Computer Numerical Control of Machine Tools and Processes
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Lecture 15
Questions on Programming and Interpolation

Welcome viewers to the 15th lecture in the open online course "Computer numerical control of machine tools and processes". So we will be discussing about programming, interpolation, computer-aided off-line programming, et cetera, 1st let's have one MCQ.

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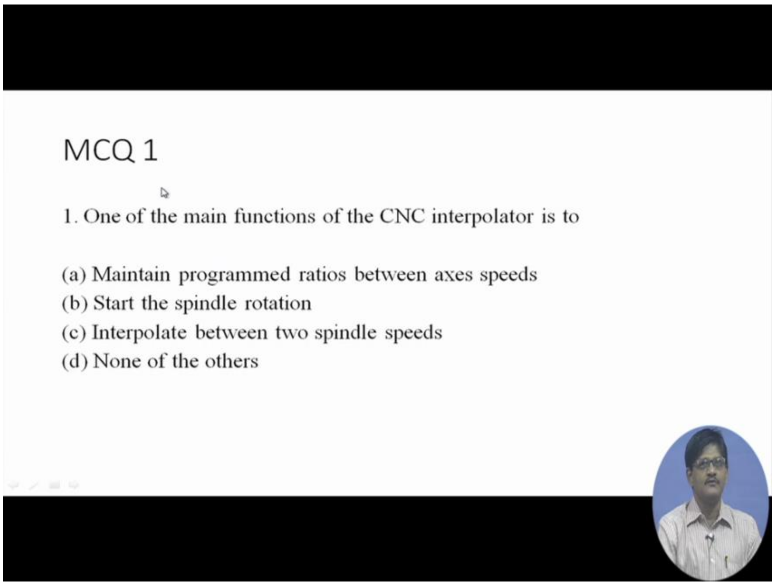

One of the main functions of the CNC interpolator is to… (a) Maintain programmed ratios between axes speeds that means maintain whatever ratio between V x, V y and V z has been programmed to maintain that. (b) start the spindle rotation, (c) interpolate between 2 spindle speeds, (d) none of the others. Here the correct answer is, maintain programmed ratios between axes speeds, why? The 2 main the 2 functions of CNC interpolator is, 1 to maintain programmed ratios between axes speeds and to maintain the programmed absolute feed value along the cutter path.

So along the cutter path we have to maintain a particular feed rate and along the different axes like X, Y, Z, we have to maintain the correct ratios of these axes feed values that ensures that the correct profile or contour will be cut. In CNC we are having no part specific jigs or templates or cams, et cetera, but all the cutter paths which are to be executed, they are executed by maintaining correct ratio between axes speeds or programmed ratio between axes speeds, so A is the correct answer.

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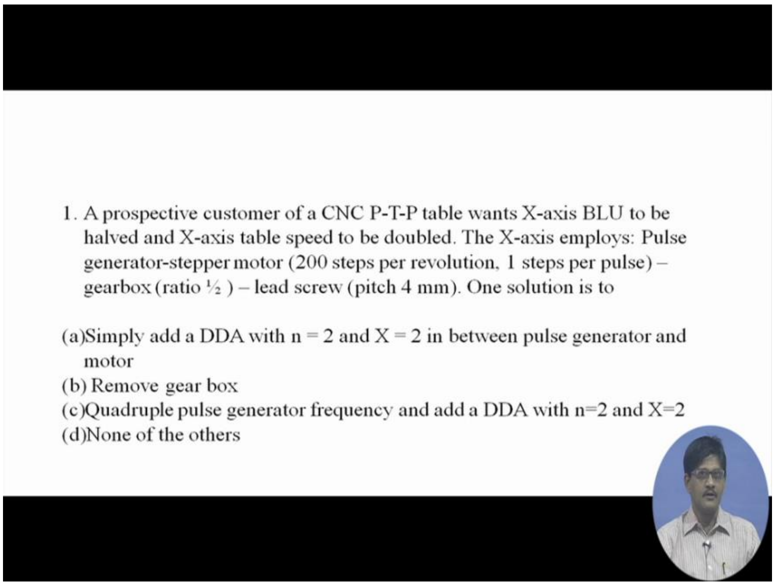

A prospective customer of a CNC point-to-point table wants X-axis basic length unit to be halved and X-axis table speed to be doubled, so this is quite expected you would like basic length unit to be less and speed to the higher. The X-axis employs Pulse generator stepper motor which is having 200 steps to carry out one revolution and one step per pulse gearbox with ratio half and lead screw with a pitch of 4 millimeters. I have not included the drawing because we have done so many of these problems till now, you would be easily able to grasp what we are talking about. So 4 possible solutions are given in order to get half the basic length unit and double the table speed.

