PhD Proposal Defense

A realtime and parallel look-ahead control and feedrate compensation strategy for CNC reference-pulse interpolation.

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Date: Thu, 27 December 2018

Outline of Presentation

(1) Introduction to CNC
(2) Problem issues in CNC operations
(3) Research proposal objectives addressing problem issues
(4) Proposed research scope
(5) Research motivations
(6) Expected knowledge contributions
(7) Literature survey (in 3 parts)
(8) Proposed research methodology
(9) Related research work (previous works)
(10) Proposed research implementation plan
(11) Proposed publication plan
(12) Conclusion (Q & A)

PhD Proposal Defense

PhD Program Registration Details		
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4	Faculty	**Faculty of Mechanical Engineering**
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6	Field of Research	**Mechatronics and System Design**
7	Type of Study	**Research**
8	Mode of Study	**Full Time**
9	Registration Date	**Tue, 03 April 2018**
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13	Document Date	**December 26, 2018**
14	Research Title	**A realtime and parallel look-ahead control and feedrate compensation strategy for CNC reference-pulse interpolation**
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CNC Milling Machine

CNC Router Machine

CNC Lathe Machine

CNC 3D Printing Machine

1. Introduction to CNC

CNC is an abbreviation for Computer Numerical Control

In a CNC machine, the function of CNC interpolation is simultaneously

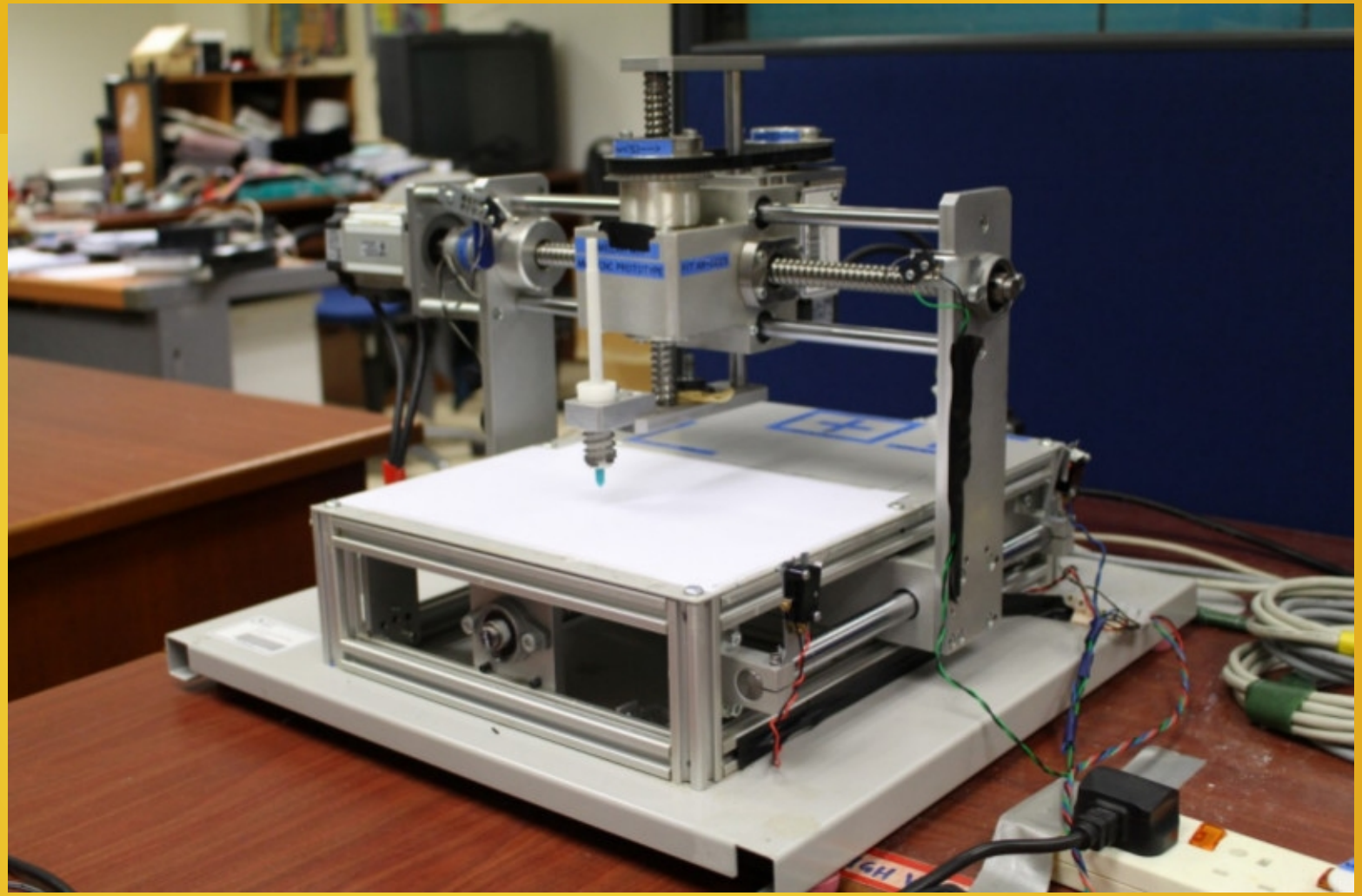
- to generate coordinated 3D movements
- to drive the separate axis-of-motions and/or rotation axes
- to achieve the desired path of the part model

for the CNC cutting or milling tool relative to the workpiece.

NC = Numerical Control means the control of a machine by using numbers.

CNC = Computer Numerical Control means using numbers and a computer to control a machine tool.

