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Design and Implementation of Function Generator Prototype by Additive, Subtractive Manufacturing and Programming

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***Abstract*— In new product development, time to market (TTM) is critical for the success and profitability of next generation products. In general, most of the time has been spent in manufacturing phase to develop a prototype. In current method of prototype time taken on waiting for required prototype to be send back to the user. If any bugs occur in the prototype that has to be debugged and the process is repeated until the required quality has been achieved. The aim of this project is to reduce the time taken for developing the prototype by using additive, subtractive manufacturing and Microcontroller programming. The manufacturing techniques of 3D printing, CNC machining, Circuit builder are integrated. CNC machine are inherently more precise and accurate. It is a technology which aims to generate and execute sequential actions that describes the behavior of the end effector. By combining the above processes, we can achieve the required prototype in lesser time.**

***Keywords*— Additive, subtractive manufacturing**

I. INTRODUCTION

A new product typically undergoes several transformations before becoming available for sale to the general public. A new device idea is initially prototyped in order to evaluate the fit and finish of the mal part as well as to optimize the fabrication process to identify difficulties in manufacture. These steps can be time-consuming and expensive, creating a significant obstacle for new product introductions especially for starts that may not have the appropriate, usually expensive, machining equipment required for prototyping. Additive Manufacturing (AM) was introduced in the late1980's in order to rapidly prototype structures and allow manufacturers to circumvent the lengthy process of traditional prototyping by providing either a scaled down or full-scale mechanical replica of the designed product.

These devices were typically only conceptual models due to limitations of the AM technologies in which compromises were made in terms of material choices, surface finish and dimensional accuracies.AM technology continues to advance in terms of material properties and minimum features sizes, the technology until recently has remained best suited for manufacturing prototypes for conceptual modelling relegated to only satisfying the need for evaluation of form and of the device casing or structural features.

A CNC router is a CNC router tool that shapes an object. The CNC works on the Cartesian coordinate system (X, Y, Z) for 3D motion control. Parts of a project can be designed in the computer with a CAD/CAM program, and then cut automatically(SM) using a router or other cutters to produce a finished part. In this project, driller machine acts and performs the operation of CNC router. It subtracts the waste materials and shape an object. It moves along its axial direction of X, Y, Z which is directed by programmed Arduino board.

II. BASIC WORKING PRINCIPLE

First, confirm that you have the correct template for your paper size. This template has been tailored for output on the A4 paper size. If you are using US letter-sized paper, please close this file and download the file “MSW_USltr_format”.

A. 3D printer, circuit builder

Though typical methodologies like clay models, one-off samples handmade by skilled craftsmen, and more recently AM technologies have largely addressed the need for prototype these types of parts have been exclusively made to test appearance and of the completed part. When the device included sophisticated electronics, these methodologies could not address the need for prototyping a fully functional part.

AM process can fabricate prototypes that will enable at least a comprehensive evaluation of the design, not only for form and appearance, but also for electronics functionality simultaneously. Although this new manufacturing technology allows for more complete evaluations with high fidelity prototypes, substantial challenges remain. The area of electronics design (e.g. schematic capture, simulation, and physical implementation of printed circuit boards _ PCBs) includes mature, commercially available software packages that allow for component placement and routing of wires to create electrical interconnects on a PCB. These programs however, operate under the assumption of the workspace being a two-dimensional surface for the circuit based on traditional PCB manufacturing.

As a result, the component placement and routing for 3D printed designs has been done manually in 3D space using mechanical engineering CAD software like Solid Works without the inherent features for electronics functionality. This lack of software support has relegated.

For circuit builder, conductive ink is used as an input into extruder to draw the path as designed in the EAGLE CAD software.

B. CNC Mechanism

CNC (Computerized Numeric Control) Machining has been widely used in manufacturing industry for many years. Most of the standardized codes (G and M Codes) and CAM (Computer Aided Manufacturing) software have made its application and learning processes easier. Machining of very complex shapes is only possible with CNC machines. Therefore not only in the industry but also in the education sector, CNC is becoming an integral part of manufacturing courses in most of the universities worldwide.