Simply add a DDA with n = 2 and X = 2 in between pulse generator and motor so that the motor is now going to get pulses at a different rate. This is definitely not the answer because when speed has to be doubled, we include a DDA in between pulse generator and motor, speed will only be reduced because the DDA cannot develop any pulse rate equal to the input pulse rate, it always has to be less. So this definitely cannot be the answer because table speed will definitely become lower. Remove the gearbox, what if we remove the gearbox? Okay, speed will be doubled because the ratio of the gearbox was half and since this is removed, speed will not be half but it will be double of the previous value, but this will definitely affect the basic length unit which will become double as well.

So removing gearbox will definitely not solve the problem because basic length unit is going to become higher, so we are not even doing the calculation though I have included one calculation page. Quadruple pulse generator frequency that means make the pulse generator frequency 4 times and add a DDA with n = 2 and X = 2 okay, this has a possibility we will check this because pulse generator frequency once it is getting increased, there is a fair chance that they might be getting double the speed and none of the others, so let us see the answers.

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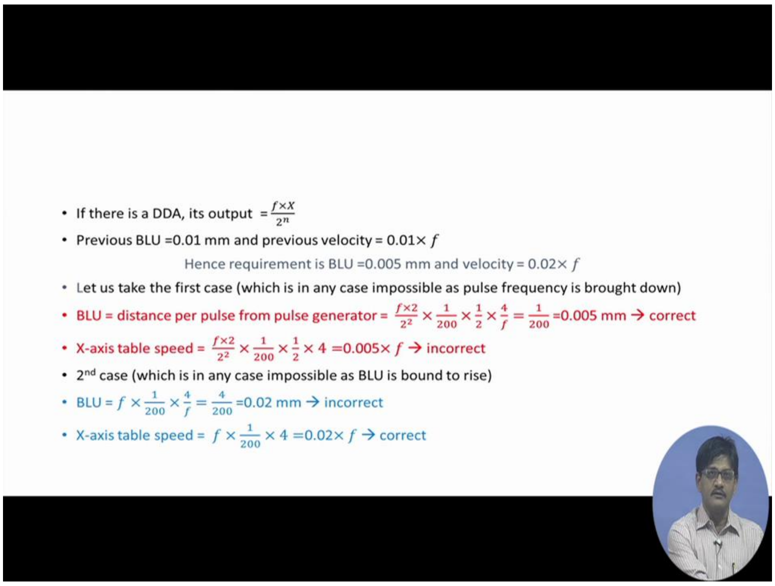

I have included the calculation for the first 2 cases, but I also include this particular I would like to remind you once again that these two can definitely not give us the answer for the reasons that we discussed just now. 1st of all what was the previous case, if you do the calculation okay with gearbox half and lead screw 4 and stepper motor 200 pulses per revolution, et cetera, you will come up with basic length unit equal to 10 millimeters and previous velocity equal to 0.01 of the input frequency okay. So the requirement therefore would be half the basic length unit means 5 microns and the velocity to be 0.02 of the input frequency that means double of the previous one 0.01.

So this is our requirement, if this is the requirement we can carry out calculation for the basic length unit and the X-axis table speed, these calculations could be carried out. I have included them, you can refer to them but we are definitely not going to discuss them because as we have discussed previously speed can never be doubled by this process, so we need not even consider it.

In the 2nd case, we are having calculation of basic length unit to be incorrect that means it does not fulfill the condition that it is half the previous basic length unit, why? As we discussed, if you remove a gearbox which was doing a reduction in the speed, it was also reducing the basic length unit and if you remove it, obviously you are not going to get half the basic length unit, so it must be incorrect.

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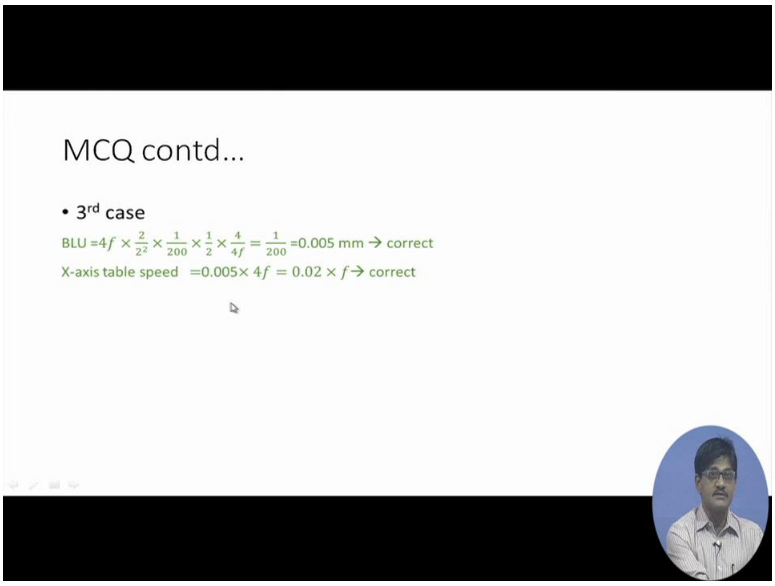

