

East Tennessee State University • Engineering, Engineering Technology, & Surveying  
**ENTC 3710 • Manual Numerical Control (NC) Programming  
Spring 2020**

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### **I Course Description**

Manual Numerical Control Programming (3 hours)—

*Prerequisites: ENTC 2170 & 2200.*

A study of the capabilities, programming procedures, advantages, and disadvantages of numerical control (N/C) and computerized numerical control (CNC) metalworking machine tools. Manual methods for generating, debugging, and running point-to-point and continuous path programs including linear and circular interpolation, canned cycles, loops, and subroutines to produce work pieces of increasing complexity. Lecture and laboratory.

#### **Overview**

This course is a study of the capabilities, programming procedures, advantages, and disadvantages of computerized numerical control (CNC) machine tools for 2–3D contouring.

The primary foci of this course are (a) manual programming of computerized numerical control (CNC) machine tools for simple 2½D contouring and (b) introductory CAM programming via 2D and 3D CADD data preparation and manipulation. Students learn the fundamentals of N/C machines. Beginning with the basic concepts of word address (G-code) program structure, students advance quickly into (2D) CADD data preparation of edges, open and closed pockets and centerline tool paths. CAM system setup, safe CNC tool operations, and techniques for toolpath optimization are also covered.

Students will produce at least three deliverables using at least three different types of CNC equipment (laser, router or mill, and abrasive waterjet). Programs and projects will become more complex as the semester progresses and require more sophisticated techniques to produce a part.

With the purchase of the XYZ CNC Router, the ProtoTrak CNC bed mills, the OMAX abrasive water jet & the ULS laser system, ETSU has significant CADD/CAM/CNC capability; ETSU is able to incorporate introductory levels of 2D & 2½D DXF->CNC & 3D CADD-CAM into the program.

## II Course Objectives

Upon the successful completion of the course, the student will be able to:

- Articulate the nature, applications, advantages, and disadvantages of computerized numerical control machine tools.
- Manually create simple point-to-point and continuous path 2½D “G-code” CNC programs.
- Use advanced G-code programming features such as canned cycles, loops, and subroutines.
- Prepare and organize CADD data (edges and optimized centerline toolpaths) for export in preparation for CAM application importation.
- Configure CAM tool paths and document program set-up & operation.
- Set-up and safely operate a CNC machine.
- Select cutters, cutting and spindle speeds, and feed rates for CNC mill &/or router programs.
- Configure basic tooling and part holding requirements.

**Note:** Course outcomes are in alignment with ETAC of ABET Criterion 3.B.1. Student Outcomes: (2) an ability to design systems, components, or processes meeting specified needs for broadly-defined engineering problems appropriate to the discipline; (3) an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature. In addition, the following student outcomes are impacted: (1) an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline; and (4) an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes.

## III Texts, Materials & Supplies

### Required Texts:

Stanton, George C. *Numerical Control Programming*. (Chapters 1 – 5; others under construction)

Available URL: <http://faculty.etsu.edu/hemphill/entc3710/nc-prog>

Hemphill, W.K., Shafer, S.P. & Bernard, J.M. (2016). Design standards & best practices for CADD/CAM/CNC. Available URL for Rev F document:

[http://faculty.etsu.edu/hemphill/pdf/ETSU\\_Standards-CADD\\_CAM\\_CNC-RevF.pdf](http://faculty.etsu.edu/hemphill/pdf/ETSU_Standards-CADD_CAM_CNC-RevF.pdf)

Youssef, H.A. & El-Hofy, H. (2008). *Machining technology: Machine tools and operations*. Chapter 8: Numerical control & computer numerical control technology. Boca Raton, FL: CRC Press.

Note: Chapter 8 is available in eBook format via **free**\* download  
<https://www.taylorfrancis.com/books/9781420043402>

Campbell, R.G., & Roth, E.S. (2002). *Integrated product design and manufacturing using geometric dimensioning and tolerancing*. Boca Raton, FL: CRC Press. eBook available on chapter-by-chapter basis via **free**\* downloads URL: <https://www.taylorfrancis.com/books/9780203910122>

\* Accessible via ETSU Library from any device logged into the ETSU domain or you may go through the Sherrod Library's Taylor & Francis E-book Collection (Available URL: <http://libs.etsu.edu/links/tfbooks.html>)  
Log in with your ETSU ID and PW if/when prompted.