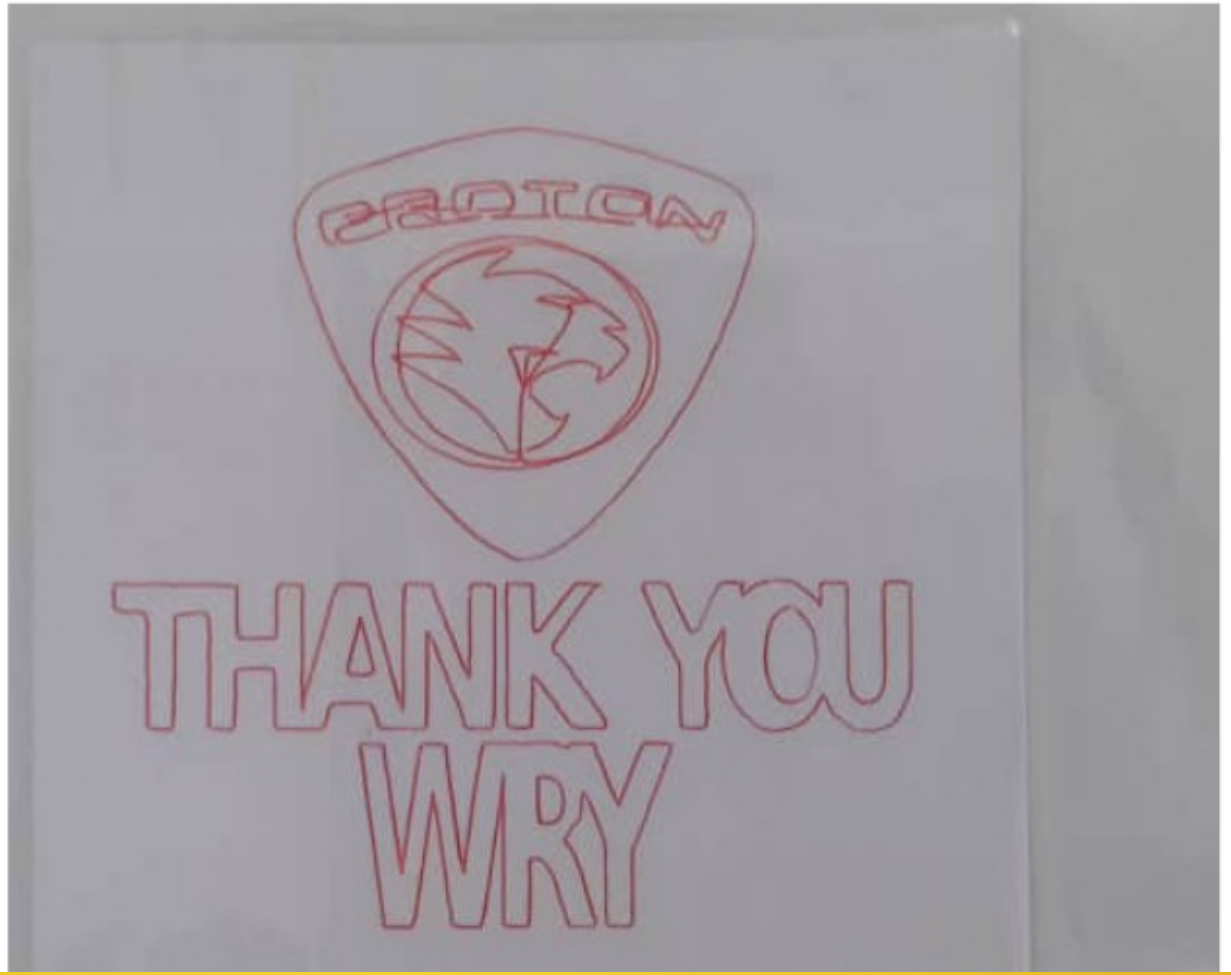
UMP CNC Research Machine



Youtube video
CNC Research
Machine Operation

A little more sophistication

D 4.10 App4-Result 4 - Raspberry Pi-3 SBC on CNC machine



2. Problem issues in CNC Interpolation

(1) Accuracy of reproducing the original drawing model part (2D or 3D)

ISSUE: This is about minimizing contour tracking or geometric errors to preserve accurate reproduction.

(2) Fast machining operations to produce the model part.

ISSUE: This is about the time it takes to finish machining the model part. It is related directly to the interpretation/interpolation of the G-Code files, speed and methods used in software computations and other hardware performance limitations.

(3) Smooth machining operations, not jerky moves of cutting tool.

ISSUE: This is about velocity profile of the cutting tool as it moves to machine a part. For example, avoid machine vibrations and machined part overheating.

3. Research Proposal Objectives

(1) Accuracy of reproducing the original drawing model part (2D or 3D)

SOLUTION: Look-ahead control and feedrate compensation strategies for minimizing contour errors. This is the proposed method or technique.

(2) Fast machining operations to produce the model part.

SOLUTION: Suitably implement realtime and parallel computing strategies based on modern software engineering technologies. This is the proposed back-end software engine.

(3) Smooth machining operations, not jerky moves of cutting tool.

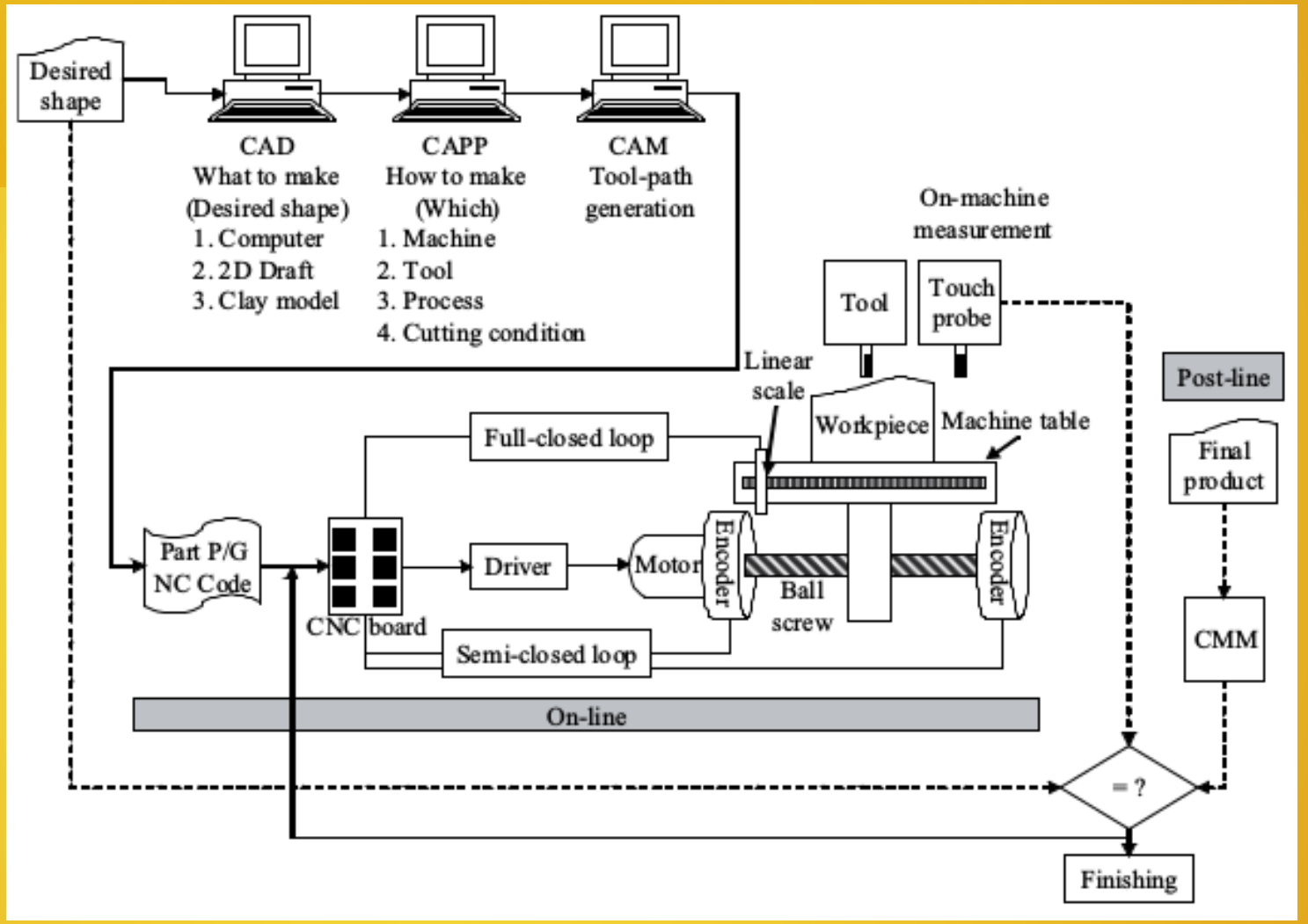
SOLUTION: A balanced control between contour error minimization and feedrate velocity (machining speed) to achieve smooth movements of the cutting tool. For example, slow down the cutting tool at sharp curves to get good contour accuracy. This is the proposed control strategy.