The third case I have included a calculation, what is that? Starting with the frequency of 4 times previous frequency, we passed through the DDA with the you know with the formula $f \times X/2^n$ to the power n, here the frequency is 4f, here X = 2 as mentioned in the problem, here n = 2, the first 3 terms when multiplied together will give us the stepper motor number of rotations per unit time. So after this if we multiply the gearbox ratio because the gearbox is still there, so this is input frequency, this is DDA, this is stepper motor rotation, this is gearbox multiplication and this is the lead screw pitch per number of input pulses. So that is why it is divided by 4F and we get equal to $1/200$ = 0.005 that means 5 microns, this is correct that is what we want it. In the table speed must be equal to number of basic length unit × the number of pulses simple, and that means that we are going to get 0.02× F, which is also correct, so the 3rd combination will give us the correct values of basic length unit and what you call it table speed, so option number C is correct.

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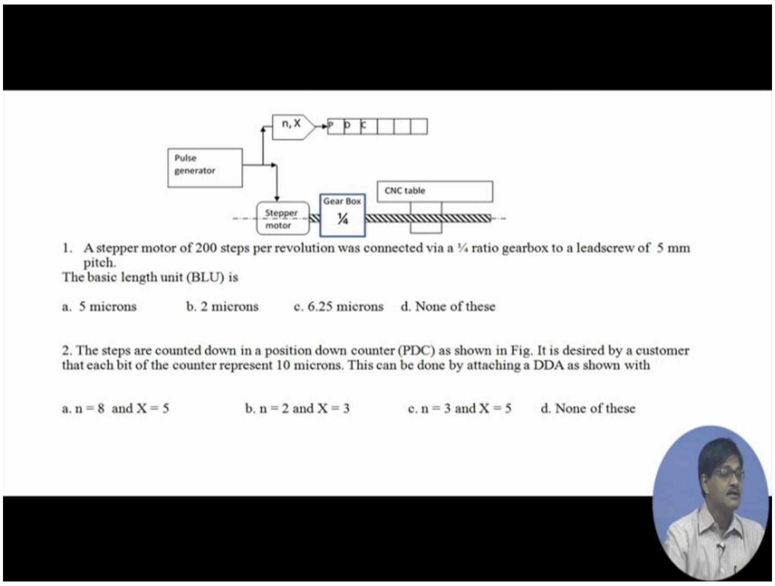

Next Question says, a stepper motor of 200 steps per revolution okay was connected via a 1 4th ratio gearbox to a lead screw of 5 millimeters pitch, the basic length unit is, we have to find out the basic length unit. Once again this is this calculation is obvious, we will have $1/200 \times 1/4$ which means $1/800 \times$ the lead screw pitch, which is 5 so 5 divided by 800 will give us 6.25 microns. Let us see yeah, $(1/ 200 \times ¼)\times 5$, this is equal to 0.00625 millimeters, which means 6.25 microns okay that is good so after that let us see the 2nd MCQ.

The 2nd MCQ says, the steps are counted down in a position down counter, this is the figure in which the position down counter is shown and it is desired by a customer that each bit of this counter represent 10 microns. At present each bit will be representing 6.25 microns, but the customer says I want this to be 10 microns. This can be done by so a solution is being provided, this can be done by attaching a DDA has shown with… n = 8 and X = 5, if you remember n is the number of bits inside the counters present here and X is the content of that counter, which is getting added to itself again and again okay, I mean added to the result of previous additions.

So if we recall that, the table is getting moved by 6.25 microns per pulse, so by the time you send 8 pulses to the stepper motor, if you can send 5 pulses to the position down counter, everything will be balanced that means 8 basic length units will be equivalent to 5 bits representing 10 microns each, 50 microns for both.

