2 CNC Milling Programs Using Nesting Programs

Objective

Students will be able to:

- Identify nesting programs to complete projects
- Evaluate and modify existing programs
- Prepare nested programs on a CNC Mill
- Analyze and rewrite nested CNC programs

Orienting Questions

- ✓ What is the difference between a main program and a sub-program?
- ✓ What is a nested program?
- ✓ Are nested programs absolute or incremental movements?

The **bolded/underlined words are key terms…click on the **blue underlined terms** for more information.

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INTRODUCTION

CNC Milling Programs can be divided into two major categories: **Main Programs** and **Sub-programs**. The main program will consist of the start-up commands, tool changes, a WPC reference, cutter compensations, speeds, feeds, absolute or incremental positioning and machining operations. When machining operations are repetitive in nature, sub-programs may be beneficial to use to shorten the length of the main program. Sub-programs will consist of incremental movements and machining operations that are reproduced in specific locations to complete the manufactured part; this is sometimes referred to as a **loop**. Sub-programs are activated when **M98** is used within the main program. The M98 is the sub-program call; the M98 will activate another program from the library to complete a tool movement or function. **Nesting** occurs when a sub-program activates or calls another sub-program from within the program library to run a sub-program within a sub-program.

2.1 MAIN BODY OF PROGRAM

The Main Program will consist of G-Codes and M-Codes that prepare the machine tool to operate properly in accordance with standard CNC movements. All Fanuc or G-Code programs will have a program number at the beginning of the program; it will begin with the letter "O" and be followed by a 4-digit number (O1234). Programs may also use **Sequence Numbers** at the start of every program line for a reference. Sequence numbers may increase by 1, 5, 10, or 100, this depends upon the programmer's preference. The programmer may also choose not to use sequence numbers at all. It does not affect the outcome of the program. A typical Fanuc milling program (Figure 1.) will have the following codes within the first line of the program, G17, G20, G40, G80, and G90. These codes will activate or deactivate certain CNC functions. G17 sets the dominate machining planes to "X" and "Y". G20 establishes the units of movement to be in "inches" vs. "metric". G40 cancels all cutter compensations that may be active. G80 cancels all canned cycles and G90 sets the movement to "**Absolute**" movement for positioning. The second line of the program normally contains the tool change and tool call command, (M6 T01). The third line of the program will activate a rapid movement to an absolute position that is relative to the "**Work Piece Coordinate**"; this is referred to as the "**WPC**". The 3rd program line will be as follows: G0 G54 X0.0 Y0.0; the "X" and the "Y" are subject to change depending upon initial positioning requirements. The WPC codes can range between G54 – 59; six different WPC's can be located within the travel allowances of the machine tool establishing six different absolute positions. The fourth line of the program will consist of codes activating tool height compensation. It will be as follows: G0 G43 H1 Z1.0; G43 instates the offset from the menu offset page by reading "H1". The active tool will travel to a "Z" position of 1.0 above the "Z" zero plane by calculating the measured tool length in offset #1. The fifth line will turn on the spindle of the machine tool by using a M3 S1000 format. The "M3" is a spindle forward or CW command and "S" sets the RPM of spindle. The speed of spindle is determined by the material being machined and the type of cutter being used for the operation. Each machine tool has a limit on the maximum RPM that it can rotate, this number will vary when factoring the proper speed. The main body of the program has been completed and is ready to perform machining operations or activate Sub-programming by using the M98 code. (Figure 1.)

```
O1234;
N5 G17 G20 G40 G80 G90;
N10 M6 T01;
N15 G0 G54 X0.0 Y0.0;
N20 G0 G43 H1 Z1.0;
N25 M3 S1000;
```

Figure 1. Main Body of CNC Program

2.1.1 ABSOLUTE POSITIONING

Absolute positioning must be established at beginning of each main program to initialize a location reference to begin machining. Absolute positioning is active when G90 has been called in the program. This will establish an origin point for all dimensions of reference. Absolute programming will remain active until it is replaced in the program by G91, this initiates the incremental positioning mode.

