 G56 G17 X20 Y20;
G43 H18 Z50;
M03 S1500;
G90 G0 Z10;
G42 D18 G01 X20 Y20 F500;
G01 Z-2.5;
G01 X110;
G03 X120 Y30 R10;
G01 Y100;
G02 X100 Y120 R20;
G01 X40;
G01 X20 Y100;
GO1 Y20;
GO1 Z5;
G40 G0 X70 Y50;
G01 Z-2.0 F100;
G03 X70 Y90 R20 F500;
G03 X70 Y50 R20;
G01 Z5;
G00 G53 Z0;
M05;
T06 M06;
G0 G56 G90 X100 Y35;
G43 H06 Z50;
M03 S1000;
G81 G99 X100 Y35 Z-2.5 R15 F100;
X45 Y105;
G80 G90 G53 G0 Z0;
M05;
M30;
```

G codes

G00 – Positioning (Rapid)
G01 – Linear interpolation
G02 – Circular interpolation (CW)
G03 – Circular interpolation (CCW)
G04 – Exact stop
G17 – X_p Y_p Plane selection
G18 – Z_p X_p Plane selection
G19 – Y_p Z_p Plane selection
G40 – Cancellation of CRC
G41 – Cutter radius compensation (Left of side)
G42 – Cutter radius compensation (Right of side)
G43 – Activating cutter length compensation
G49 – Compensation de-activating cutter length
G53 – Selection of M/C co-ordinate system
G56 – Work co-ordinate system
G80 – Cancellation of canned cycle
G81 – Canned cycle(Drilling cycle)
G99 – Return to “R” point in canned cycle
G90 – Absolute command
G91 – Incremental

M CODE

M01 – Optional stop
M03 – Cutter rotation CCW
M04 – Cutter rotation CW
M05 – Spindle stop
M06 – Tool change
M08 – Coolant ON
M09 – Coolant OFF
M30 – Program stop