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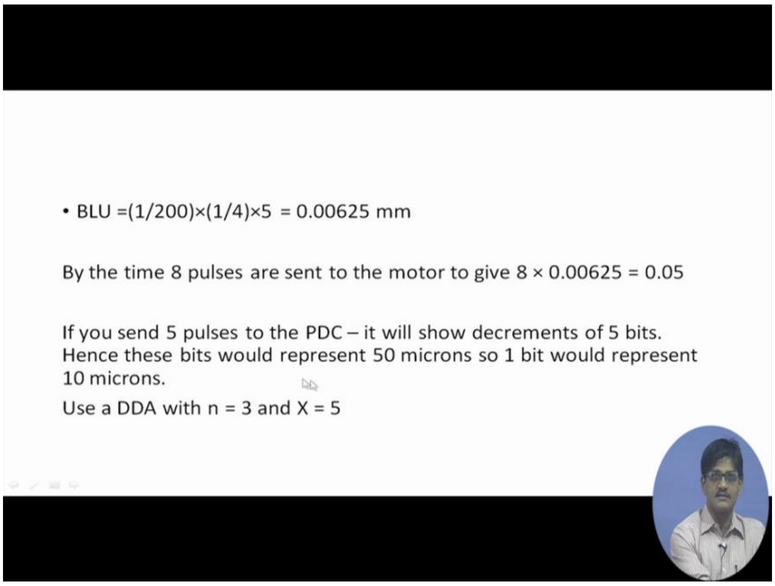

So by the time we send 8 pulses here, we should send 5 pulses to the position down counter which means that if X = 5 and n = 3 therefore, this particular pulses coming out here will be input pulse rate × 5 divided by 2^3 that means 5 /8 and that will satisfy all conditions. So I have written down the answer here just like we discussed, if you send 5 pulses to the position down counter, it will show this decrements of 5 bits that is correct. Hence, these bits would represent 50 microns so one bit should represent 10 microns.

What we have initially stated is that by the time 8 pulses are sent to the motor to give 50 microns or 0.05 millimeters, if we can send 5 pulses to the position down counter at the same time, it will serve our purpose. So use a DDA with n = 3 and X = 5 so that its output pulse frequency will be input pulse frequency × 5/8, so correct answer would be number C, n = 3, X = 5.

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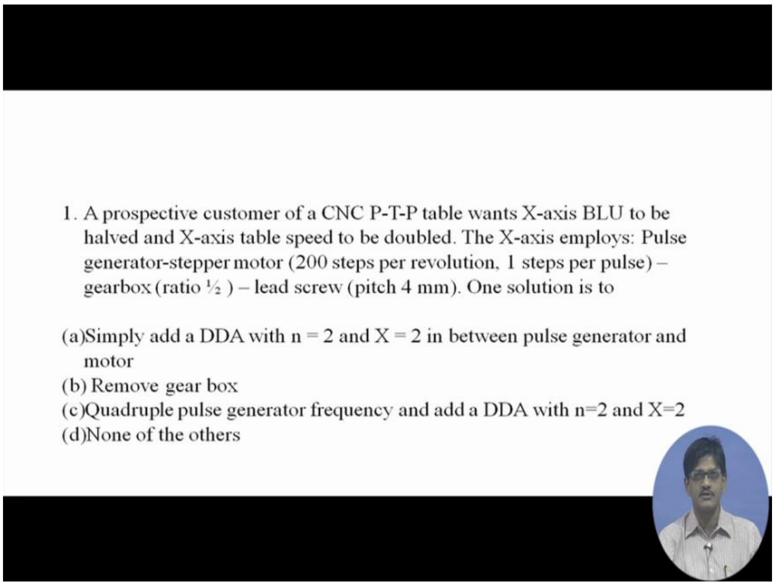

The feed in millimeters per minute along X-axis corresponding to the program line G91 G01 X40 Y30 F50 is… 40, 50, 30, none of the others. So 1st of all what we notice is that linear interpolation is taking place that means straight-line motion with a particular feed rate and G91 means that incremental motion is being carried out. Incremental motion means 40 along X that means 40 millimeters of movement is taking place along X, 30 millimeters of movement taking place along Y, so we understand that the velocities along X and Y will also be in this ratio because in linear movement that means in straight-line movement, the velocity triangle is similar to the displacement triangle.

So movement along X and Y will be 4 **:** 3 and therefore, feed velocity which is 50 along the main path, it will be in the ratio of 40 millimeters per minute along X and 30 millimeters per minute along Y, so that 40^2 + 30^2 will give us 50^2 ,so 40 millimeters along X-axis is the answer that means A is the correct answer.