2.1.2 ACTIVATION CODES

G54 – 59 will be our activation codes for establishing absolute positioning in reference to the WPC being used to set our initial origin for our main program. The WPC offset page (Figure 2.) will list “X”, “Y” and “Z” for G54 through G59; these numbers will establish the distance from the machine home position to the absolute origin point of the part to be machined. This is why G54 – 59 is referred to as the “Work Piece Coordinate”. Most WPC’s only use a “X” and “Y” reference number to establish location. “Z” reference is normally controlled by G43 with reference to the menu offset page recording various tooling lengths as needed.

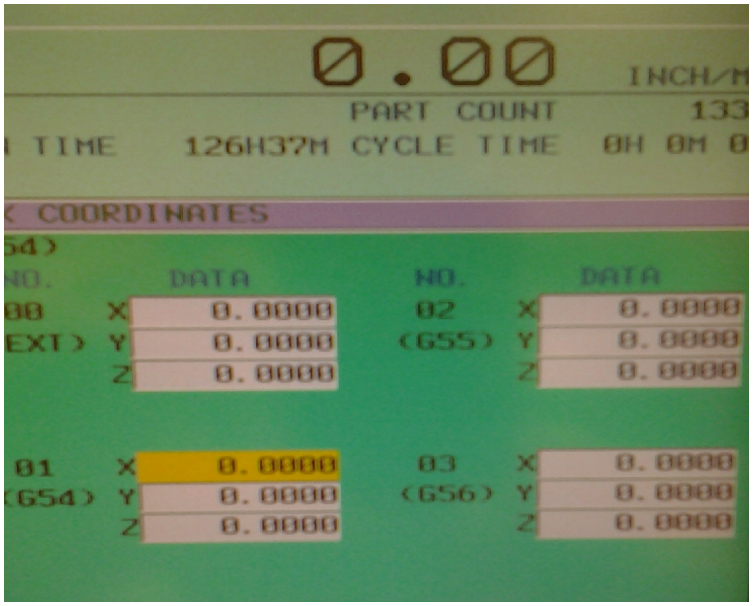

Figure 2. WPC Screen (by: Mark Cramer CC-BY 4.0)

ACTIVITY #1

Match the following G-codes and M-codes with the correct definitions listed below.

1. G17	_____	A.	Height Compensation
2. G90	_____	B.	Incremental Movement
3. G91	_____	C.	Sub-Program Call
4. G54	_____	D.	Absolute Movement
5. G43	_____	E.	X & Y Cutter Plane
6. G40	_____	F.	Sub-Program End
7. G0	_____	G.	Spindle Direction
8. M3	_____	H.	WPC
9. M98	_____	I.	Cancel Compensation
10. M99	_____	J.	Rapid Command

Activity #1 Answers

1. E
2. D
3. B
4. H
5. A
6. I
7. J
8. G
9. C
10. F

2.2 CALLING THE SUB-PROGRAMS

The following programs will machine the geometry for the (Figure 3). We will be machining a .1875 wide slot, .500 deep on a .500 radius from the 90 degree position to the 270 degree position. We will establish the tooling and absolute position in the Main Program **(O1000)** and then call Sub-Program No. 1. Sub-Program 1 will then call Sub-program No. 2. Sub-programs are activated when a M98 code is used within the active program. The M98 is sequenced in the following pattern: M98 P00011001. The P0001 portion of the code is referring to the number of times the Sub-program is to repeated; in this case, sub-program 1001 will be repeated "1" time. The 1001 or last four digits of the code is the number of the Sub-program to be called. So, this M98 code would call program 1001 one time to perform the programming operation according to (Figure 4.).