PhD Research Proposal Topic

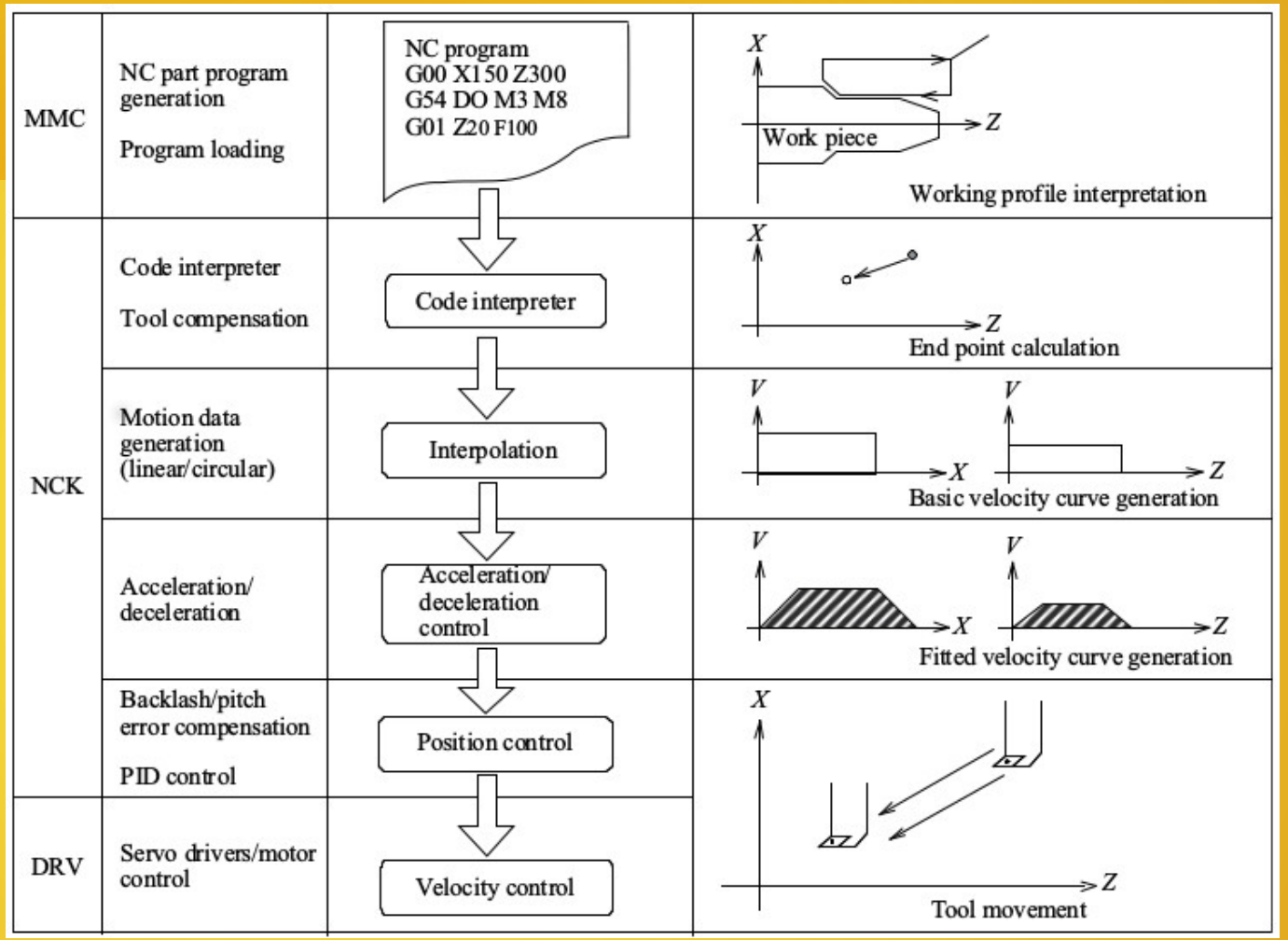
To address the three issues:

A realtime and parallel look-ahead control and feedrate compensation strategy for CNC reference-pulse interpolation.