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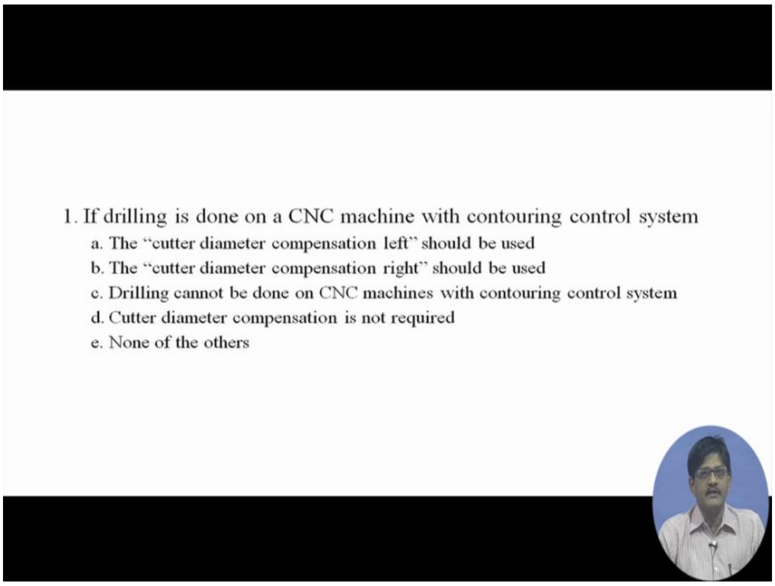

If drilling is done on a CNC machine with contouring control system, so we have a machine with contouring or continuous control system say machining centre milling machine okay, in these machines suppose you are carrying out drilling then 1st option reads, the "cutter diameter compensation left" should be used,(b) the "cutter diameter compensation right" should be used, (c) drilling cannot be done on CNC machine with contouring control system, cutter diameter compensation is not required and (d) none of the others. The first two options, cutter diameter compensation left or right, they are not relevant to this discussion because in point-to-point operations like drilling cutter diameter compensation does not come into the picture, it is not required.

Drilling cannot be done on CNC machine with contouring control system, this is also not correct because machine which can carry out or which has contouring control or continuous control system, it can also carry out point-to-point operations, so C is also not correct. Cutter diameter compensation is not required, this is correct so D is the correct answer.

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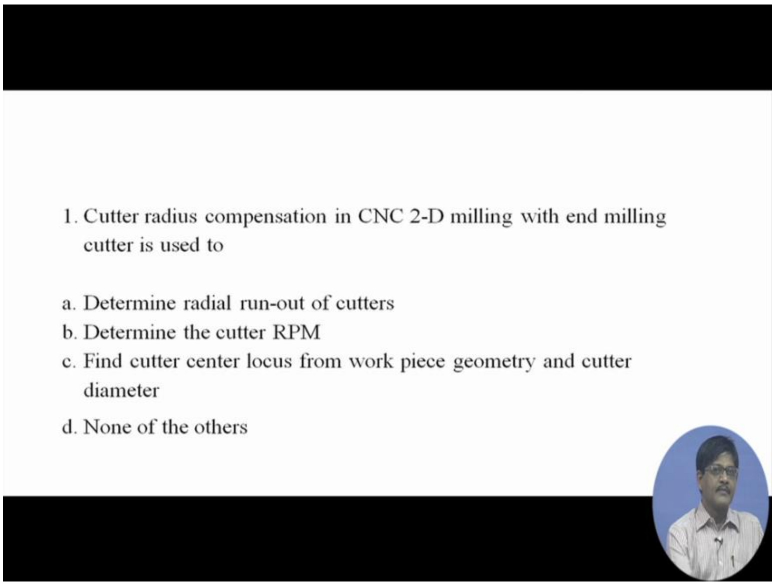

Cutter radius compensation in CNC 2 dimensional milling with end milling cutter, so cutter radius compensation is it means the same thing as cutter diameter compensation for all practical purposes in this question. Cutter radius compensation in CNC 2 dimensional milling with end milling cutter that means maybe you are cutting all around a particular contour in 2 dimensions, so it is used to… (a) Determine radial run out of cutters, (b) Determine the cutter RPM, (c) find cutter centre locus from work piece geometry and cutter diameter, (d) none of the others.

Here the third; number C is correct because if you are cutting all around a particular contour in 2 dimensions, what happens is that the cutter centre moves around in a particular locus and it is difficult to determine this cutter centre locus without applying number of equations I mean number of coordinate geometry formulae and equations. So instead of that we can intimate to the computer about the geometry of the work piece and the cutter diameter and that way the computer can find out for us the cutter centre locus. The cutter is not a point object, but it has a finite diameter so that makes the centre line locus move away from the work piece Contour, so C is correct.