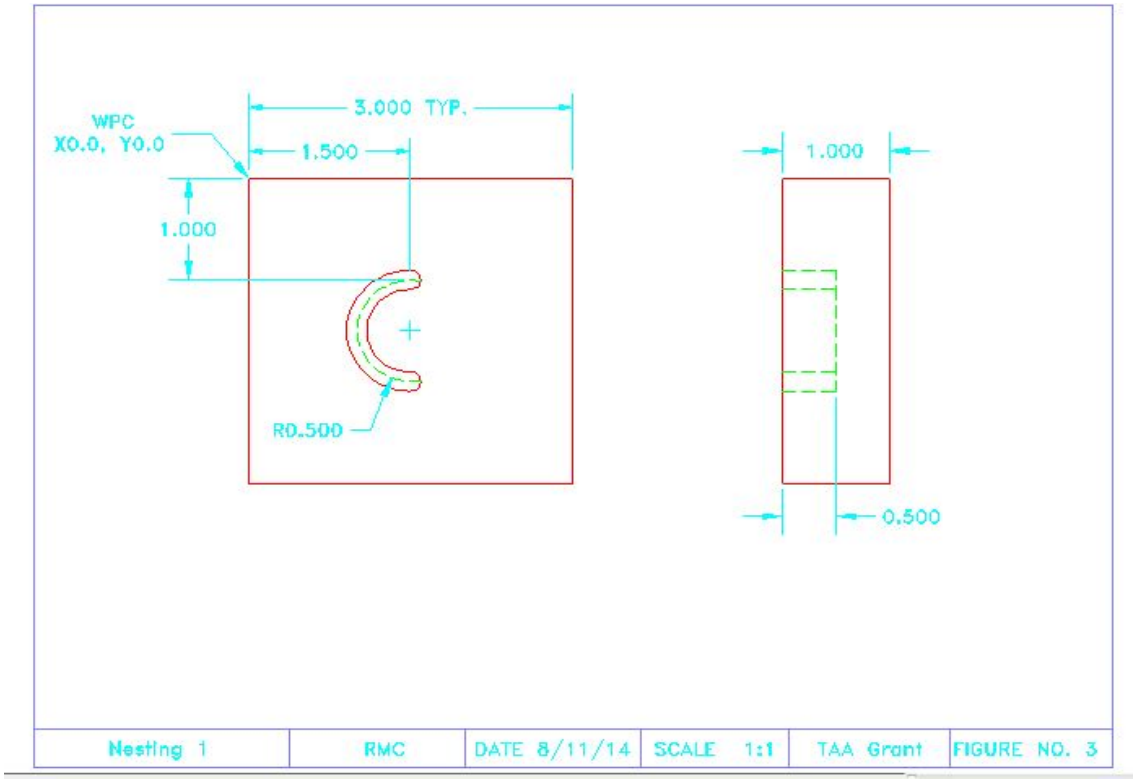

Figure 3. Print

```
O1000;                    (Main Program Number)
G0 G17 G40 G80 G90;       (Start-Up Commands)
M6 T01;                   (Tool Change Command)
G0 G54 X1.5 Y-1.0;        (Workpiece Reference establishing Absolute Position)
G0 G43 H1 Z1.0;           (Tool Height established 1" above the part)
M3 S1000;                 (Forward Spindle Speed at 1000 RPM's)
G0 Z0.1;                  (Move to .100 above Absolute Z to begin Sub-programming)
M98 P00011001;            (Sub-program call activating Program 1001 one time)
G90 G0 Z1.0;              (Move to Absolute Position of Z1.0)
G91 G28 Y0.0 Z0.0;        (Incremental move to "Y" and "Z" Home Position)
M30;                      (Ends Main Program)
```

Figure 4. Main Program

2.2.1 ACTIVATION OF 1ST SUB

The activation of the 1st Sub-Program (Figure 5) accomplishes two phases of the over-all program. The first action is positioning the tool to the top of the part by incrementally moving "Z" -.100 to absolute "Z" zero (G91 G1 Z-.100 F5.0). Now the tool is in position to begin machining. The second phase of the first Sub-Program is to call the second Sub-Program 5 times (M98 P00051002) to complete the machining operations. This is referred to as "Nesting".

2.2.2 INCREMENTAL MOVEMENT

```
O1001;                    (Sub-Program #1)
G91 G1 Z-.100 F5.0;       (Incremental Linear feed movement to top of part)
M98 P00051002;            (Sub-program call activating Program 1002 five times)
M99;                      (Sub-program end)
```

Figure 5. 1st Sub-Program

2.2.3 ACTIVATION OF 2ND SUB

The activation of the 2nd Sub-Program (Figure 6.) will machine the geometry according to the print (Figure 3). The 3/16" Endmill will feed into the material .050 deep and machine a counter-clockwise arc to an incremental position of X0.0 Y-1.0 using a G3 command (G3 X0.0 Y-1.0 R.5). The next line of the program will feed the endmill into the material an additional .050 deep and machine a clockwise arc to the original starting position of the arc using a G2 (G2 X0.0 Y1.0 R.5) . This sequence will be repeated 5 times following the 1st sub-program command (M98 P00051002). The result of the over-all programming process will be a 3/16" wide, 180 degree counter-clockwise slot, .500 deep, on a .500 radius.