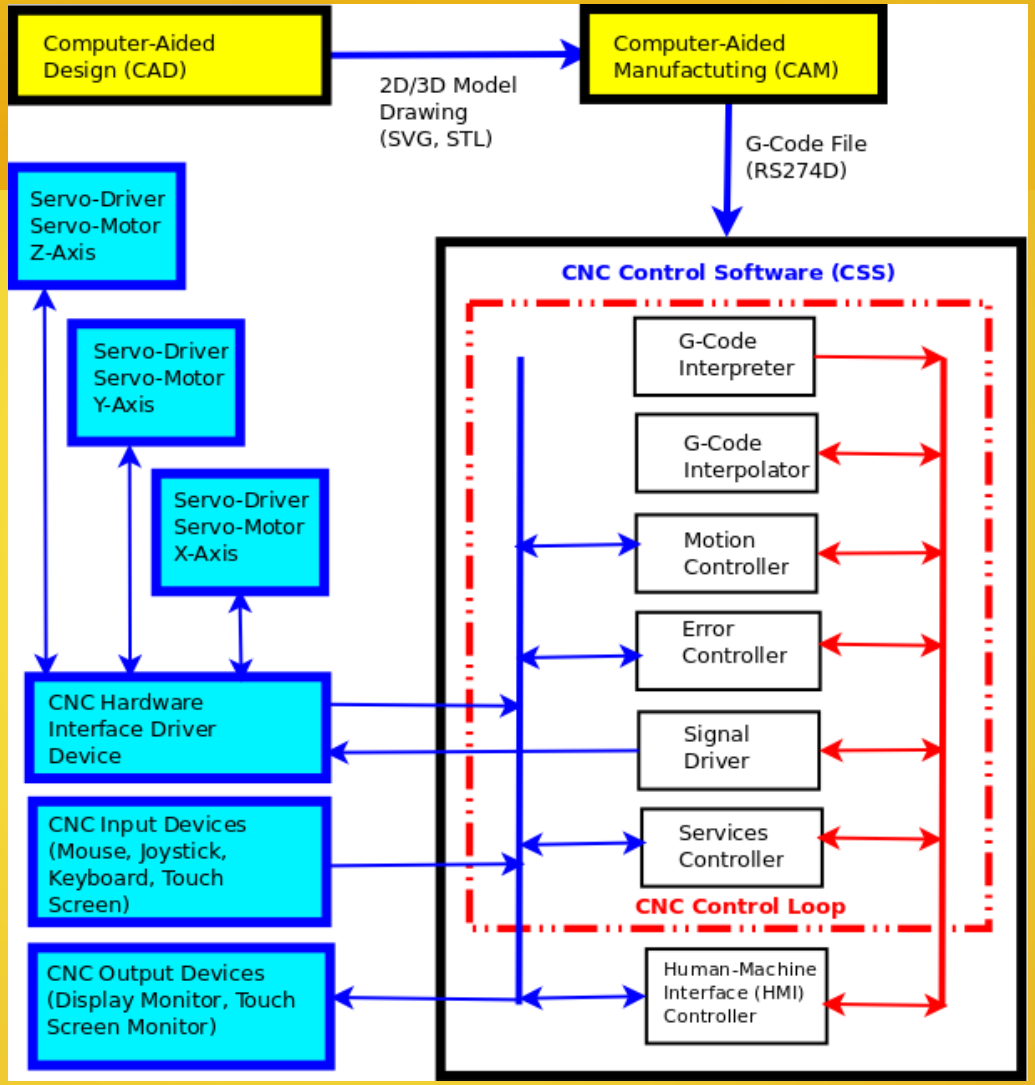
CNC System Architecture



CNC Generic Process Flow



CNC Functional Block Diagram



4. Proposed Research Scope

(1) Start with G-Codes, specifically RS274D NGC standard G-Code.

(2) Choose Reference-pulse CNC interpolation for computing efficiency.

(3) Implement look-ahead and feedrate error compensation.

(4) Execute realtime, parallel, online/offline for the CNC control loop.

(5) Conduct parallel execution methods for 2D/3D G-Code interpolation.

(6) Address design for extension to 5-axis interpolation implementation.

5. Research Motivations

(1) Commercial interest – interpolation is the ”brain & heart” of CNC machine

(2) Intellectual ownership and sense of accomplishment

(3) Wants to be an enterpreneur

(4) Exciting technical challenges

(5) Future potential and possibilities

6. Expected Knowledge Contributions

(1) Implementation of a simple, practical and achievable strategy in CNC interpolation

(2) A technique that utilizes both true realtime and parallel execution in CNC interpolation

(3) Innovative ideas for an efficient design of the CNC interpolator based on modern software engineering methods

7. Literature Survey Part 1

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7. Literature Survey Part 3

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8. Proposed Research Methodology – Part 1

(1) Software engineering perspective - not from a control or instrument engineer‘s perspective. Improvement in core CNC Control Software.

(2) Software engineering methods – development and delivery of the CNC control software product, inclusion of software components, like Rust, Python, Julia, Octave and Scilab, in addition to the base C/C++ codes.

(3) Linux, open source and cost-free software completely – making CNC machines affordable, available community support, and so on.

(4) Use of own developed motion control devices – Microchip Curiosity Demo Board for some user prototyping, and full prototyping using Microchip 28-Pin-LIN Demo Board.

(5) Research validation - ”The proof of the pudding is in the eating.” Real manual measurements and compare against desired model dimensions.

8. Proposed Research Methodology – Part 2

(1) Reference-Pulse CNC Interpolation method for computing efficiency.

(2) Feedrate look-ahead control algorithm - to deal with sudden changes of feedrate pulses, essentially the CNC cutting tool move velocity smoothness.

(3) Feedrate compensation is adjusting move velocities but for reducing contouring path errors, instead of maintaining movement smoothness.