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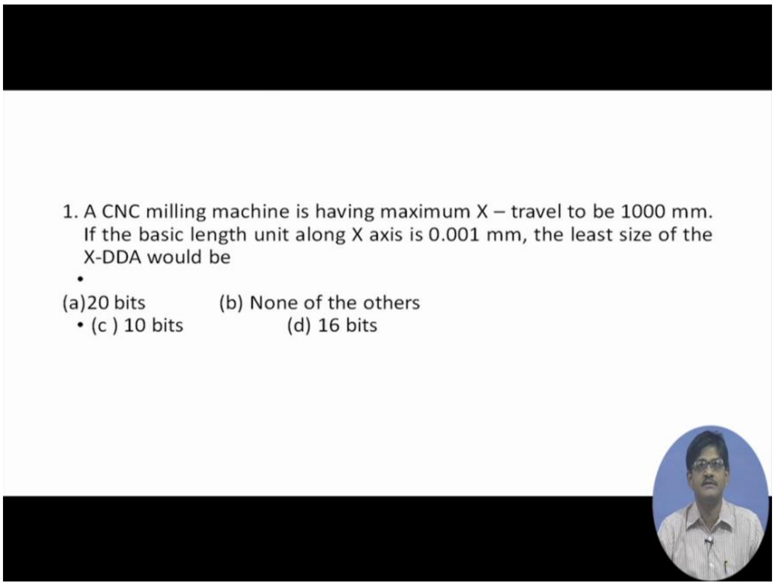

A CNC milling machine is having maximum X-travel to be 100 millimeters. If the basic length unit along X axis is 0.001 millimeters, the least size of the X-DDA, so we are talking about the linear interpolator here or for that matter hardware interpolator and this we are referring to the X Digital differential analyzer in that interpolator. So if the maximum X-travel the 100 millimeters, then the and the basic length unit be 0.001 millimeters, in that case the least size of the X-DDA would be… (a) 20 bits, (b) none of the others, (c) 10 bits, (d) 16 bits. Here I will leave the problem to you, you have to choose first you have to find out 1st of all what should be the maximum number which has to be accommodated inside the X-DDA, how can we find that out?

The travel that the CNC machine might have to carry out along X might well be the maximum possible one which is coming out from these figures. 100 millimeters divided by the basic length unit gives us the total number of basic length unit which are contained in the maximum possible travel, so 1000 millimeters, 1000 divided by 0.001 that means 10^6 basic length unit, so we have to find out the size of the X-DDA which would be able to accommodate 10^6 for example, if you have 16 bits the size of the DDA will be maximum number which can be accommodated is 2^{16} - 1.

So what you have to do is, open your calculators, find out, you have to find out 2^{20} - 1, 2^{16}- 1, 2^{10} - 1 and find out the 1 which is the smallest number which can accommodate 10^6 so I leave this to you I am sure that you will be able to solve it.

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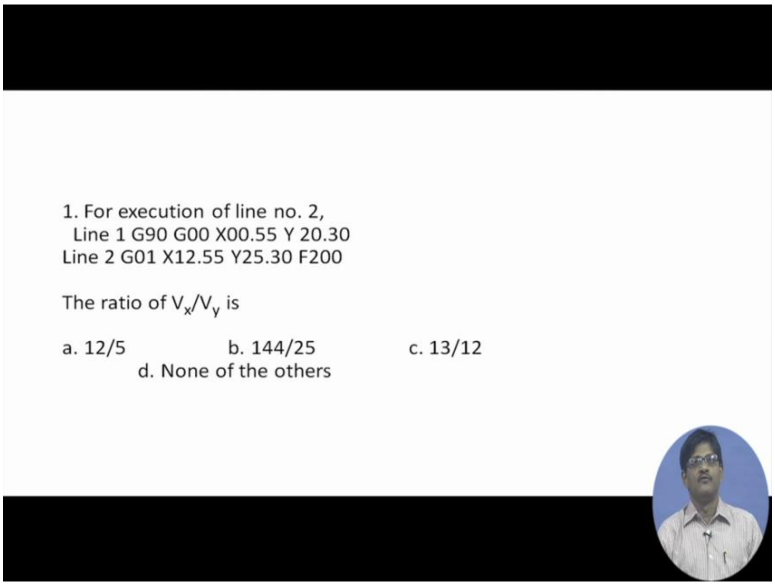

For execution of my number 2, the ratio of Vx/Vy is… so this is again from interpolators. So we have line number 1 G90, G90 means that we are having absolute motion, so G90 G00 X00.55 and Y20.30. Line number 2 reads G01 that means we are now moving in a linear with linear interpolation X12.55, so as we are having absolute motion the incremental motion from line number 1 to line number 2 the incremental motion along X is 12 millimeters and the incremental motion along Y is 5 millimeters, 12 millimeters along X, 5 millimeters along Y and feed is 200, so the ratio of V x and V y is required. Ratio of V x and V y will be as ΔX divided by ΔY, which means 12/5 so the 1st option is correct.