2.2.4 INCREMENTAL MOVEMENT

O1002;	(Sub-Program #2)
G91 G1 Z-.050 F5.0;	(Incremental Linear feed movement .050 deep into part)
G3 X0.0 Y-1.0 R.5;	(G3 machines 1.0 Arc from 90 Degree position to 270 Degree position)
G1 Z-.05	(Incremental Linear feed movement .050 deeper into part)
G2 X0.0 Y1.0 R.5;	(G2 machines 1.0 Arc from 270 Degree position to 90 Degree position)
M99;	(Sub-program end)

Figure 6. 2nd Sub-Program

ACTIVITY #2

Answer the following questions concerning the following CNC programs.

Program O2001

```
O2001;
G91 G1 Z-.100 F5.0;
M98 P00052002;
M99:
```

Program O2002

```
O2002;
G91 G1 Z-.100 F5.0;
G2 X0.0 Y-1.0 R.5;
G1 Z-.100;
G3 X0.0 Y1.0 R.5;
M99;
```

```
O2000;
G0 G17 G40 G80 G90;
M6 T01;
G0 G55 X2.5 Y-2.5;
G0 G43 H1 Z1.0;
M3 S1000;
G0 Z0.1;
M98 P0012001;
G91 G28 Y0.0 Z0.0;
M30;
```

1. What is the program number of the Main Program? _____

2. What WPC is being used to establish the absolute position of the workpiece.
   A. G54
   B. G55
   C. G56

D. G57

3. What is the first absolute position move?
   X _____
   Y _____

4. What is the number of the first Sub-Program being activated?
   A. 1001
   B. 2001
   C. 3001
   D. 4001

5. How many times is the first Sub-Program going to be activated?
   A. 1
   B. 2
   C. 3
   D. 4

6. What is the number of the 2nd Sub-Program? _____

7. How many times is it being activated?
   A. 1
   B. 3
   C. 5
   D. 7

8. What is the depth of cut in the "Z" axis?
   A. .050
   B. .100
   C. .150
   D. .200

9. Is the first circle interpolation CW or CCW? _____

10. What will be the final depth of the machined arc?
    A. .250
    B. .500
    C. .750
    D. 1.000

Activity #2 Answers

Activity #2 Answers

1. 2000
2. B
3. X2.5 Y-2.5
4. B
5. A
6. 2002
7. C
8. B
9. CW
10. D

ACTIVITY #3

Using the program examples of Figures 4, 5 and 6, fill in the blanks to the following program that will machine the slot detail on Figure 7.

Figure 7. Nesting 2 Program Print.

O2000;	(Main Program Number)
G0 G17 G40 G80 G90;	(Start-Up Commands)
M6 T01;	(Tool Change Command)
G0 G54 X _____ Y _____;	(Workpiece Reference establishing Absolute Position)
G0 G43 H1 Z1.0;	(Tool Height established 1” above the part)
M3 S1000;	(Forward Spindle Speed at 1000 RPM’s)
G0 Z0.1;	(Move to .100 above Absolute Z to begin Sub-programming)
M98 P00012001;	(Sub-program call activating Program 2001 one time)
G90 G0 Z1.0;	(Move to Absolute Position of Z1.0)
G91 G28 Y0.0 Z0.0;	(Incremental move to “Y” and “Z” Home Position)
M30;	(Ends Main Program)

Figure 8. Main Program

Figure 9. 1st Sub-Program

O2001;	(Sub-Program #1)
G91 G1 Z-.100 F5.0;	(Incremental Linear feed movement to top of part)
M98 P_____2002;	(Sub-program call activating Program 2002 10 times)
M99;	(Sub-program end)

O2002;	(Sub-Program #2)
G91 G1 Z-.050 F5.0;	(Incremental Linear feed movement .050 deep into part)
G3 X_____ Y _____; I 0.0 J -1.0	(G3 machines Arc from 90 Degree position to 0 Degree position)
G1 Z-.05;	(Incremental Linear feed movement .050 deeper into part)
G2 X _____ Y _____ I -1.0 J 0.0;	(G2 machines Arc from 0 Degree position to 90 Degree position)
M99;	(Sub-program end)

Figure 10. 2nd Sub-Program

ANSWERS TO ACTIVITY #3

Program 2000 (Figure 8.)

