A Test Bed for Evaluating and Comparing Designs for Embedded Control Systems

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Motivation

- PhD project: “Distributed fault-tolerant software architectures for X-by-wire”
- Future drive-by-wire applications will require low cost implementation but demand high safety standards.
- To find suitable solutions we need a we need a way to evaluate each system and to be able to draw comparisons between them.

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Overview

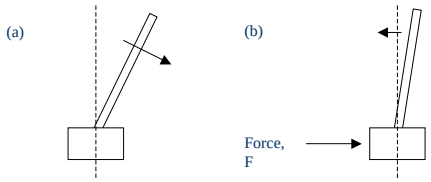
- Test bed systems
- Single processor control
- Distributed (multi-processor) control
- Test bed 1: An inverted pendulum
- Test bed 2: A diesel generator
- Summary

Test bed criteria

- Allow repeated tests under laboratory conditions
- Give a clear indication of control
- Allow for future fault-tolerance tests using redundant components
  - Sensors and actuators

The inverted pendulum problem

- Well established problem – used as an example in many control systems texts.
- The underlying theory is straight forward
  - As the pendulum falls in one direction..
  - A force is applied at its base base to correct its angle
- It is a naturally unstable system that requires relatively fast closed-loop control.



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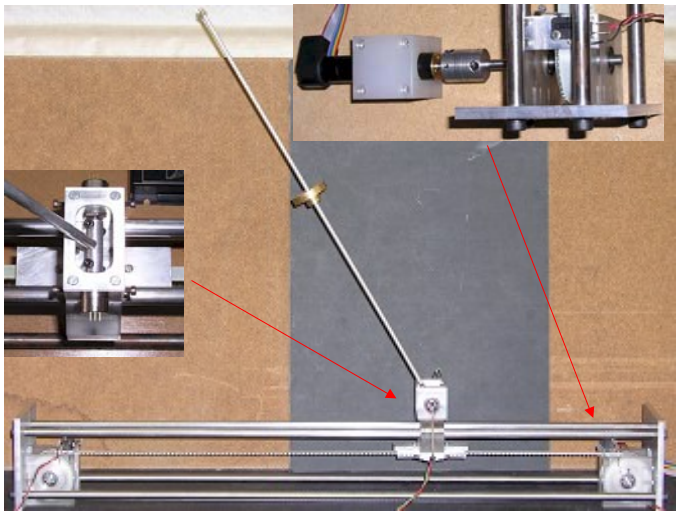
Designing the rig



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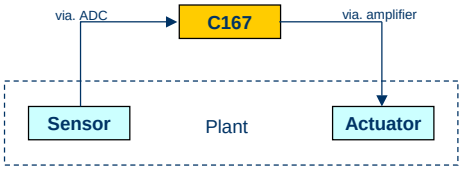
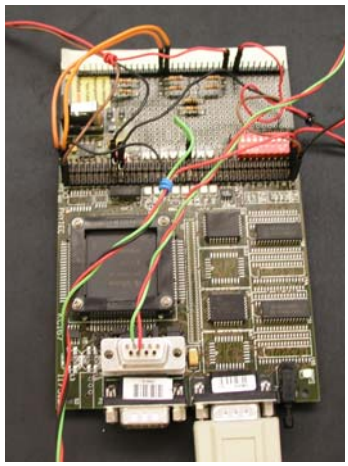
Embedded system design

- C167 microcontrollers widely used in the automotive industry.
- Developments boards for prototyping:
  - 1 RS-232 + 2 CAN interfaces.