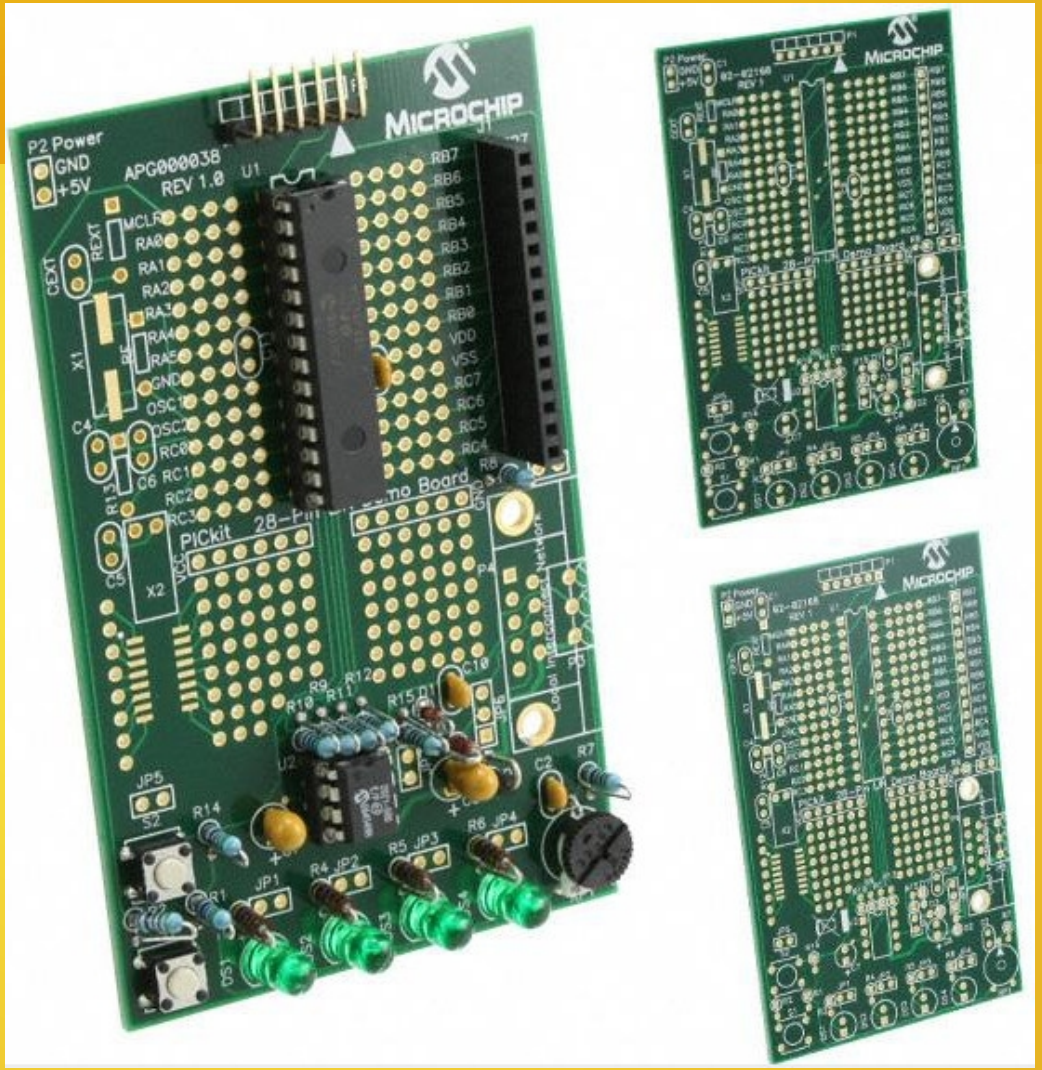
(4) Adoption of realtime execution strategies for CNC Control Loop

(5) Adoption of parallel execution strategies for CNC Control Loop

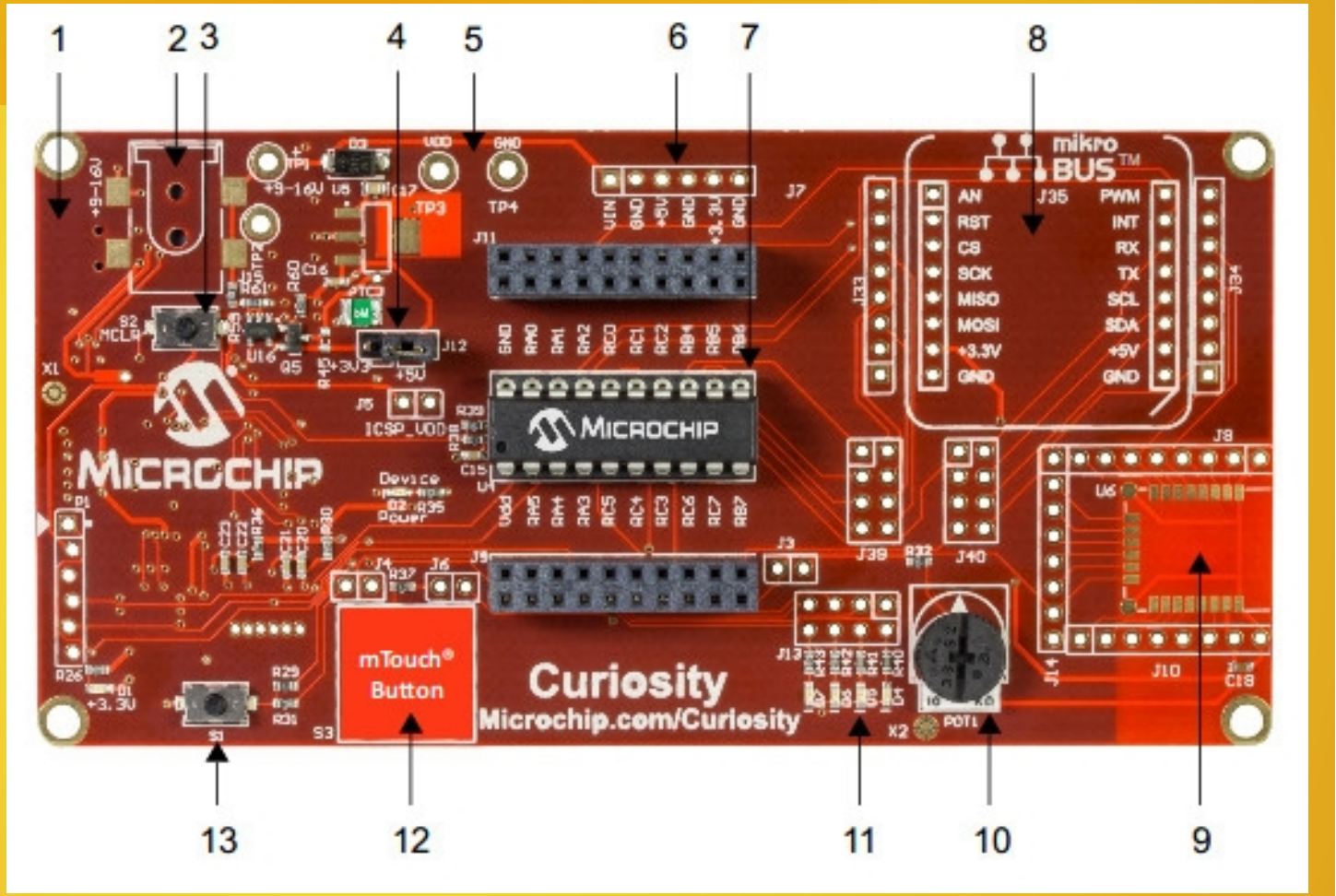
(6) Infrastructure design for extension to 5-axis CNC interpolation