G0 G54 X 1.5 Y -.50;

Program 2001 (Figure 9.)

M98 P00102002;

Program 2002 (Figure 10.)

G3 X 1.0 Y -1.0 I 0.0 J-1.0;

G1 Z-.05;

G2 X -1.0 Y 1.0 I -1.0 J 0.0

ACTIVITY #4

Using the previous programming examples; write a nesting program to machine the slot detail on Figure 11. Print.

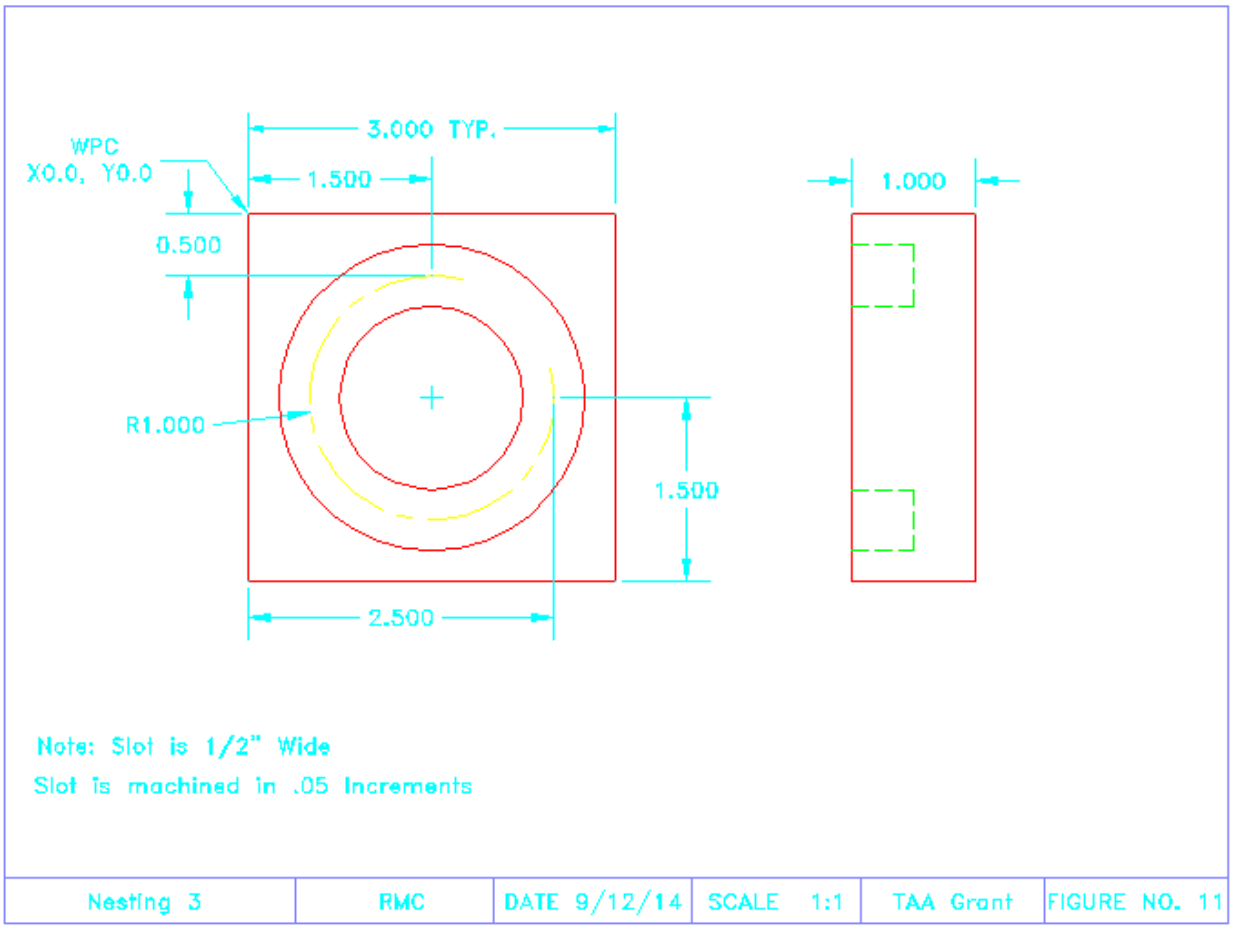

Figure 11. Nesting 3 Program Print.