A CNC router is a computer controlled cutting machine related to the hand held used for cutting various hard materials, such as wood, composites, aluminium, steel, plastics, and foams. CNC stands for computer numerical control. CNC routers can perform the tasks of many carpentry shop machines such as the panel saw, the spindle moulder, and the boring machine. A CNC router is very similar in concept to a CNC milling machine. Instead of routing by hand, tool paths are controlled via computer numerical control. The CNC router is one of many kinds of tools that have CNC variants.

A CNC router typically produces consistent and high-quality work and improves factory productivity. Unlike a jig router, the CNC router can produce a one-off as effectively as repeated identical production. Automation and precision are the key benefits of CNC router tables. CAM software makes the CAD drawing/design into a code called g-code. This code the CNC machine can understand. In short, CNC technology is not very complicated. It is a tool controlled by a computer. It only becomes more sophisticated when considering how the computer controls the tool. The illustration shows what a bare bones CNC machine might look like without its controller.

Applications

A CNC router can be used in the production of many different items, such as door carvings, interior and exterior decorations, wood panels, sign boards, wooden frames, moldings, musical instruments, furniture, and so on. In addition, the CNC router helps in the thermoforming of plastics by automating the trimming process. CNC routers can help ensure part repeatability and sufficient factory output.

C. Micro controller

A typical embedded system involves both hardware and software components. The hardware may include sensors and actuators, while the software is used to control these hardware modules. For example, to implement an auto-pilot system, we can apply camera to locate the road markings and motors to drive the robot. The software written should process signals received from the camera and then produce a proper output to control the actuators so that the robot can follow a path.

The initial stages of the operation mechanism are defining the input and output modules included in the current design. The system will provide a list of available I/O components for the user to select and the user only need to input information regarding the port and pin number that the component is connected to; all these are through a graphical user interface (GUI). Once the I/O components have been defined, the next step which is optional, user can also define the initial operation to be performed when powered is on. The next step is most important; it allows the user to relate the action to be performed.

Hardware modules

The hardware components do not require special design consideration provided that they can be interfaced with the I/O ports of the processor. On the other hand, the software of the system is more significant and is presented in the next section.

The software system

The major role of the software component is to assist students to develop a proper C language program for the ADuC832 processor so that control of the input/output devices can be achieved. Based on the design of a similar system [4], which was tailored for assembly language programming, we had identified the following design criteria:

1) User-friendliness;
2) Proper support of hardware modules; and
3) Able to produce the correct C program.

In order to make the system user-friendly, a graphical user interface (GUI) based on the Windows Forms programming is adopted as it is easy to implement and maintain.

D. Function generator prototype

A function generator is usually a piece of electronic test equipment used to generate different types of electrical waves over a wide range of frequencies. This prototype of function generator can generate the waves of sine, triangle and square. It is the prototype of mobile function generator in which 5v battery is placed on the top and it is acts as a power source. The tuner for amplitude and frequency is taken on the both sides of the prototype. By using the probe connection the waves are finally displayed in CRO. PIC16F876 is placed inside the function generator, where it is already programmed and stored in Micro controller programmer kit**.**

III. MATHEMATICAL MODEL

Transfer function for stepper motor

$$\frac{C(S)}{R(S)} = \frac{\omega_n^2}{+2\varepsilon\omega_s}$$

ω_n – *undamped frequency*

S -- Variable
ε -- damping ratio

Transfer function for CNC router

$$\frac{C(S)}{R(S)} = \frac{1}{TS}$$

T – Time variant
S – Variable

Transfer function heater

$$\frac{C(S)}{R(S)} = \frac{T_2 S}{1 + T_1 T_2 S}$$

$T_1 - Heater$
$T_2 - Thermistor$
$T_1 T_2$ - Time taken to reach 0.632 times the final value
S – Variable