### Recommended (Hardcover) Text:

Valentino, J.V. & Goldenberg, J. (2013). *Introduction to computer numerical control* (5<sup>th</sup> Ed.). Upper Saddle River, NJ: Prentice Hall. ISBN-13: 9780132176033 (MSRP: \$111.80)

[Note: A used 4<sup>th</sup> Edition (ISBN-13: 9780132436908) of this text is also OK.]

### Materials & Supplies:

A pair of safety goggles or glasses (plastic lens) with side shields.

One or more USB flash/jump/thumb drives or portable hard disk drives (for program backup & transfer).

Access to an up-to-date, graphics-level PC (see next page for specs) with:

- AutoCAD 2019, Fusion 360 &/or equivalent 2D/3D CADD software application(s). The free version of AutoCAD Classic and Fusion 360 for students are recommended; for more information, visit Autodesk's Education Community site at <https://www.autodesk.com/education/free-software/featured>.

Other suitable and affordable CADD applications include TurboCAD, or Visual CADD. Check for on-line downloads of limited-use (i.e., 30 day) evaluation versions or even free 2D CADD applications like Siemen's parametric Solid Edge 2D:

[http://www.plm.automation.siemens.com/en\\_us/products/solid-edge/free2d/index.shtml](http://www.plm.automation.siemens.com/en_us/products/solid-edge/free2d/index.shtml)

- For G-code programming and editing, a **programmer-friendly**, Windows-based **ASCII text editor** (i.e., something...anything other than MS Notepad). Look for one that supports user-specified tab width settings. There are numerous text editors available through the Internet (e.g., [JG Soft's Edit Pad Lite](http://www.editpadlite.com) (free version available from <http://www.editpadlite.com>) or Edit Pad Pro (\$40); TextPad (\$31), etc.). Other inexpensive text editors are available on-line through searchable shareware/freeware depositories such as <http://download.cnet.com/>.

**Recommended Equipment:**

"Wintel" desktop or laptop PC with the fastest processor that you can afford; 8+ Gb RAM (16Gb recommended), 500+ Gb HDD, a boatload of USB slots, wireless Internet connectivity; OpenGL graphic card recommended; 17+" monitor (widescreen and/or dual monitors highly recommended); DVD player/recorder; three button, optical scroll mouse; O/S: Windows 10 or higher.

AutoCAD 2018 (or earlier) or similar 2D CADD software. (Note: 2019 and subsequent releases of AutoCAD have embedded "Student Edition" markers.

Fusion 360, Rhino 3D (Student Version), or similar 3D CADD/CAM modeling software.

A small to medium capacity USB portable hard drive (e.g., 2 Gb to 32 Gb thumb drive)

Scientific calculator (or app) with sine, cosine, tangent, reciprocal, and square root functions

Personal Ear Protection (disposable ear plugs provided as necessary in lab)

**IV Attendance Policy**

Attendance will be taken at some time during each class meeting. **Your presence and participation is important.** In-class design/programming assignments will not necessarily be announced prior to those class meeting(s). All quizzes &/or exam and term project assignments will be announced at least five calendar days prior to the test/due date.

Three or more **unexcused** absences may result in reducing your grade; i.e., an A becomes an A-, an A- becomes a B+, and so on. If you know you are going to be absent from class for an authorized University activity, please let the instructor know before hand. When unexpected problems arise, contact the instructor by phone or E-mail as soon as possible.

**Students are responsible for the material covered in  
all class sessions as well as all assignments.**

**Cancellations, Alerts, & Emergencies:** Classes are seldom canceled; cancellation announcements will be made using local television, radio, and ETSU's Gold Alerts system. Visit <https://www.getrave.com/login/etsu> to register your mobile devices to receive official ETSU notifications, alerts, and emergency communications. The University's radio station is WETS, 89.5 FM (URL: <https://www.etsu.edu/wets/>).

