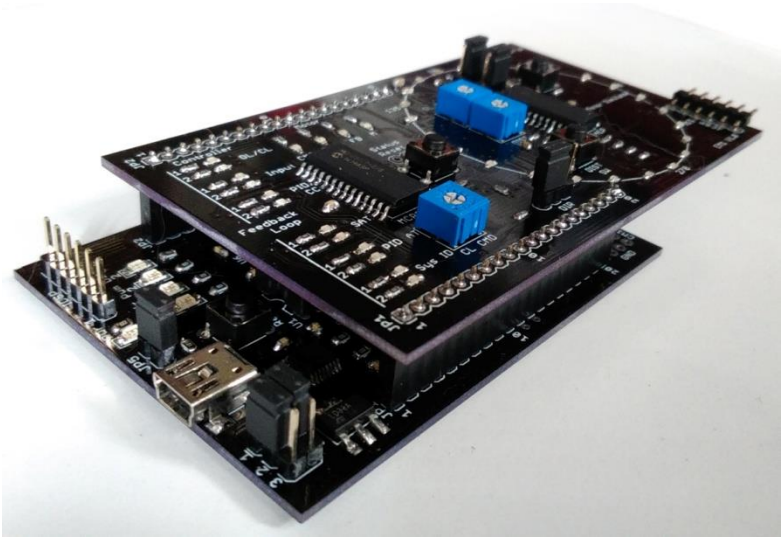


Embedded Control Design

Experimental boards for control engineering study

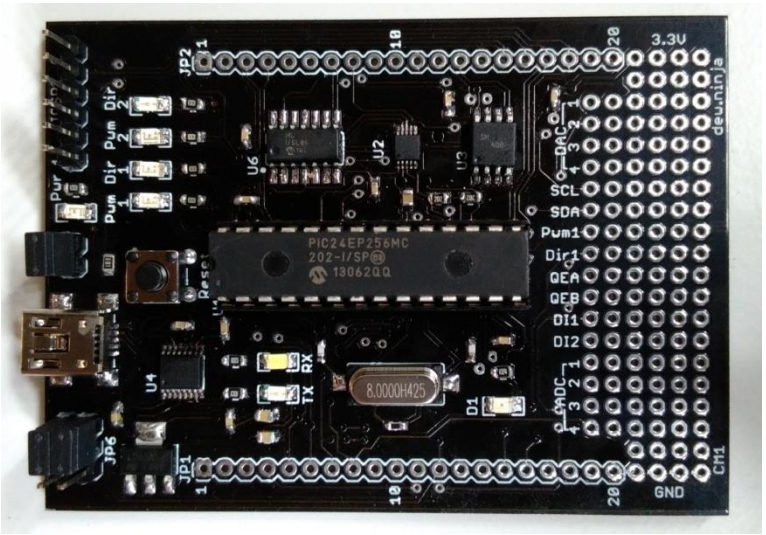
Author bio : Dr.Varodom Toochinda, creator of dew.ninja website, received Ph.D in Mechanical Engineering at the University of Massachusetts, Amherst. He is now a researcher/lecturer at Kasetsart University, Thailand.

With rapid progress of electronics and embedded hardware nowadays, control system analysis and design has become even more interesting and challenging for engineering students. Projects that one could only dream of in the past are now feasible. In a developing country where budget is often limited, even though embedded hardware might be affordable, controller implementation normally requires sophisticated, proprietary, and expensive software. That means a significant investment beyond the reach of an average student or hobbyist.

While many beginners choose to start basic programming experience with off-the-shelf products like Arduino instead of building a customized embedded hardware, when it comes to serious feedback control design that path is more or less problematic. Stringent stability and performance requirements imposed upon a closed-loop system urge for tighter hardware

resource utilization, faster processor, and less firmware overhead (no room for that wiring language processing). At the other extreme, selecting a 32-bit processor for this purpose adds unnecessary complexity and may not be cost-effective. Thanks to the new PIC24E and dsPIC33E product line from Microchip Technology, Inc., we can construct a high-performance, reliable embedded platform that executes a control algorithm at 70 MIPs, with minimal hardware and peripherals.

The main purpose of our recent embedded development is to construct low-cost experimental boards for control education. At the heart of this project is the Controller Module 1 (CM1) that serves as a target board for controller implementation.