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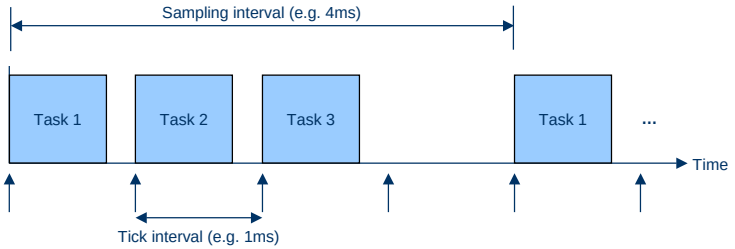
Task scheduling

- The control process has been broken down into 3 tasks
  - Sampling
  - Calculation
  - Actuation
- A time-triggered co-operative scheduler is used to run the tasks



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The PID algorithm

- The calculation task is based on a simple PID algorithm

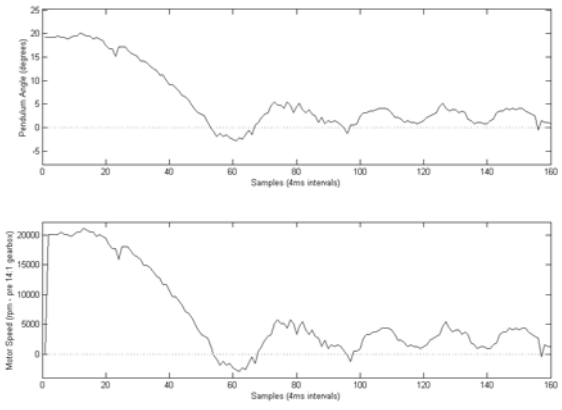
```
// Proportional term
signed float Control_new = (PID_KP * Error);

// Integral term
Sum_G += Error;
Control_new += PID_KI * Sum_G;

// Differential term
Control_new += (PID_KD * SAMPLE_RATE * (Error - Old_error_G));
```

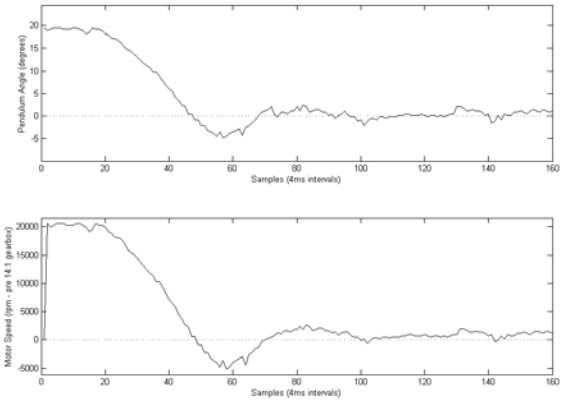
Code listing – “Patterns for time-triggered embedded systems” Pont, 2001

PID tuning



Proportional gain = 2000

Under control



Gains: KP = 350; KI = 3; KD = 20

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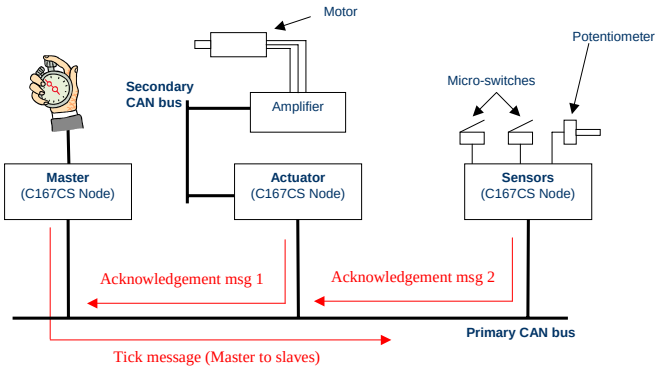
Networked control



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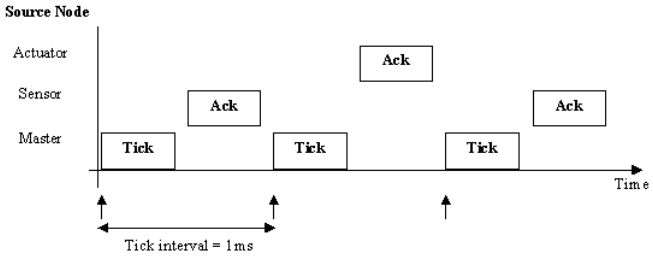
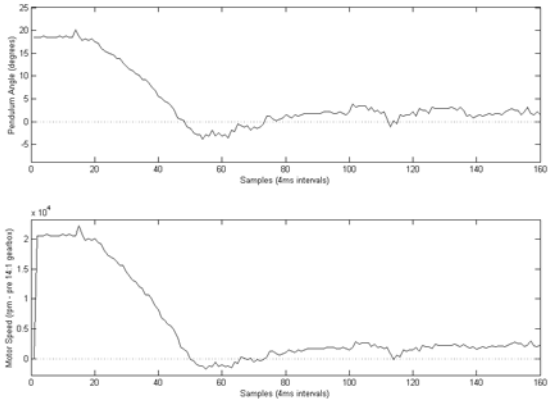
Shared clock scheduling

