

ELECTRO-MECHANICAL Engineering Control System

Real-Time Control Multiple Control Mode

TeraSoft ELECTRO-MECHANICAL Engineering Control System (EMECS)

Is a set of electro-mechanical devices for control engineering research and education. EMECS consists of modular mechanical and electrical hardware such that a variety of control experiments can be easily constructed and are suitable for all level of instruction. It is also sophisticated enough to provide a platform for investigating a variety of control related problems such as system modeling, system identification, linear control, nonlinear control, optimal control, haptic control, intelligent control, and switching control to name just a few. In addition to hardware, Simulink blocks for the experiments are provided to help users in control design and simulation. Furthermore, in Simulink environment, using The Mathworks Embedded Target for TI C2000 DSP and Texas Instruments Code Composer Studio, the user can automate the implementation of real-time control on a DSP-target board.

TeraSoft EMECS is to provide multi-function control model experiments to carry out the procedure of Theories→ Program simulations →Controller design → Hardware implements. Students can easily learn the control design theories from the whole procedure and verify it by implementing the laboratory experiences.



【Structures of EMECS】

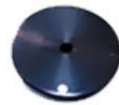
Multi-Function Model Experiments

| Experiment \ Hardware | Servo-Motor Module | DSP-Target Controller | Link 1 | Link 2 | Inertial load Control Tuner |
|--|--------------------|-----------------------|--------|--------|-----------------------------|
| Swing up and balancing control of rotary inverted pendulum | √ | √ | √ | | |
| Swing up and balancing control of arm-driven inverted pendulum | √ | √ | | √ | |
| Position Control | √ | √ | | | √ |
| Speed Control Mode | √ | √ | | | √ |
| Haptic Control | √ | √ | | | √ |

EMECS consists of DSP-Target Controller, software and control module:

1. DSP-Target Controller :
 - High performance 150MHz TI-F2812DSP and MATLAB/Simulink auto-code supported.
2. Inertial Load Control Tuner :
 - 甲、Φ 60mm, Weight 75g
 - 乙、 Supports position/speed/haptic control mode.
3. Servo-Motor Module Link 1/2
 - Including both M5068-24V-6K motor and 500 Pules/Rev. Encoder.
 - Link 1 : Rotary Inverted Pendulum
 - ✓ Arm
 - length: 16cm, Weight 60±5g
 - ✓ Pendulum
 - length: 16cm, Weight 25±3g
 - ✓ Encoder:
 - 500 Pules/Rev. Weight 58±3g
 - Link 2 : Double-Link Inverted Pendulum
 - ✓ Arm
 - length: 20cm, Weight 60±5g
 - ✓ Pendulum
 - length: 16cm, Weight 25±3g
 - ✓ Encoder
 - 500 Pules/Rev. Weight 58±3g
4. Servo-Motor Module
 - Weight: 3±0.1kg
 - Includes Servo-Motor and Encoder:
 - ✓ Encoder(500 Pules/Rev.)
 - ✓ Servo-Motor (M5068-24V-6K)
 - Highest efficiency: 5800RPM 1.6°/0.4Kgf-cm
 - Export power: 31.5 Watt
 - Starting Injector : 1.8Kgf-cm
 - Flexible Control System: Can also connect with other controllers.

【HARDWARE STRUCTURE】



Inertial Load Control Tuner :

- Φ 60mm, Weight 75g
- Supports position/speed/haptic control mode.

DSP-Target Controller :

High performance 150MHz TI-F2812DSP and MATLAB/Simulink auto-code supported.

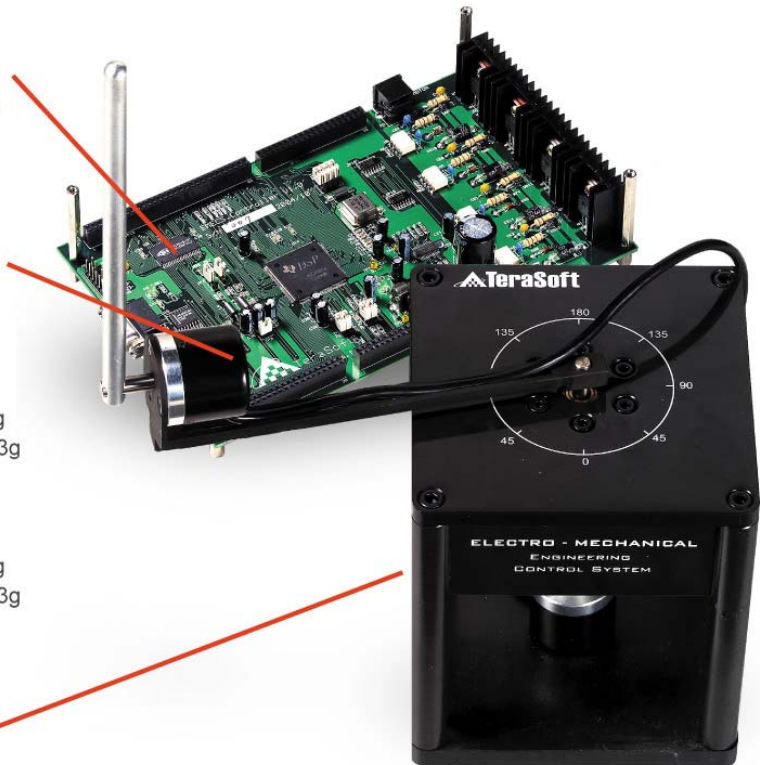
Servo-Motor Module Link 1/2

Including both M5068-24V-6K motor and 500 Pules/Rev. Encoder.

