

Integrating Data Acquisition Tools to Accomplish An Automation Course Project

**Anna Shiver, Marvin Needler, Elaine Cooney
Purdue School of Engineering and Technology, IUPUI**

Abstract

This automation course introduces students to interfacing a wide-range of equipment: programmable logic controllers (PLCs), conveyors, pneumatic actuators, control relays, hardware sensors; robots, machine vision and smart-sensors; computers and data-acquisition cards; and to diverse kinds of software: machine vision, Matlab, and PLC software, with a major use of LabVIEW software for control and data acquisition.

Background

EET 371 Automation, Instrumentation and Process Control is a junior-senior level course in the Department of Electrical and Computer Engineering Technology, IUPUI. The purpose of the course is to introduce ECET majors to automation concepts and control and instrumentation equipment and software.

Emphasis of the course is on integration of hardware and software systems. It focuses on a major laboratory project to implement a model automated-assembly-line-style test system for an FM circuit board. (Figure 1)

To update the course to provide for more experience with state-of-the-art technology, machine vision has been added and control of a Rhino Selective Compliance Assembly Robot Arm (SCARA) with the DOS-based Robotalk has been converted to control of SCARA by the use of PCI counter/timer data acquisition cards and National Instruments LabVIEW software.

The model testing system employs a belt conveyor to move a test unit containing the FM circuit board first to a tuning station where electrical connections are made by a pneumatic actuator. The robot arm adjusts a potentiometer on the circuit board. The conveyor then moves the test unit to a testing station where the output and frequency response of the circuit board are verified. Finally, the unit is moved to the end of the conveyor where the robot arm removes it. Units are then sorted by the robot in accordance with the test results.

This paper describes the major features of the project: the PLC programming, the machine vision, and the robot control hardware and software.