O3000; (Main Program Number)

_____ _____ _____ _____ _____ (Start-Up Commands)

_____ _____ (Tool Change Command)

_____ _____ _____ _____ (Workpiece Reference establishing Absolute Position)

_____ _____ _____ _____ (Tool Height established 1" above the part)

_____ _____ (Forward Spindle Speed at 1000 RPM's)

_____ _____ (Move to .100 above Absolute Z to begin Sub-programming)

_____ _____ (Sub-program call activating Program 3001 one time)

_____ _____ _____ (Move to Absolute Position of Z1.0)

_____ _____ _____ _____ (Incremental move to "Y" and "Z" Home Position)

_____ _____ (Ends Main Program)

Figure 12. Main Program

O3001; (Sub-Program #1)

_____ _____ _____ _____ (Incremental Linear feed movement to top of part)

_____ _____ (Sub-program call activating Program 3002 10 times)

_____ (Sub-program end)

Figure 13. 1st Sub-Program

O3002; (Sub-Program #2)

_____ _____ _____ _____ (Incremental Linear feed movement .050 deep into part)

_____ _____ _____ _____ _____ (G3 machines Arc Machining 360 degrees)

_____ (Sub-program end)

Figure 14. 2nd Sub-Program

ANSWERS TO ACTIVITY #4

O3000;

G0 G17 G40 G80 G90;

```
M6 T01;

G0 G54 X1.5 Y-.5;

G0 G43 H1 Z1.0;

M3 S1000;

G0 Z0.1;

M98 P00013001;

G90 G0 Z1.0;

G91 G28 Y0.0 Z0.0;

M30;


O3001;

G91 G1 Z-.100 F5.0;

M98 P00103002;

M99;


O3002;

G91 G1 Z-.050 F5.0;

G3 X0.0 Y0.0 I 0.0 J -1.0;

M99;
```

PHYSICAL LAB FOR A NESTED PROGRAM

Introduction: The following lab activity will require machining the actual part using the previous written programs. This activity will require 3 CNC programs: one main program **(O3000)** and two sub-programs (O3001) and (O3002). This process will require setting up and programming the CNC mill to machine the actual part according to the specifications listed on Figure 11 print.

Materials and methods: The material will be 3.00 x 3.00 x 1.00 thick machinable wax stock being held in a standard vise.

Requirements for successful lab completion: This lab will require all safety procedures to be followed to complete the manufactured part. WPC and offset set-ups including proper programming format, graphic evaluation coupled with first piece single-block application. The final machined part will match the program specifications as detailed on Figure 11 print.

MAJOR CONCEPTS

KEY CONCEPTS

- CNC Milling Programs can be divided into two major groups known as **"Main Programs"** and "**Sub-Programs"**. The main program will consist of basic commands such as tool changes, offsets, and WPC references. Main programs primarily use absolute positioning.
- CNC Programs must have an **"absolute reference position"** to establish the WPC (Work Piece Coordinate). Absolute reference position is the amount traveled from home or WPC to a given position.
- The process of **"Nesting"** occurs when a Sub-Program is called from within another Sub-Program. Nesting gives the flexibly to machine geometry at various increments.
- **"Sub-Programming"** is commonly used when machining movements are repeating the same geometry. Sub-Programming shortens the program codes required for machining operations.

KEY TERMS

CNC Milling Programs: The body of code that controls the movement of the machine tool.

Main Program: Governs the start-up commands, tool calls, WPC's, Offsets, and absolute positioning.

Sub-Programs: Governs incremental repetitive movements.

Sequence Numbers: Reference numbers at the beginning of each program line.

Nesting: The process of calling a sub-program from another sub-program.

Loop: Reproduced machining movements.

Absolute: Dimensions that are relative to a base location.

M98: Activates the sub-program call.

M99: Deactivates the sub-program and returns to main program.

WPC: Work Piece Coordinate

MODULE REINFORCEMENT

True or False: Read the following questions and determine whether the statement is true or false.