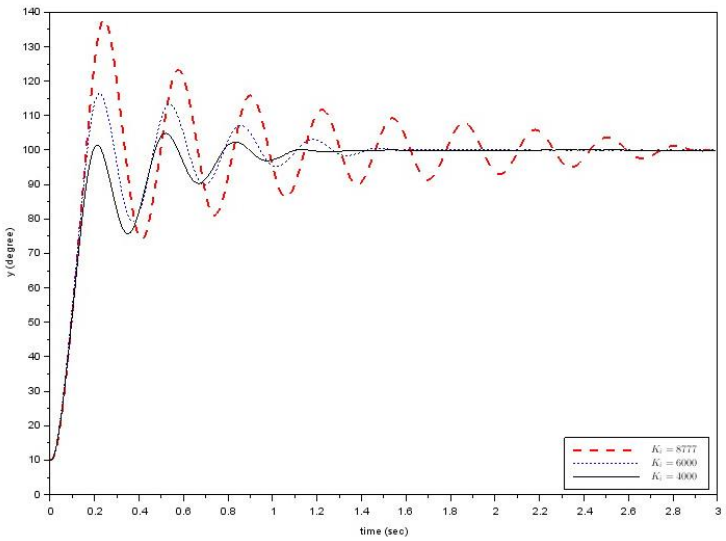
The Controller Module 1 (CM1)

Technical details for the CM1 board are as follows:

- PIC24EP256MC202[1] MCU running at 70 MIPS
- Number of ADC channels: 4
- Number of DAC channels: 4
- DAC external IC: MCP4728[1] with I2C interface
- DAC channel buffer: MCP6004[1] quad opamp
- EEPROM: 24LC128[1], 128 Kbits with I2C interface
- USB to UART converter: FT230X from FTDI
- Power supply: 5V from USB, adjusted to 3.3 V by LD1117 regulator
- Other features: Quadrature encoder interface. External UART communication and power supply selectable by jumpers. Prototype area.

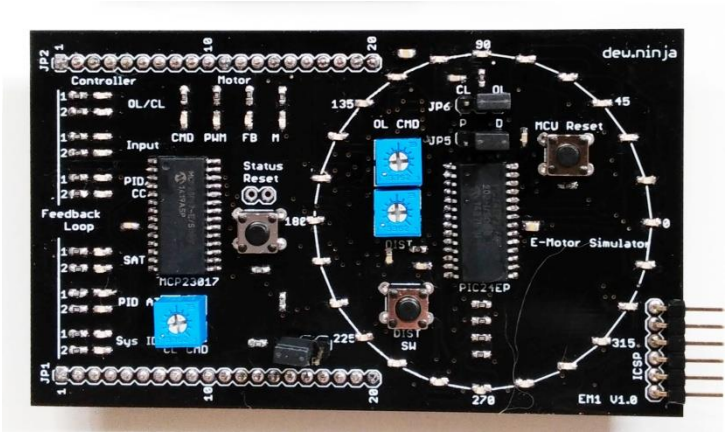
(1) products of Microchip Technology, Inc.

The user can select standard PID structure and adjust the parameters, or using PID autotuning feature, or even design a custom controller using plant data from system identification process. To accommodate user communication, the CM1 executes a simplified real-time operating system named *RED (Responsive Embedded Development)*, which utilizes a variant of cyclic executive scheduling.



Commands such as PID parameters adjustment, timer period selection, and other settings can be sent via a serial port terminal program. In data capture mode, the board transfers requested information in ASCII text format. The data is easily copied to an open-source software like Scilab for analysis and control design. For example, to study the effect of PID gains on tracking performance, step responses from different PID settings can be compared. Apart from standard PID, the CM1 board can implement more advanced linear controller such as one obtained from H_∞ synthesis. With firmware modification, one could implement other nonlinear control laws like adaptive control or fuzzy logic.

Motor Simulation Module



A physical motor is not quite suitable for feedback control experiments in a classroom. It requires a drive circuit and external power supply to operate. So a DC motor simulation board, designated EM1 module, is constructed. This auxiliary board behaves like a real DC motor, with programmable parameters to change its dynamics. For a more challenging control problem, it can even simulate a motor with harmonic drive mechanisms. In addition to the motor simulation part implemented

on PIC24EP256GP202, this board also provides various status LEDs such as feedback loop open/closed, PID autotuning active, etc. using MCP23017 16-bit I/O expander from Microchip. Output disturbance can be applied by pressing a push-button switch, just like the user presses on a motor shaft disc to drag the rotation.

The EM1 board can be coupled to the CM1 board via connectors along the board edges. Both boards have their own ICSP connector for easy programming using Microchip's PICKIT3 or ICD3, MPLAB X and XC16 compiler. Once development is completed, there is no need for students to do any C programming, because all operations are performed via the RED firmware running on the CM1 board.

While the RED firmware is still under final development, The CM1 and EM1 prototypes are currently used as teaching aids for both undergrad and graduate classes at Kasetsart University. On Microsoft Windows and MAC OS X, a user needs only to install corresponding VCP driver from www.ftdichip.com, and a serial port terminal program such as hyperterminal (Windows) or CoolTerm (MAC). For Ubuntu 15.04 the driver is already in the kernel. Student feedback is essential to improve the functionality and user-friendliness of these experimental boards so that they could serve as valuable tools for control engineering study.

Future development of the CM1 board is to install it as a controller module in certain industrial control applications. The hardware is already designed to accommodate such extension, with most inputs and outputs accessible via connectors. With jumper selection, To control the module remotely, the USB-to-serial chip can be disconnected from MCU UART and replaced with other modules such as Bluetooth or WiFi.