8.1. PWM Board
Implementation as pulse driver device

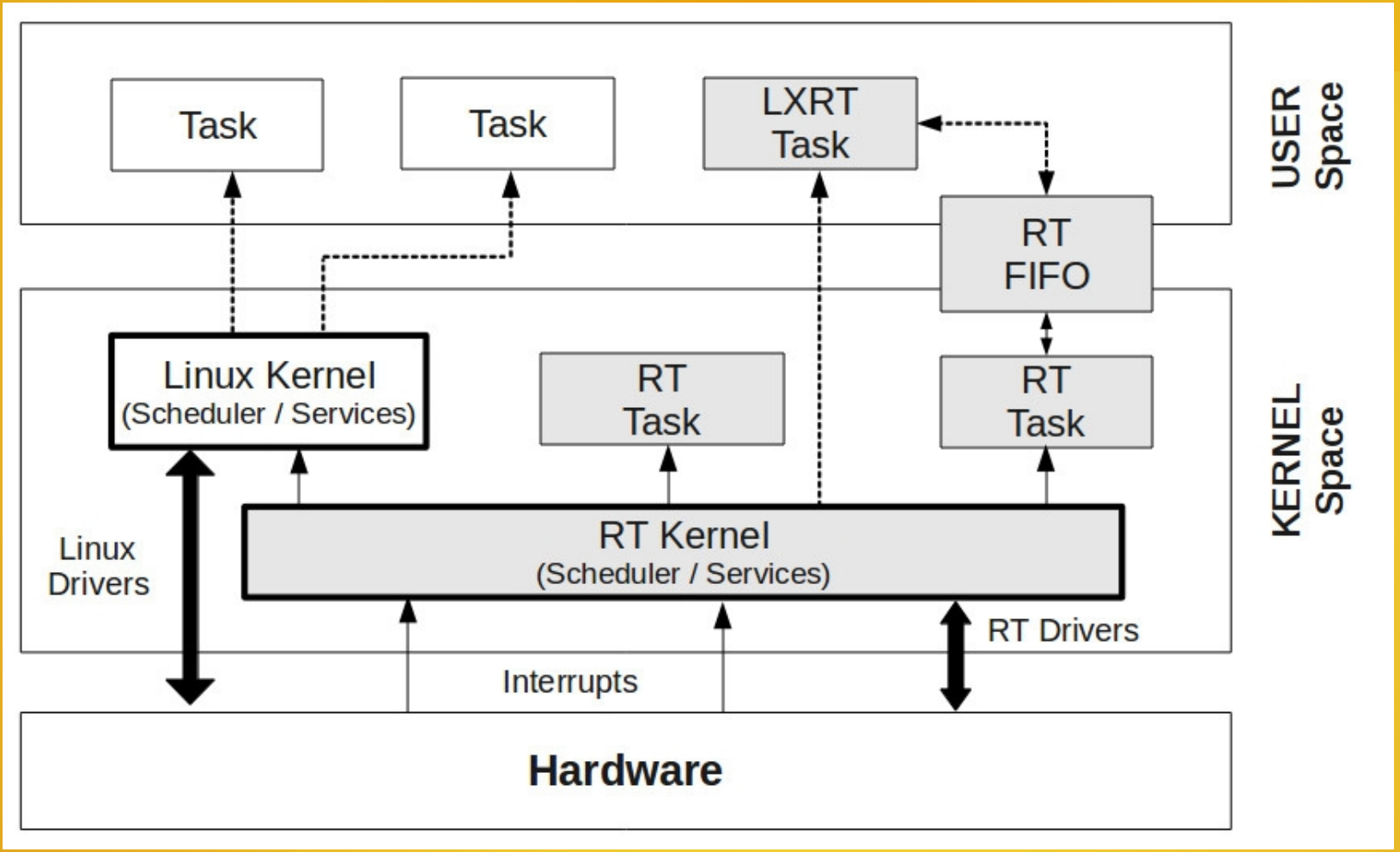
8.2. MCU 28-Pin LIN Dev Board as pulse generator device



8.3 MCU Curiosity Dev Board as pulse generator device



8. Realtime Infrastructure - RTAI



9. Related Research Work (Previous Works Part 1)

Previous projects we have undertaken using computer extension boards as pulse generator devices that successfully drive the CNC research machine.

(1) PC parallel port, [1.26], [1.27], [1.28].

(2) Velleman K8000 Parallel extension board, [1.30].