- Link 1 : Rotary Inverted Pendulum
 - Arm : length 16cm, Weight 60+-5g
 - Pendulum : length 16cm, Weight 25+-3g
 - Encoder : 500 Pulses/Rev. Weight 58+-3g
- Link 2 : Arm-Driven Inverted Pendulum
 - Arm : length 20cm, Weight 60+-5g
 - Pendulum : length 16cm, Weight 25+-3g
 - Encoder : 500 Pulses/Rev. Weight 58+-3g

Servo-Motor Module

- Weight: 3+-0.1kg
- Includes Servo-Motor and Encoder:
 - Encoder(500 Pules/Rev.)
 - Servo-Motor (M5068-24V-6K)
 - Highest efficiency: 5800RPM 1.6°/0.4Kgf-cm
 - Export power: 31.5 Watt
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- Flexible Control System:
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【SPECIFICATIONS】

1. DSP-Target Controller

DSP target controller is an integration of a DSP Target controller and motor power driver.

- Includes TMS320 F 2812 DSP
- 32K words on board data RAM
- 32K words on board program RAM
- On board 30 MHz crystal
- I/O Functions
 - PWM*12
 - Digital I/O*56(shared)
 - CAP/QEP*6
 - Enhanced Controller Area Network (eCAN)*1
 - Serial Communications Interfaces (SCI)*1, Standard UART
 - Serial Peripheral Interface (SPI)*1
 - Multichannel Buffered Serial Port (McBSP)With SPI Mode*1
 - ADC*16(12 Bit):
 - ◆ 2 * 8 Channel Input Multiplexer
 - ◆ Two Sample-and-Hold
 - ◆ Single Conversion Time: 200 ns
 - ◆ Pipeline Conversion Time: 60 ns
 - DC Motor Driver Circuit(+/- 24V) : PWM to DAC circuit module
 - Switching Power Supply (100/240V) : Output +/-24V, 1.8A



2. Software Requirements

Auto-Code: Work on MATLAB/Simulink Model-based environment, and with Real-Time workshop to have auto-code generation. Compiling the code by TI CCS (Version 2.2 or above), then download it to DSP target controller with JTAG Emulator.

Software : MATLAB (Version 7) / Simulink / RTW / Link for TI CCS / Embedded Target for TI C2000 / Signal Processing Blockset / Control Toolbox / Fixed Point Toolbox / RTW Embedded Coder(Optional) and TI CCS (Version 2.2 above) including JTAG Emulator ◦

Hand-Code : Write C –Source Code and compile it by TI CCS (Version 2.2 or above), then download it to DSP target controller with JTAG Emulator.

【Functions of EMECS】

1. Swing up and balancing control of rotary inverted pendulum



A laboratory exercise is to configure EMECS as a rotary inverted pendulum. The rotary inverted pendulum is a highly nonlinear system. The control purpose of this experiment is to design a hybrid controller for swing up and balancing control of the pendulum in the vertical-upright position.

2. Swing up and balancing control of arm-driven inverted pendulum



An arm-driven inverted pendulum is a two-link robot arm where both links can rotate freely in the vertical plane but only one is actuated. The objective of this experiment is to design swing up and balancing controllers for two different unstable equilibrium configurations.

3. Position Control

EMECS can be configured to control a DC servo motor with an attached inertial load. A position control system is designed such that the output angle tracks a commanded position.

4. Speed Control Mode

EMECS can be configured to control the speed of a DC servo motor. The configuration is the same as that of position control above. A feedback controller is designed to regulate the speed of the output shaft and reduce the closed-loop steady state error.



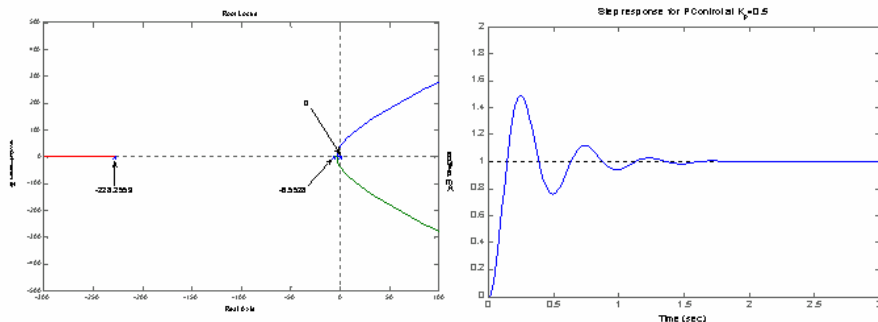
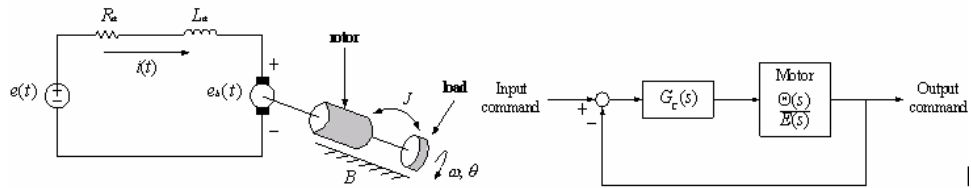
5. Haptic Control