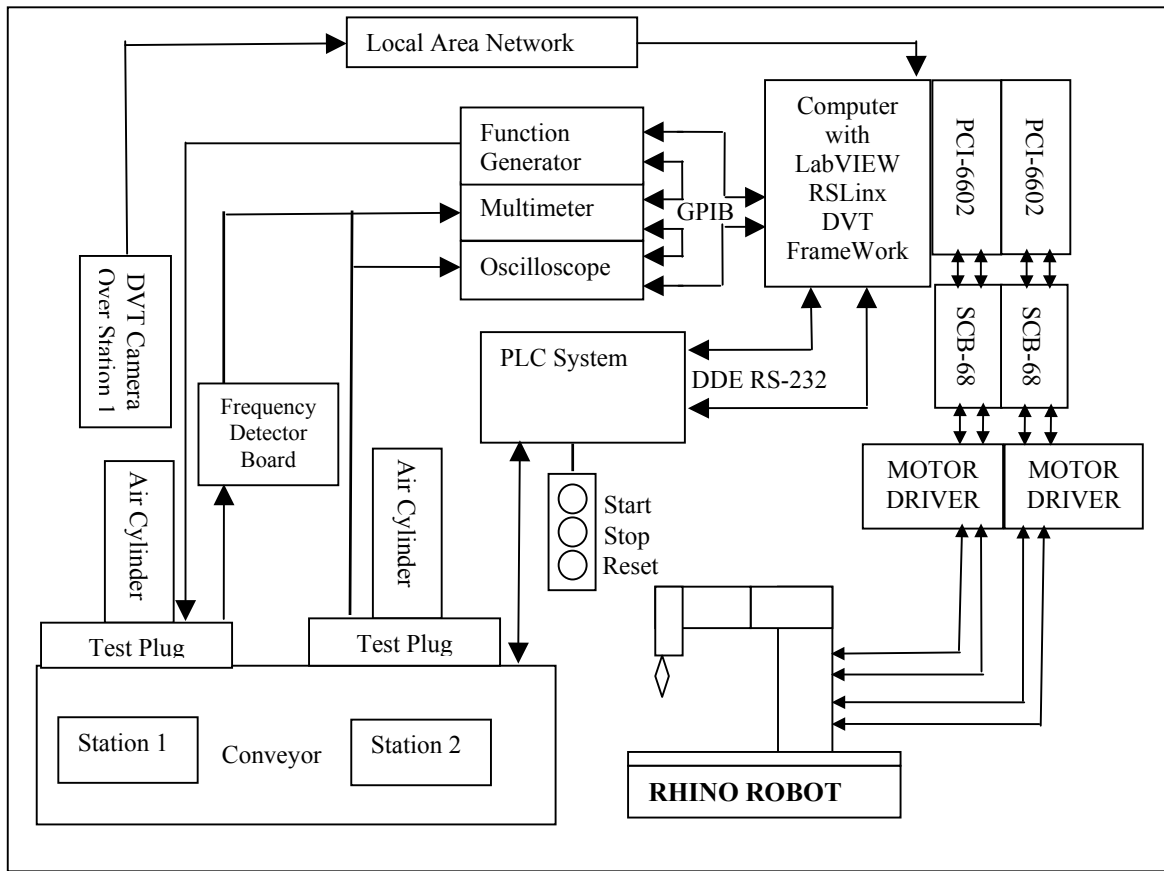


Figure 1

Block Diagram FM Circuit Board Test System

PLC Implementation

The project is of sufficient complexity that ad-hoc PLC programming becomes quite cumbersome; a very real communications problem exists for the members of the team to understand the author's "patching and fixing" approach to programming. For this reason, the programming is required to be structured^{1,2}. Structured programming also goes by the names sequential function charts (SFC), stage logic, state logic, Grafset, and Petri Nets (from robot programming).

Some PLC controllers have embedded stage logic. For other PLCs, it is necessary to program stage logic by providing a ladder logic rung for each state. The n^{th} state is activated by a change of the transition element, such as a limit switch or a timer done switch, but only if in a wait state from the $n-1^{\text{th}}$ state. The n^{th} state is rendered inactive, by the activation of the next state, and finally it is held active by its own bit output. Using this repeated logic rung for each transition, it is straightforward to program the ladder logic once the flow chart is determined. The flow chart is implemented by determining each step of the operation sequence; providing a logic-bit output that corresponds to each step, and then adding rungs to use each stage logic bit to drive real-world outputs that are active for those respective steps. For example, the conveyor

may be active during several logical steps, as it carries the part from one machining and/or inspection station to another.

This method of programming provides a built-in mechanism to force the programmer to program in an easily edited and understood framework. An editorial comment is that students who had built a long-term method of using ad hoc programming found stage logic a nuisance and resisted its use, but for the majority of them, they relented and agreed to its viability, especially in the face of this instructor. Others who were less experienced at programming seemed to accept and embrace stage programming more readily. Finally, this instructor especially appreciated it when it came to reviewing and grading projects.

Machine Vision

Digital vision technology has advanced greatly over the last few years to the point that it is a competitive means of sensing and controlling automation processes. Today, the price of a useful vision system is five to six thousand dollars, making it feasible for many industrial automation applications. Two popular systems are DVT Corporation and Keyence Corporation. The system that was adopted here is the DVT system³ due to the sizable educational discount, the strong user support, and the free downloadable software.

The first experience in the course with vision systems was use of the emulator. The DVT system comes equipped with a hardware emulator. By using the DVT camera a series of images are recorded that represent differing conditions of acceptable work product and unacceptable work products. These images are defined as an image sequence inside the emulator. The next step is for the student to use the emulator and a good work product to produce a set of “soft sensor” tools called an emulator product. Some of the soft-sensor tools are described as follows:

Positioning tools	For handling part movement. These tools can be “chained” to compensate for x and y displacement of the work part.
Translational tools	For detecting parts with simple geometry, straight and normal edges – fast computation, 2 to 3 ms.
Fiducial tools	For detecting areas and curved edges.
Rotational arc tools	For detecting rotational orientation.
Rotational parallelogram Tools.	For detecting rotated straight edges.

These tools can be used on the image sequence to set up a passing condition on the good part, and then to display a failing condition on a bad part. This process is identical to the online testing in a real-world situation. Once the set of sensor tools are in place, they can be named and saved to computer memory along with other products, and reselected as needed.