- The first distributed control tests were done using a simple shared clock scheduler.
- Here a master is the only processor running using an internal timer
- All other nodes run schedulers based on messages from the master
- Acknowledgement messages are used to tell which “slave” nodes are working

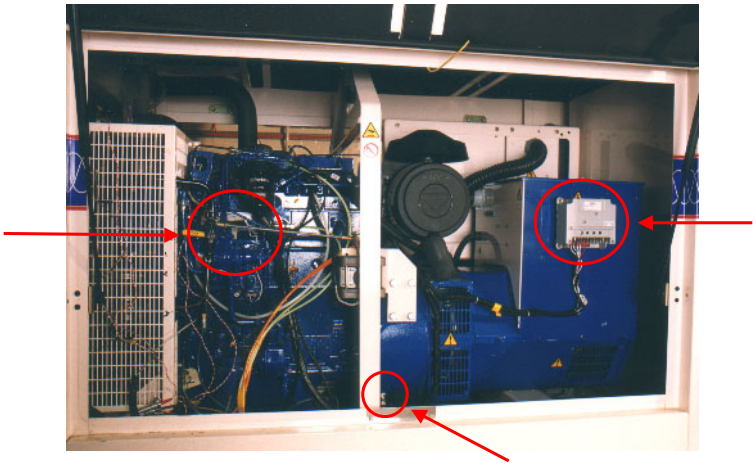


Networked control



Gains: KP = 350; KI = 3; KD = 20

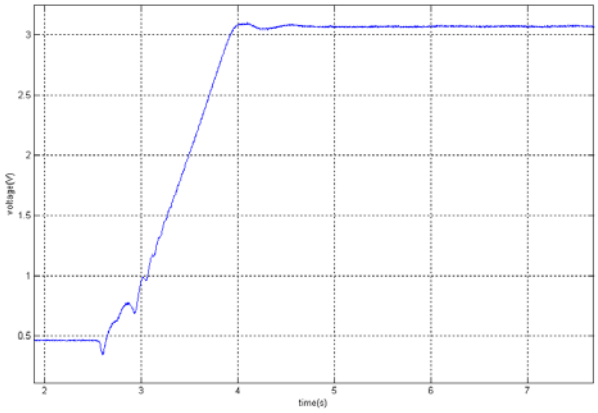
The Perkins diesel generator



The two test beds

- Advantages of the pendulum system:
  - Visual indication of control
  - Fast sampling required
- Disadvantages
  - Mechanical complications
- Advantages of a diesel gen set system
  - Widely used in industrial applications
  - Control has already been demonstrated
- Disadvantages
  - Slow system
  - No visual indication of performance

Test bed 2: Single processor control



Gains: KP = 1.8; KI = 0.01

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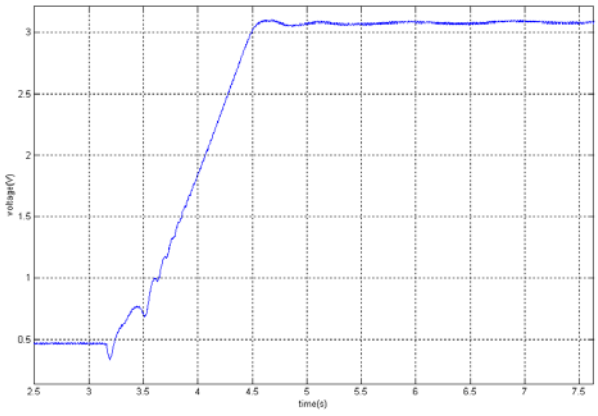
Test bed 2: Multi processor control