**V Academic Integrity & Misconduct**

(from [ETSU Undergraduate Catalog, Policies & Procedures, Student Conduct & Rights, and Institutional Disciplinary Rules](#))

**Honor Code:**

East Tennessee State University is committed to developing the intellect and ethical behavior of its students. Students found to be in violation of policies on plagiarism, cheating, and/or fabrication will be held accountable for their actions. Any knowledge of academic misconduct should be reported. Students are expected to act with honesty, integrity, and civility in all matters.

**Academic and Classroom Misconduct**

- (1) The instructor has the primary responsibility for maintenance of academic integrity and controlling classroom behavior, and can order the temporary removal or exclusion from the classroom of any student engaged in disruptive conduct or conduct that violates the general rules and regulations of the institution for each class session during which the conduct occurs. Extended or permanent exclusion from the classroom, beyond the session in which the conduct occurred, or further disciplinary action can be effected only through appropriate procedures of the institution.
- (2) Plagiarism, cheating, and other forms of academic dishonesty are prohibited. Students guilty of academic misconduct, either directly or indirectly, through participation or assistance, are immediately responsible to the instructor of the class. In addition to other possible disciplinary sanctions which may be imposed through the university's academic misconduct policy as a result of academic misconduct, the instructor has the authority to assign an "F" or a zero ("0") for the exercise or examination, or to assign an "F" in the course.

**Copying/Sharing/Stealing CADD &/or CNC Assignment Files**

Copying &/or appropriating—with or without permission of the original file creator—another student's work and calling it your own is plagiarism. ETSU does not and will not tolerate this serious type of academic misconduct. **Sharing files with other students is itself an act of academic misconduct.** CADD files can be easily copied, transferred electronically, and shared. However, please also note that your instructor is not an idiot and can, just as easily, electronically compare students' work. Even within seemingly identical assignments, there will be myriad differences among submitted drawings.

**Everyone** caught sharing, copying &/or turning in nominally identical files as his &/or her own work effort will receive zero (0) points for that assignment. A second instance of academic misconduct will result in failure of the class (F) for any/all students. All instances of plagiarism/academic misconduct will be documented and reported subject to published [University policies](#) and college/departmental procedures. If another charge of academic misconduct has been made in any ETSU class against one of the students involved, the instructor will work with the CBAT dean's office to determine the appropriate penalty for repeat offenders of academic misconduct.

In situations involving allegations of plagiarism or the theft of file(s), the instructor reserves the right to require any student(s) to resubmit one or more similar assignment(s)—with appropriate modifications—to demonstrate proficiency, understanding and competence. If determined that academic misconduct did occur, assignment grade and/or course grade will be adjusted accordingly; the actions will be documented and the individual(s) subject to relevant University policies & procedures.

## VI Evaluation and Grading

1. Lab work (2 major projects w/ documentation, at least 3 deliverables) ... 80%
2. Pre-operational Practical Exams, Quizzes, Presentations, etc. .... 5%
3. Attendance & participation (individual &/or team) ... ..... 15%

### Lab Work:

N/C programs either do what they are supposed to do or they don't. Only programs that do what they are supposed to do are acceptable (minimum passing grade of 'C'). The lab grade will be further based upon

- (a) how well the lab assignment(s) are programmed (i.e., optimized without unnecessary moves or wasted motion);
- (b) the complexity of the design (e.g., "ledges" > pockets); and
- (c) the quality of the work submitted including organization, descriptive comments, and accompanying documentation (drawings, set-up/operating instructions, photos, screenshots, etc.).

### Each lab project **MUST** include:

- CADD drawing(s) of the part and, if appropriate, center line tool path(s), self-organizing (named) layers, reference data, etc.
  - CADD drawings should follow the standards and best practices of [ETSU's Drafting/Drawing Standards for CADD/CAM/CNC](#) or subsequent release. Check D2L for latest version of the document.
  - "Master" CADD data file and appropriate exportable, machine-specific CADD data files in appropriate format(s).
- Setup instructions &/or Programming Planning and Process Check-off sheets including but not limited to:
  - the names(s) of the programmer(s), filename(s), and date
  - a list of the cutting tools (description, dia., feed rates) in their order of use,
  - a graphic/textural description of all tooling and fixtures is required,
  - information regarding the material(s) to be machines (type, spec, & cutting speed)
  - Coordinate information (part origin, tool change and work piece change points)

- (For optional G-code assignments—non-CAM): A commented source program explaining what each line of code is supposed to do and (when appropriate) subroutine header info.
- A sample work piece or pen plot (G-code).