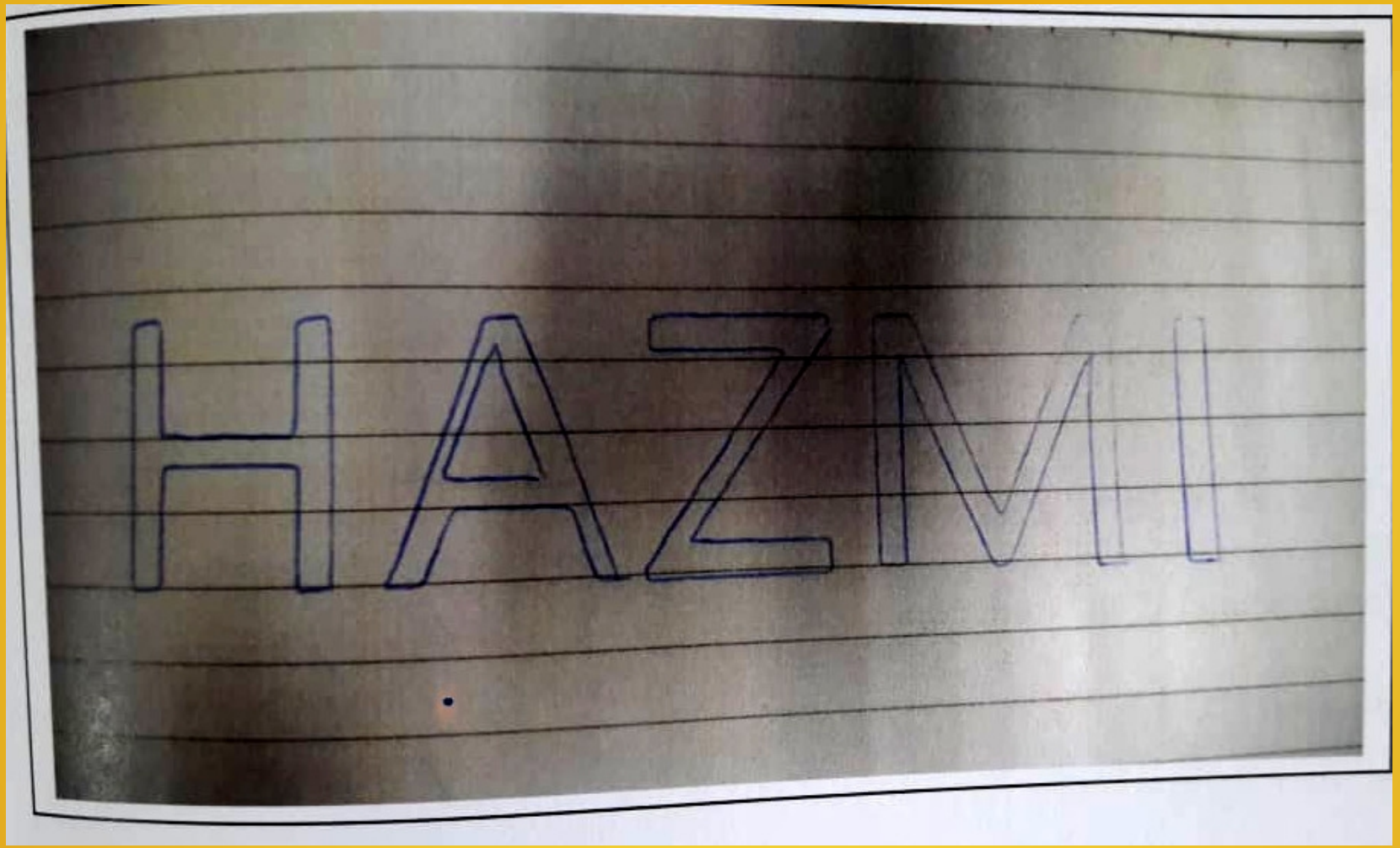
(3) Velleman K8055 USB extension board, [1.31].

(4) Heber X10i USB extension board, [1.32].

(5) Arduino Due USB extension board, [1.33].

(6) Digilent Nexys-3 Spartan-6 FPGA board. [1.34].

9. Previous Project – Arduino Due drive CNC machine



9. Related Research Work (Previous Works Part 2)

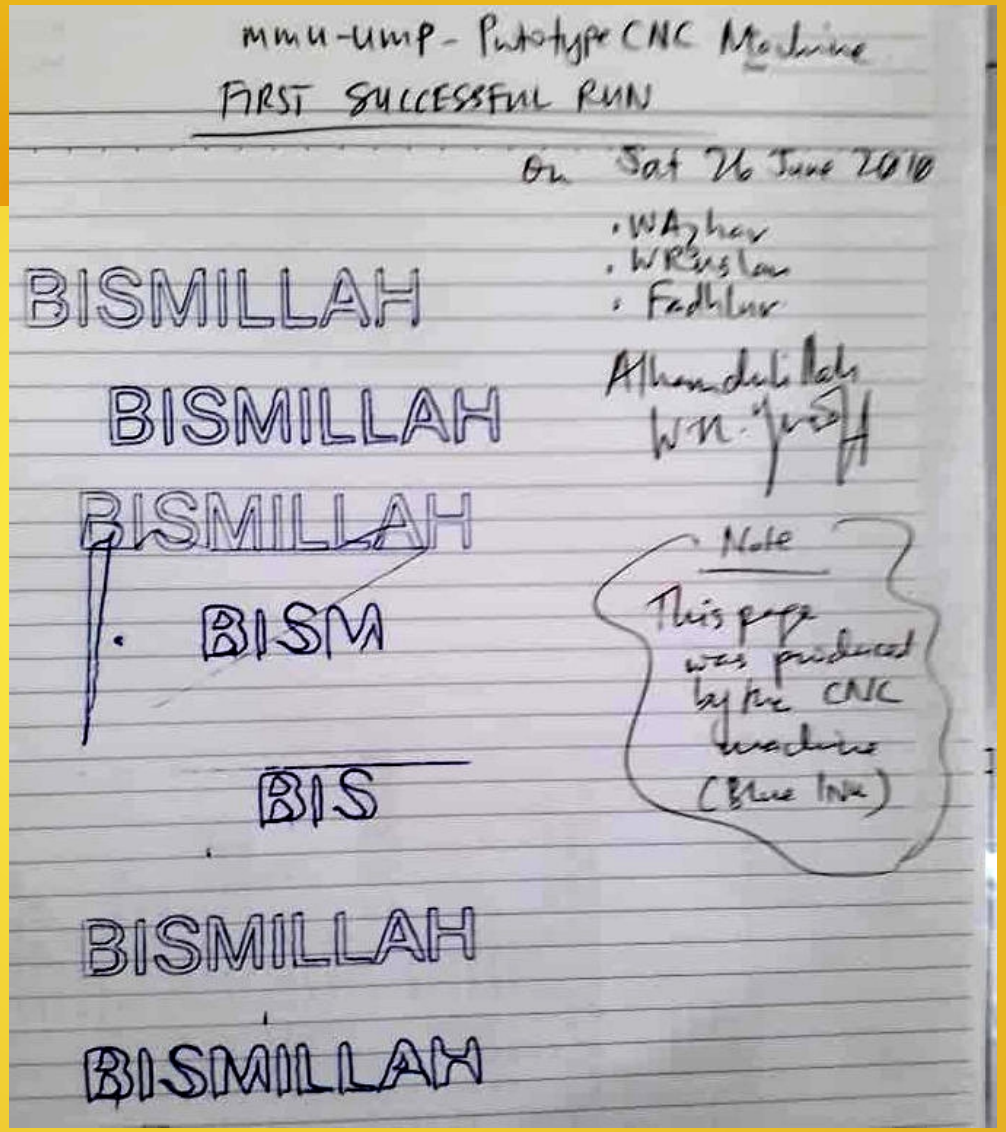
Previous projects we have undertaken using Single Board Computers (SBC) as pulse generator devices that successfully drive the CNC research machine.

(1) Raspberry Pi SBC, General purpose. [1.35], [1.36].

(2) Banana Pi SBC, Graphic processing focus. [1.37]

(3) Beagle-Board xM SBC. Graphic processing plus DSP focus. [1.38].