The second experience that is provided for students is the real-time use of machine vision including setting up the camera, interfacing with the camera, using an Ethernet data link, and talking to LabVIEW. Camera considerations follow:

- Use of the camera requires describing camera basics such as lenses, focal length, depth of field, lens aperture, f number, etc.
- Understanding of CCD cameras requires describing construction, mounts, pixels and CCD aspects.
- Setting up the camera requires knowledge of the spectrum, the nature of different kinds of lighting, the effects of shading, and the effects of color and intensity, and experimenting with lighting and appreciating the paramount importance of lighting in acquiring acceptable images.

Interfacing with the camera requires a breakout board to access the signals. The breakout board provides the following:

- An RJ-45 Ethernet connection and a RJ-11 RS-422 serial port to access camera images.
- Four strobe terminals that are active during exposure time
- A trigger button for manual operation, and
- Power terminals for 24-V dc power.

Communications are set up with LabVIEW by the following steps:

- The DVT Framework software connection dialog box is selected and the smart image sensor with the name and IP address is selected.
- The data link is set up by selecting I/O and Data Link in the DVT Framework software, and inserting the appropriate string data for communication with the LabVIEW DDE.

The third student experience is using the data from the DVT images to direct the robot to a target, such as the circuit board part position in x and y coordinates, or the rotational position of the potentiometer mounted on the board. This problem is open-ended in that several suggestions are made to the student groups and they are left to find the “best” solution, ranging from using “fixed-point” solutions to more elegant methods such as converting image displacement measurements to encoder counts of the robots. This effort is an ongoing field of investigation.

Robot Control Hardware

The Rhino robot arm has four axes of motion and a gripper. It uses five pulse modulated DC servo motors with integral gearboxes and incremental optical encoders for real-time closed loop operation.

Robot control hardware consists of two National Instruments PCI-6602 counter/timer cards with associated cables and breakout boxes, and locally manufactured motor driver circuits. The driver circuits (one for each axis) convert TTL level signals from the counter/timer cards to the +/- 12 Volt, high current signals necessary for the servo motors. The motor driver circuits also provide connectivity to the encoder and home signals from the robot. (Figure 1)

Motion control for each axis is achieved using two counter/timer circuits configured for pulse-train generation output, and one counter/timer circuit configured for quadrature encoder input. Digital I/O available on the counter card is used for axis home signal input.

Robot Control Software

Control software using National Instruments LabVIEW 6.1 graphical programming environment⁴ was developed to control the robot. A very modular, object-oriented approach to the software development gives maximum flexibility for hardware changes and rapid development of application specific movement sequences. (Figure 2)

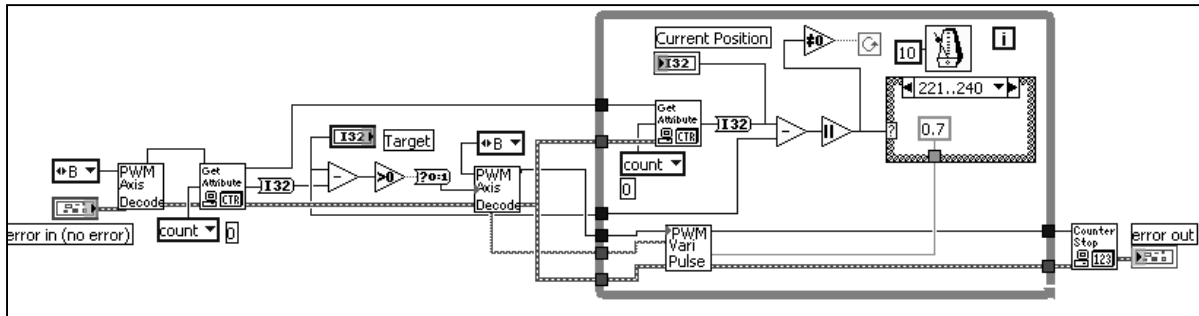


Figure 2

Modular design makes diagram of a top-level application is easily understandable.

Control software is bundled into a library of LabVIEW virtual instruments (VIs). The highest functions available to students as part of the library are individual axis movement VIs. (figure 3) Although robot control is possible using only the individual axis movement VIs as distributed, students are strongly encouraged to modify them and utilize the more basic modules to customize and fine-tune the robot movement applications. This approach has yielded some outstanding results in student projects.