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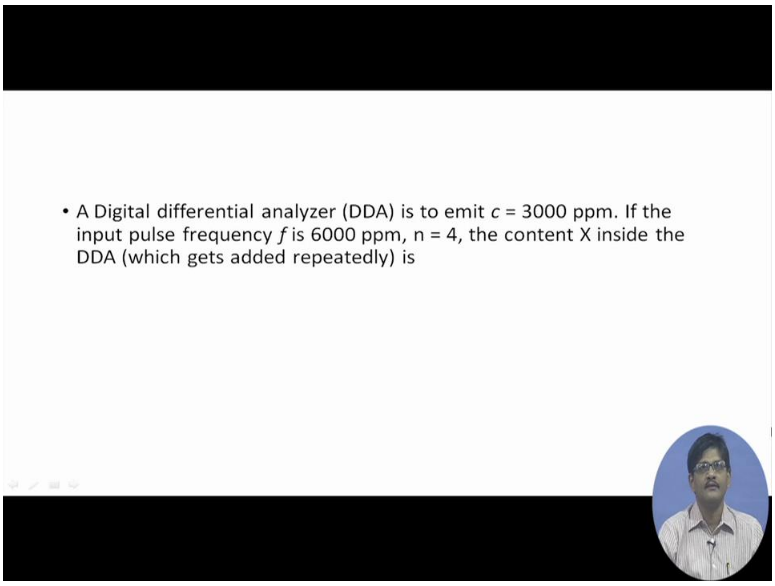

A Digital differential analyzer is to emit 3000 pulses per minute. If the input pulse frequency F is 6000 pulses per minute, so *f* is 6000 and n is 4 bits, the content inside the DDA which gets added repeatedly is? It can be calculated as follows:

$(X/2^4) \times 6000 = 3000$

Or, $X=8$

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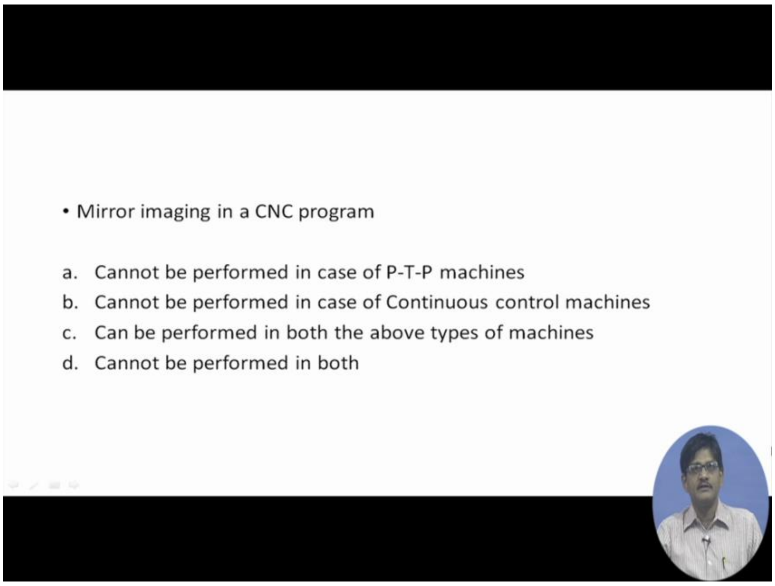

Mirror imaging in a CNC program… (a) Cannot be performed in point-to-point machines, (b)cannot be performed in case of continuous control machines, (c) can be performed in both the above types of machines, (d) cannot be performed in both. So D is obviously wrong, if it cannot be performed in both it would not have existed. And A and B they are also wrong, Mirror imaging can be carried out both in point-to-point as well as continues control machines, so option C is correct.

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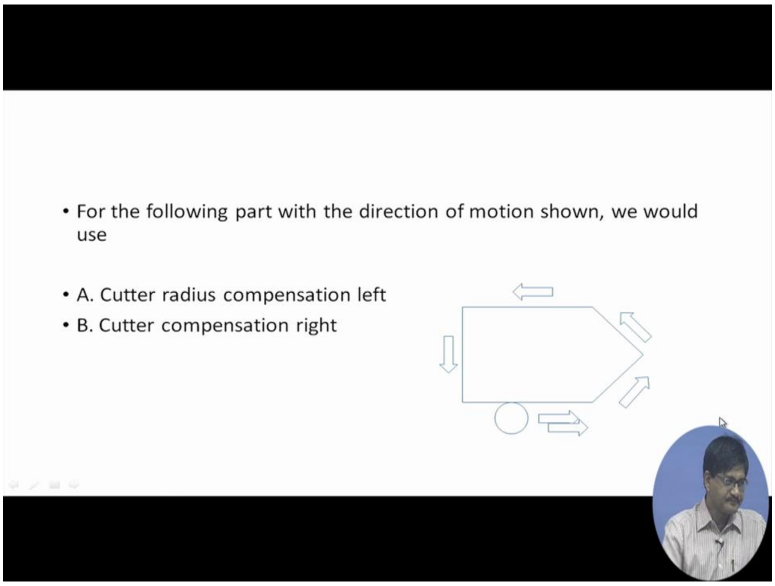