Laplace transform stepper motor for step signal

$$\frac{\omega_n^2}{s^2 + 2\varepsilon\omega_n} = \frac{A}{s} + \frac{B}{s^2} + \frac{C}{s + 2\varepsilon\omega_n}$$

$$A(S)(S + 2\varepsilon\omega_n) + B(S + 2\varepsilon\omega_n) + CS^2 = {\omega_n}^2$$

$$(A + C)S^2 + (2A\varepsilon\omega_n + B)S + 2B\varepsilon\omega_n = \omega_n^2$$

$$2B\varepsilon\omega_n = \omega_n^2$$

$$B = \frac{\omega_n}{2\varepsilon}$$

$$2A\varepsilon\omega_n + \frac{\omega_n}{2\varepsilon} = 0$$

$$A = \frac{-1}{4\varepsilon^2}$$

$$C = \frac{1}{4\varepsilon^2}$$

$$C(s) = \frac{\frac{-1}{4\varepsilon^2}}{s} + \frac{\frac{\omega_n}{2\varepsilon}}{s^2} + \frac{\frac{1}{4\varepsilon^2}}{s + 2\varepsilon\omega_n}$$

Router for step signal

$$\frac{C(S)}{R(S)} = \frac{K_p}{TS} \qquad C(s) = \frac{K_p}{Ts^2}$$

Heater for step signal

$$\frac{C(S)}{R(S)} = \frac{\frac{K_p}{TS}}{1 + \left({K_p}/{T_1 S}\right)\left({1}/{T_1 S}\right)}$$

$$= \frac{\frac{K_p}{T_1 S}}{\frac{T_1 T_2 S^2 + K_p}{T_1 T_2 S^2}}$$

$$= \frac{K_p T_2 S}{T_1 T_2 S^2 + K_p}$$

$$C(S) = \frac{1}{S}\,\frac{K_p T_2 S}{T_1 T_2 S^2 + K_p}$$

$$C(S) = \frac{K_p T_2}{T_1 T_2 S^2 + K_p}$$

Inverse Laplace transform

$$C_1(t) = \frac{-1}{4\varepsilon^2} + \frac{\omega_n}{2\varepsilon}(\sin 0^2) + \frac{1}{4\varepsilon^2}e^{-2\varepsilon\omega_n}$$

$$C_1(t) = \frac{-1}{4\varepsilon^2} + \frac{1}{4\varepsilon^2}e^{-2\varepsilon\omega_n}$$

$$C_2(t) = t\,\frac{K_p}{T}$$

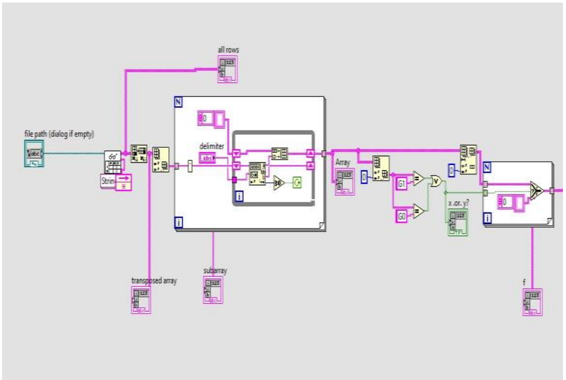
$$C_3(t) = \frac{{K_p T_2}/{T_1 T_2}}{s^2 + ({K_p}/{T_1 T_2})}$$

$$C_3(t) = T_2 \sin(\sqrt{K_p T_1 T_2})t$$

IV. SIMULATION AND RESULTS

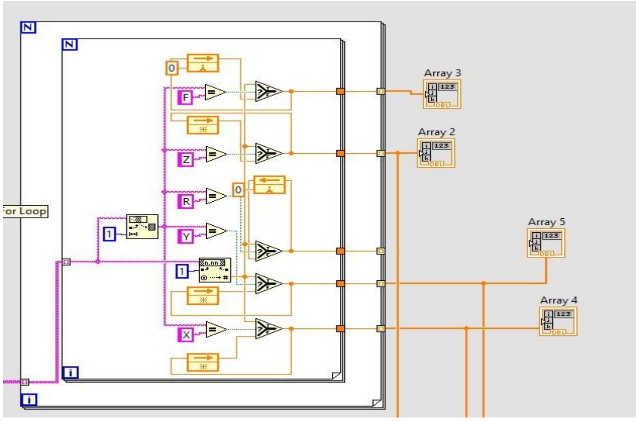
Block 1 Data Acquisition

In this data acquisition block, the G code file is acquired from the file. Then the file is split into different entities for future processing. After that, based on type of interpolation the data is split.