The objective of this experiment is to establish the detent-action models for haptic control. Two Simulink models are provided and implemented on the servo motor module with the inertial load disc. The inertial load disc serves as a haptic knob. By turning the haptic knob, the user can feel the effects of the force-feedback of haptic detents.

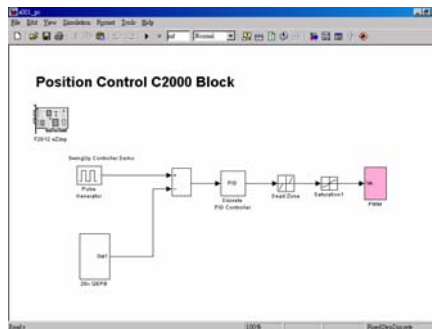
【EMECS OPERATION THEORIES】

1. System Modeling

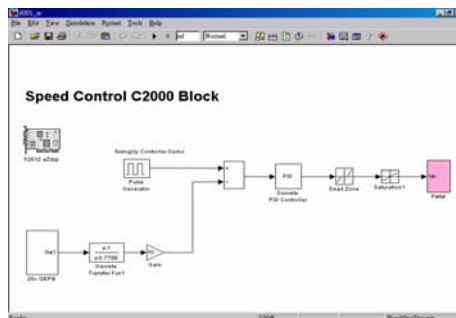
System-Level Algorithm simulation → Root-Locus of the system-level Proportion controller / Unit step response → DC Motor integration control



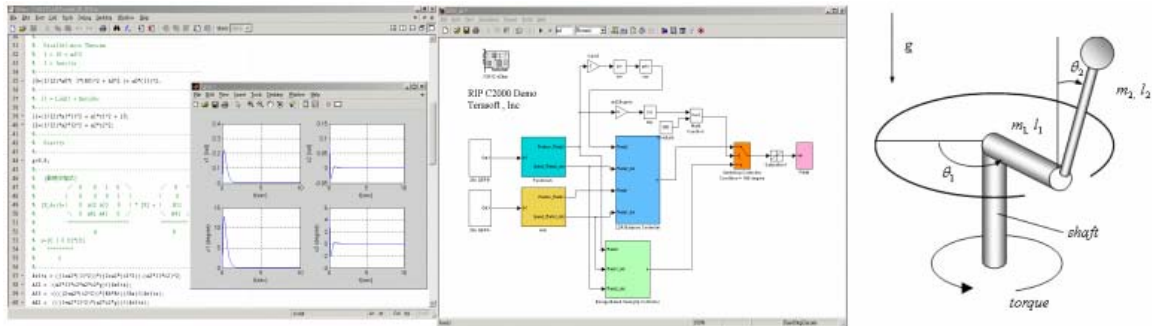
Control system algorithm design and simulation



DC Motor Position Controller Design



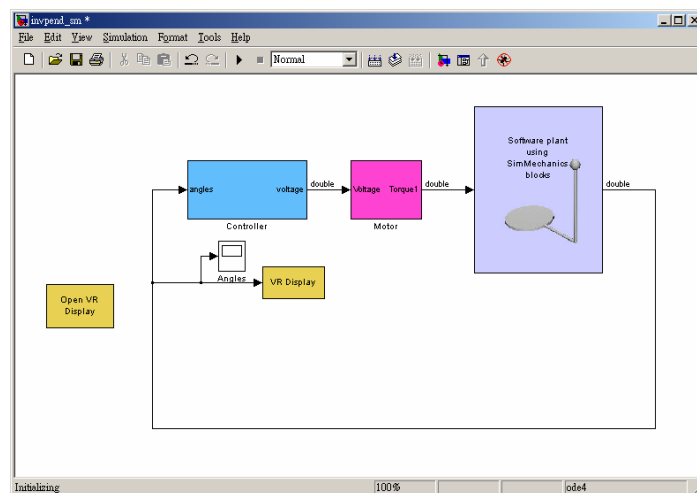
DC Motor Speed



Swing up and balancing control of rotary inverted pendulum design by LQR theory(Energy-Based)

2.EMECS Theories and Models

Rotary Inverted Pendulum System consists of servo- motor, shaft and pendulum rod. Use servo-motor to drive the shaft moving as a circle path, then control the pendulum rod swing up and stand still. The system is using MATLAB / Simulink to implement controller design and the simulation chat is as follow.



Rotary Inverted Pendulum System Model



Rotary Inverted Pendulum Control System 3-D simulation