For the following part with the direction of motion shown, we would use… (a) Cutter radius compensation left and (b) cutter radius compensation right, which one would be the one that we are using. So the cutter is shown as the small circle here, the cutter is seen from the top, it it is say simply a milling cutter moving like this, rotating and moving like this all around, so the direction of motion is right wards and looking in the direction of motion and we find that cutter has to be shifted towards the right side from the the work piece contour, so this is the work piece contour. And if we have to shift the cutter to the right-hand side looking in the direction of cut then it is right tool compensation, so B is correct, cutter compensation right has to be used here which is G42, B is correct.

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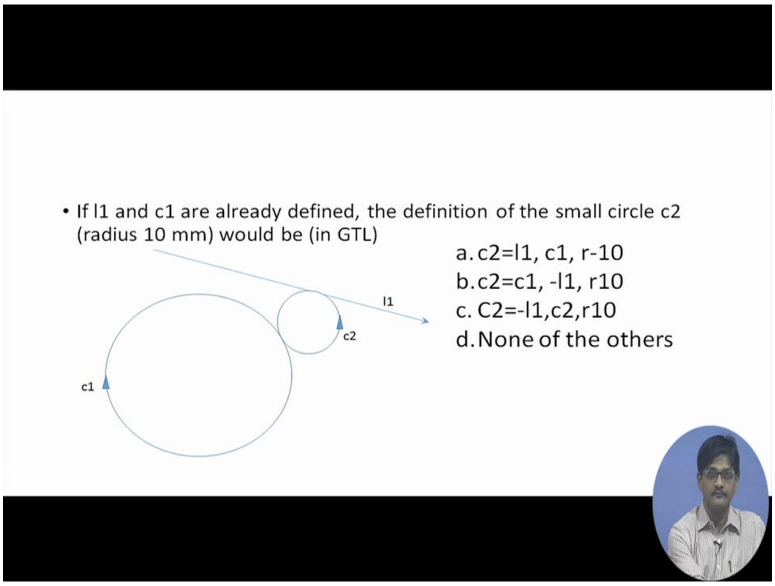

So 1 GTL example, if L1 and C1 are already defined, let us see which one is L1, L1 is this line directed towards the direction as shown in the figure and C1 is this circle with the clockwise sense of rotation, these directions of rotations or sense, these are incorporated in the very definition of these lines and circles. The definition of the small circle C2 with radius 10 millimeters would be (in GTL)… (a) C2 = L1, C1, R - 10, etc, some options are provided. Let us see which one can be can be the correct one, let us see 1st one. Driving along L1, you want to shift your car to the lane C1, so you are driving along L1, you are starting from here, you are moving this way, you take this particular shortcut okay and this diversion leads you to this particular route okay.

You might say, why do not I simply move this way and then this way, no this is not allowed. You have to use this as a shortcut where you always maintain the correct direction along in a smooth line. So if you move this way, you are moving this way and ultimately you are ending up in the opposite direction of C1 that is not allowed because you are supposed end up along C1 direction only, you are ending up in opposite C1, so the 1st one definitely cannot be correct. And in fact, since it is R - 10 this would have defined had it been correct, then also it would have defined a a a circle with clockwise sense and this is obviously counterclockwise, so this is definitely it would have been wrong anyway.

2nd one, 2nd one reads driving along C1, you are ending up so you are driving along C1 that is good and you are ending up by taking this particular diversion, you are ending up in the - L1 direction, okay it s it is - L1 direction that is good and R 10 that means counterclockwise circle, this is also counterclockwise circle but mind you, this particular definition will not be allowed since it is taking the major arc along C2. Once everything is correct, you have to further check whether a major arc or a minor arc is involved in the definition, so 2nd definition is not allowed major arc.

C2 = - L1, so you are coming this way - L1 and ending up in the sorry this is a misprint, please note, this should be C1 in the 3rd definition. - L1 you are driving this way and you are ending up in C1 direction, this is C1 direction, everything is correct in this particular definition. And the and the diversion that you are taking that is counterclockwise as well, so C is correct okay so this brings us to the end of the 15th lecture thank you very much.