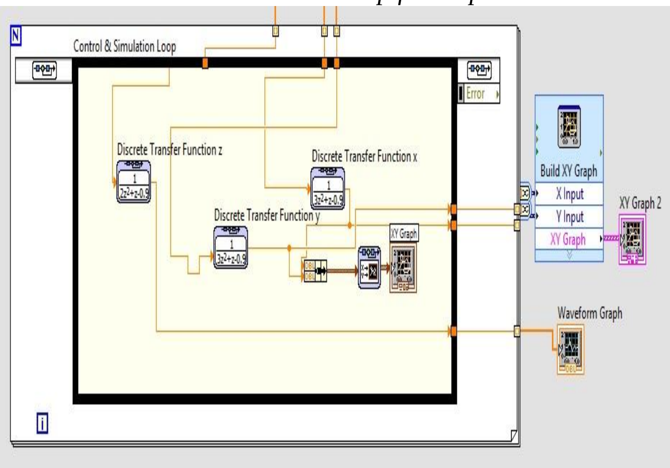


Block 2 Value Allocation

After the completion of data acquisition, the next step is to use this semi processed data to run the stepper motors and other actuators. This is done by segregation of data based on the path actuator connected, interpolation being used and feed rate in G code. The output is in integer array form.



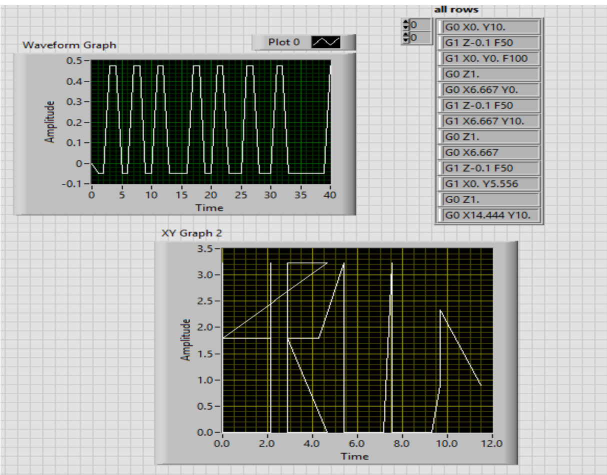
Block 3 Control and simulation loop for output



Here the processed data which is in integer form is given as input. This input is given to simulation equivalent of actuator based on their transfer function. The output is plotted on XY graph and waveform graph. The movement in X and Y axes are plotted on XY graph. The movement in Z axis is plotted in waveform graph.

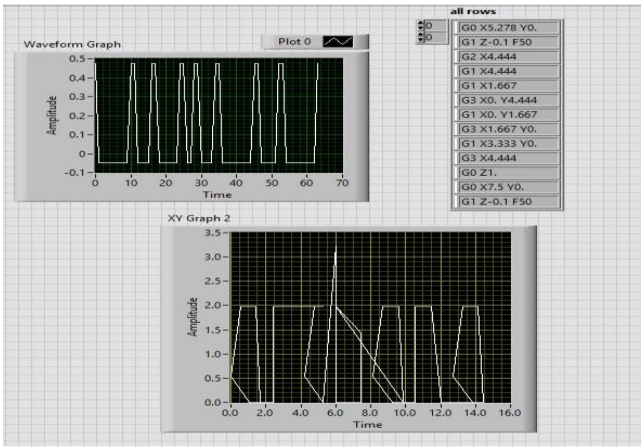
Output 1 Output for the word-HELLO

From the above description, for the word HELLO the axes of XY is plotted in XY graph and Z axes is taken in waveform graph.



Output 2 Output for the word-archana

From the above description, for the word archana the axes of XY is plotted in XY graph and Z axes is taken in waveform graph.



V. RESULTS AND DISCUSSION

The aim of this project is to reduce the time taken to develop a prototype. It makes use of additive manufacturing, subtractive manufacturing and Microcontroller programming. The simulation part is being completed in LABVIEW 2013 software. In this simulation, the simulated mechanical movement of 3D printer, CNC router and circuit builder is being done in all 3 axes. The output of this simulation is plotted in the XY graph and Z axis is in waveform graph. Then the transfer function is taken for all actuators and net transfer function of the control system design is calculated.

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