It is the **student's** responsibility to verify during the last week of the course that all lab work has been recorded in the instructor's record sheet. Omissions discovered after the course ends will not be corrected.

#### Minimum Percentage Score for Grades

	A 93%	A- 90%
B+ 87%	B 83%	B- 80%
C+ 77%	C 73%	C- 70%
D+ 67%	D 60%	F Below 60%

A test, exercise, or paper may be given (or submitted) early for a University sponsored absence (please provide suitable notice, if possible). Make-up tests may be given at the discretion of the instructor and only if a student presents suitable documentation (evidence) explaining the (emergency) absence to the instructor.

**Quizzes and exams may include any material covered in the lectures, assigned readings, videos, classroom discussions or exercises.**

Students with documented needs for note taking, test taking, or other classroom accommodations should make arrangements with the instructor early in the term. Contact the ETSU Disability Services at <https://www.etsu.edu/students/ds/>  
or  
Voice: (423) 439-8346; Fax: (423) 439-8489; TDD: (423) 439-8370

## VII. Access to University and Departmental Labs, Facilities & Services

There **MUST** be an authorized, supervisory ETSU employee present whenever students are working in lab areas. This is especially true for labs with rotating &/or automated machinery or equipment. Special written permission must be secured if you desire to work in any labs outside of normal lab hours. See your instructor, staff, or the graduate assistant(s) for additional information.

Access to the department's computer resources for CADD may be limited. For generating DXF-formatted drawings &/or the CNC "G-code" programs, it is suggested that you use other PCs (e.g., personal laptop or desktop or an ETSU lab machine) and transmit CNC files to the Machine Tool lab PCs using "sneaker net" (a.k.a USB thumb drive) or via E-mail attachment.

Many CNC controllers—specifically, the ToolPath program for the XYZ CNC router—use variants of the (pre-Windows) DOS operating system. Accordingly, you should remember to **limit CNC file names to the old 8.3 filename.ext DOS file naming standard to ensure compatibility** with newer operating systems (e.g., Windows NT, 2000, XP, Vista, 7, etc.) that allow for long file names.

For information on location and operating hours of other University computer labs, contact the Office of Information Technology at 439-4OIT (that's 439-4648) or the [ITS web site](#).

Hours of operation of the University's library are posted at the library and in various handouts. For more information contact the Sherrod Library at 439-4337.

**Mental Health:** College can be a very stressful environment. Students often have questions about mental health resources, whether for themselves or a friend or family member. There are many resources available for students on or off the ETSU main campus including:

- If you or a friend are in **immediate crisis, call 911**
- ETSU Counseling Center (423) 439-4841
- ETSU Behavioral Health & Wellness Clinic (423) 439-7777
- ETSU Community Counseling Clinic: (423) 439-4187
- National Suicide Prevention Lifeline: 1-800-273-TALK (8255).

**Campus Safety and Security:** ETSU strives to provide a safe and secure educational experience. Information regarding all aspects of the University's general emergency procedures is available at <http://www.etsu.edu/safety>. The primary notification platform for mobile devices is the [ETSU SAFE App](#). In addition, to receive emergency text alerts, please text **ETSU** to **237233** (new for Spring 2020).

### VIII. Food, Drinks, and Tobacco Products

Food and drinks are never permitted in any of the University labs. In certain lecture-type classrooms, food and lidded or screw-capped beverages may be permitted by the instructor (please clean up afterwards). Heavily caffeinated beverages may be consumed during the really boring morning lectures. You cannot afford the \$55,000+ cash replacement cost; keep beverages off CNC equipment.

**ETSU is a tobacco-free campus.**

The use of any type of tobacco products (repeating: **any type**) is completely prohibited in and around all University buildings including doorways, sidewalks, and pretty much everywhere else except in personally-owned vehicles. Don't litter. Tobacco "juice" is a gross biohazard. It is recommended that you quit using all forms of tobacco sooner rather than later. You've been warned; don't play cute.