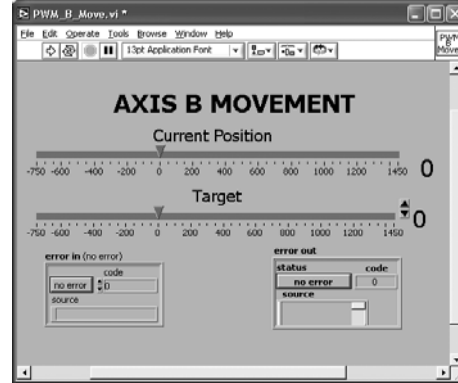


Figure 3

Front Panel of Axis B Movement VI.

Student Response to the Course and its Objectives

The response of the student body to the project was generally favorable, as shown in the table of student responses. The responses were anonymous and confidential.

Table of student responses to course objective statements

Agreed or strongly agreed	Course Objective: As an outcome of this course EET 371, I can do the following:
86 %	Write computer programs using LabVIEW to control instrumentation.
79 %	Write LabVIEW programs to control a robot (under listed conditions).
93 %	Write programs for PLC with system I/O.
64 %	Write PLC programs in state logic form.
36 %	Use MATLAB to tune a PID controller (under listed conditions).
79 %	Use machine vision to identify and locate components.
86 %	Perform as part of a team (under listed conditions).

On a qualitative basis, below are the responses of four students for their brief comments on the course and its objectives. The students were chosen at random several months after the completion of the course and were asked to be candid in their comments.

“EET 371 was a class that brought several things together for me. First it taught us how to use each system individually and then gradually integrated them into a single system. First we learned how to create Labview virtual interfaces and program various PLCs. It also showed how to work as a group to create a system using Labview, AB SLC500 series PLC and a GPIB board to create a system that would control a conveyor, robot arm and record data as the robot adjusted a potentiometer to a set range.” Douglas Wilson.

“Great class to improve team working skills and develop problem solving skills for programming and hardware. I was disappointed with the repeatability of the hardware but overall it was a great class.” Jason Roberts.

“EET 371 is a very educational course that covers material such as automatic testing and controls. The part of 371 I personally enjoyed the most was that at the end of the semester we were able to integrate several different brands of products into a working system. Those products included Horner, A-B, Labview, DVT, HP, and Fluke. Some people believe that if you have one brand that everything integrates flawlessly. I believe that products have strong points and in the real world we must know how to integrate different product brands to achieve the goals for real applications. Overall, 371 provided a good foundation for system integration as well as several other topics.” Brandon Wilson.

“EET 371 was a beneficial course. It helped me to see how robots are programmed. In order to do this project, things needed to be linked together as well. Working with a team for the class project was also beneficial. I was in a group where I didn’t know anyone so I had to become acquainted with them. We were able to combine our separate parts together and make the project work. This helped for me to see how this could work in a career. I thought the class was interesting and valuable.” Gregory Cool.

Summary

This project course is successful in bringing new technology into the curriculum. Since the course was introduced, the PC has moved into the foreground with the use of LabVIEW and machine vision. LabVIEW is not only used to display the testing outcomes and to communicate actions to the PLC, but it is also used to communicate with the vision system and to drive the robot through high-speed timer-counter cards. The need for a separate microprocessor has been eliminated. The use of machine vision allows part acceptance/rejection as well as part location identification for the purpose of robot control. Finally, the use of structured PLC programming upgrades the course to meet current programming standards.

Bibliography

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ANNA SHIVER is a visiting lecturer in Electrical and Computer Engineering Technology of IUPUI. She received her BSET from Purdue School of Engineering and Technology, IUPUI. Her areas of expertise include local area network administration, embedded programming, and graphical programming for motion control.

MARVIN NEEDLER is Professor and Chair of ECET of IUPUI. He has been teaching in engineering and technology for many years and has consulted with many companies and organizations.

ELAINE COONEY is an Associate Professor of Electrical Engineering Technology. She received her BSEE from General Motors Institute and MSEE from Purdue University in West Lafayette, IN. Her areas of expertise include electronics manufacturing and test engineering