Gains: KP = 1.8; KI = 0.01

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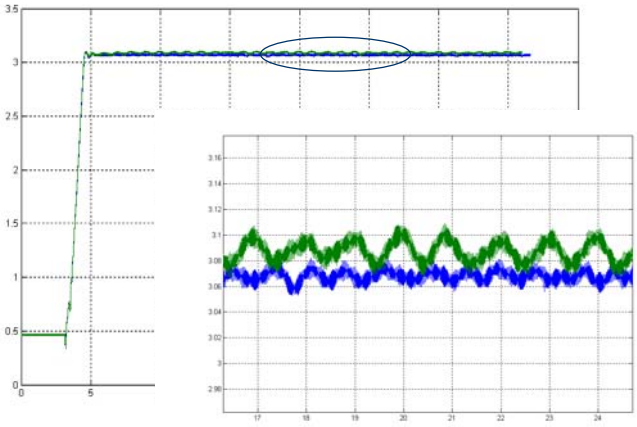
Comparing single and multi processor control



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Comparing single and multi processor control

- Average values calculated over 3 x 10 minute runs:

	Single	Multi (S-C)
Mean average	3.0607	3.0909
Std deviation	0.0047	0.0112

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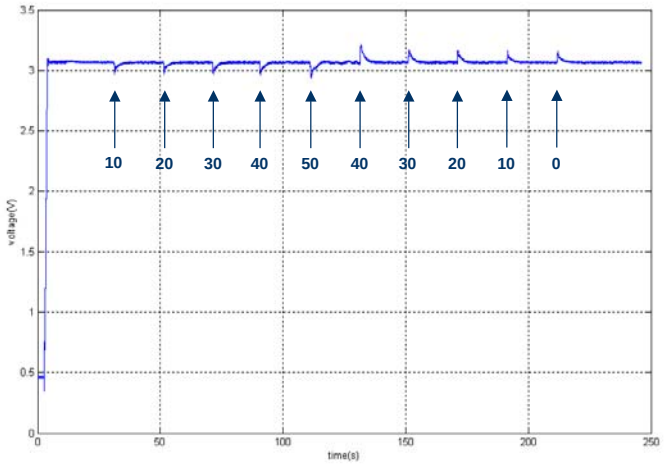
Load changing – Single processor



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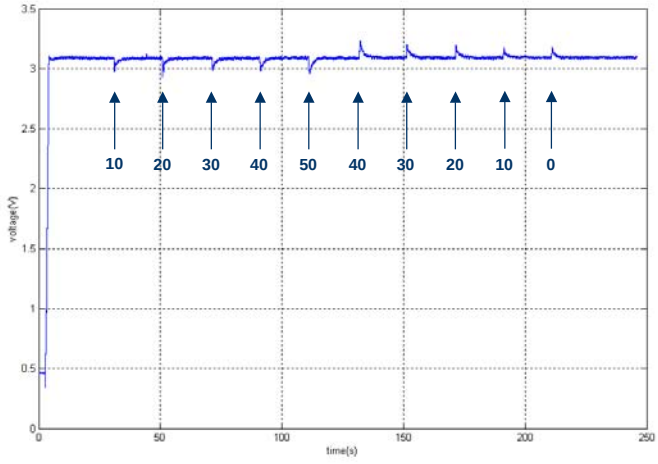
Load changing – Multi processor



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Comparing single and multi processor control

- Average values calculated over 3 x 10 minute runs:

	Single	Multi (S-C)
Mean average	3.0607	3.0909
Std deviation	0.0047	0.0112

- Average values with load changes:

	Single	Multi (S-C)
Mean average	3.0669	3.0891
Std deviation	0.0190	0.0192

Summary

- I have introduced two test bed systems
- Both systems enable the testing and evaluation of different controller architectures
- Each test bed has advantages and disadvantages
- My final thesis will draw conclusions based on results from both systems.

Further info and a copy of this presentation can be found at:

`http://www.le.ac.uk/eg/embedded/ess04.html`