1.	Nesting is the process of calling a sub-program.	T	or	F
2.	Nesting is the process of calling a sub-program from a sub-program.	T	or	F
3.	The code for activating a sub-program is G98.	T	or	F
4.	The code for ending a sub-program is G99.	T	or	F
5.	Main programs establish absolute positions using a G90 WPC format.	T	or	F
6.	Sub-programs are written in a G91 format.	T	or	F
7.	P00103001 would be a correct sub-program call.	T	or	F
8.	Sub-programs reduce the length of the main program.	T	or	F
9.	Sub-programming generally focus on the machining geometry.	T	or	F
10.	Sub-programs normally begin with a G91 absolute move.	T	or	F

Multiple Choice: Read the following questions or statements and select the best answer.

1. Select the correct line sequence for establishing a WPC.
   A. G1 G55 X1.5 Y1.5
   B. G0 G60 X1.5 Y1.5
   C. G0 G54 X1.5 Z1.5
   D. G0 G59 X1.5 Y1.5
2. Select the correct line sequence for establishing a tool call.
   A. M3 T01
   B. M6 TO1
   C. M6 T0101
   D. M6 T01
3. Select the correct line sequence for establishing a tool height call.
   A. GO G41 H1 Z1.0
   B. G0 G43 H5 Z1.0
   C. GO G43 H1 Z1.0
   D. G0 G42 H1 Z1.0

4. Select the correct line sequence for establishing sub-program call.
   A. M98 P01001111;
   B. M99 P01001111;
   C. M98 P0001O1111;
   D. M99 P0001O1111;

5. Select the correct code for a sub-program end.
   A. G99
   B. G98
   C. M99
   D. M98
6. Select the correct code for a main program end.

A. M30
B. G30
C. M98
D. M99

7. Select the correct line sequence for calling sub-program O1234 5 times.
   A. M98 P00501234
   B. M99 P00501234
   C. M98 P00051234
   D. M99 P00051234
8. Select the correct line sequence for calling sub-program O1234 10 times.
   A. M98 P0010O1234
   B. M99 P00101234
   C. M98 P00101234
   D. M99 P0010O1234
9. Select the correct line sequence for incremental machining in the “Z” movement.
   A. G91 G0 Z-.100 F5.0
   B. G91 G1 Z.100 F5.0
   C. G90 G1 Z-.100 F5.0
   D. G91 G1 Z-.100 F5.0
10. Select the correct line sequence for incremental machining a 360 degree CCW movement.
    A. G91 G3 X0.0 Y0.0 I0.0 J-.5
    B. G91 G2 X0.0 Y0.0 I0.0 J-.5
    C. G91 G3 X0.0 Y-.5 I0.0 J.5
    D. G91 G2 X-.5 Y0.0 I.5 J0.0

Answer Key

True or False	Multiple Choice

True or False	Multiple Choice
1. F 2. T 3. F 4. F 5. T 6. T 7. T 8. T 9. T 10. F	11. D 12. D 13. B 14. A 15. C 16. A 17. C 18. C 19. D 20. A

DISCUSSION PROMPTS

LIST THE DIFFERENCES BETWEEN THE MAIN PROGRAM AND THE SUB-PROGRAM.

In Module 2, we machined geometry using sub-programs being called from main programs. What are the different functions and purposes of both programming formats?

DISCUSSION PROMPT TITLE #2

In Module 2, we used nested sub-programs; when is nesting convenient for machining?

ATTRIBUTION TABLE

Author/s	Title	Source	License

Author/s	Title	Source	License
Mark Cramer	*Figure 1. Main Body of CNC Program*	*Module author*	*CC BY-SA 4.0*
Mark Cramer	*Figure 2. WPC Screen*	*Module author*	*CC BY-SA 4.0*
Mark Cramer	*Figure 3. Nesting 1*	*Module author, developed using AutoCad software.*	*CC BY-SA 4.0*
Mark Cramer	*Figure 4. Main Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure 5. 1st Sub Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure 6. 2nd Sub Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure7. Nesting 2 Program Print*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure 8. Main Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure 9. 1st Sub Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*
Mark Cramer	*Figure 10. 2nd Sub Program*	*Module author, developed using AutoCad software*	*CC BY-SA 4.0*

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