9. Realtime parallel port device drive CNC machine



10. Proposed Research Implementation Plan - Part 1

File | Print | Project

	Name	Duration	Start
1	⊟Research Implementation Plan	356 days	11/20/18 8:00 AM
2	⊞PhD Proposal Preparation	20 days	11/20/18 8:00 AM
18	⊞Issue Drafts PhD Proposal	26 days	11/20/18 8:00 AM
29	⊞Procurement Long Lead Items	30 days	11/20/18 8:00 AM
46	⊞Setup CNC Research Machine	5 days	11/20/18 8:00 AM
55	⊞Other Hardware Resources	5 days	11/26/18 8:00 AM
60	⊞Computer Notebooks Setup	5 days	11/20/18 8:00 AM
117	⊞Computer Desktops Setup	7 days	12/25/18 8:00 AM
146	⊞UseCase Design - CNC Control Software	30 days	1/1/19 8:00 AM
157	⊞Architecture Design - CNC Control Software	15 days	2/1/19 8:00 AM
168	⊞Process and Data Flow Design	15 days	2/15/19 8:00 AM
178	⊞CNC Control Loop Development	20 days	3/1/19 8:00 AM
190	⊞CNC Control Loop Integration Testing	20 days	3/15/19 8:00 AM
199	⊞Create Test Models G-Codes	3 days	4/12/19 8:00 AM
202	⊞Execute Test Models without Error Compensation	3 days	4/15/19 8:00 AM
205	⊞Contour Error Module Development	40 days	4/1/19 8:00 AM
216	⊞Execute Test Models with Error Compensation	4 days	5/25/19 8:00 AM
219	⊞Test with signal generator devices	20 days	6/3/19 8:00 AM
224	⊞Publications Plan	140 days	6/30/19 8:00 AM
228	⊟Project Closing	110 days	10/30/19 8:00 AM
229	Write PhD Thesis	20 days	10/30/19 8:00 AM
230	Submit PhD Thesis WriteUp	2 days	11/30/19 8:00 AM
231	Perform Thesis Corrections	10 days	1/31/20 8:00 AM
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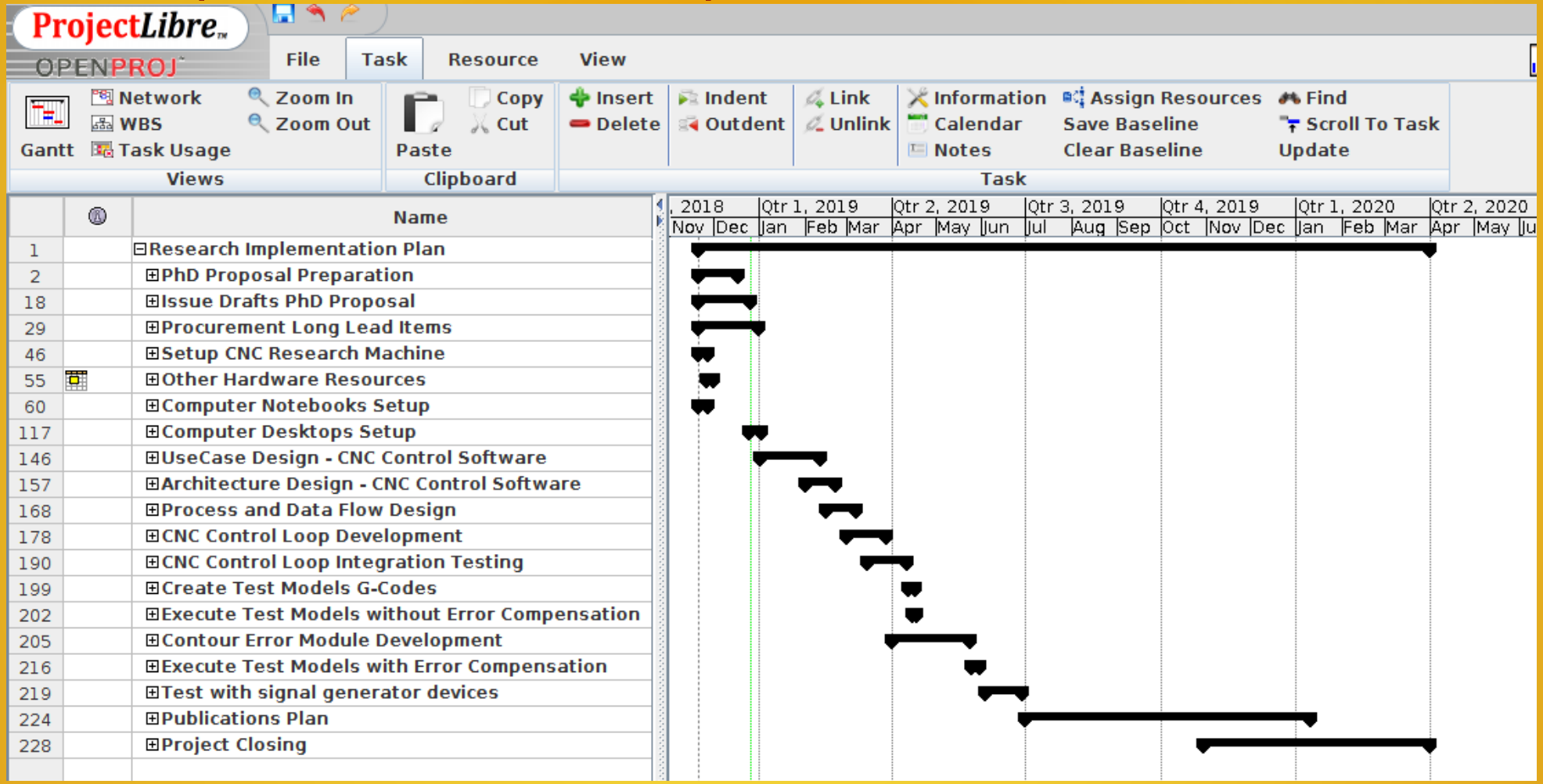
233	Complete Viva Voce	2 days	3/30/20 8:00 AM

10. Proposed Research Implementation Plan – Part 2



11. Proposed Publication Plan

(1) Three publications total spread three months apart.

(2) Two conference publications and one journal publication.

(3) Conference Publications
- Pico Universal PWM hardware with LinuxCNC
- Microchip MCU Curiosity and 28-Pin LIN Development Boards

(2) Journal publication
- On the subject of PhD thesis

12. Question & Answer

Thank you.

Question & Answer session.