

## Implementing PID Control Systems Using Resource-Limited Embedded Processors

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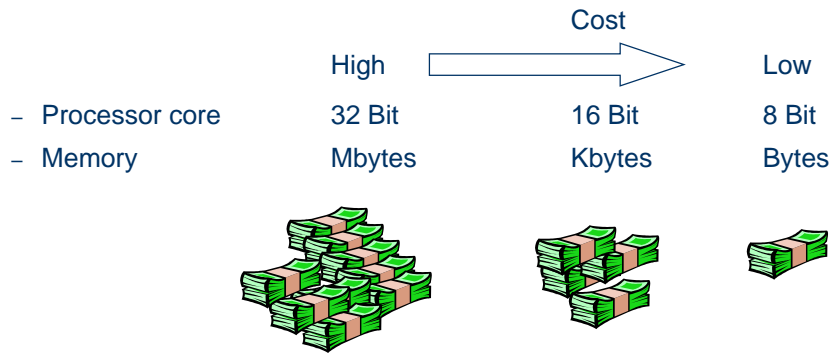
### Overview

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- Motivation
- Control performance of an embedded controller
  - Control loop
  - Control performance for software changes
- Resource usage of the embedded controller
  - RAM/ROM
  - CPU cycles

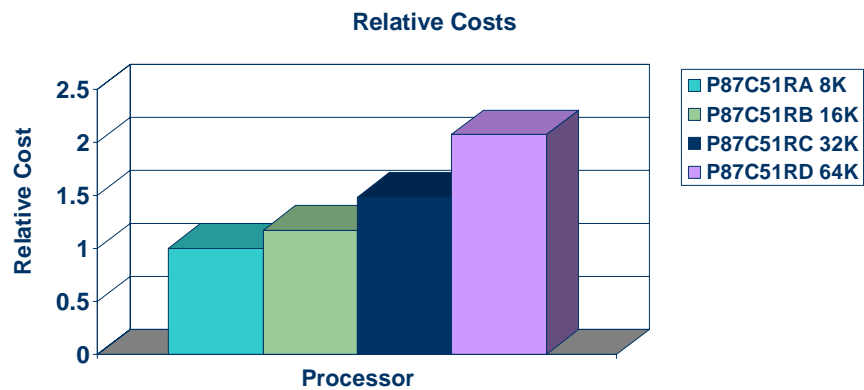
## Motivation

- How can I implement my embedded control system for minimum cost?
- Implementation cost



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## Reduce code, reduce cost



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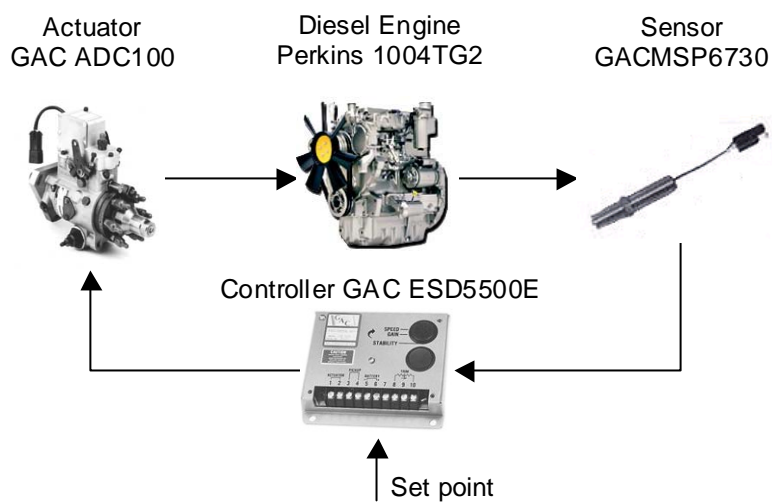
## Overview

- Motivation ✓
- Control performance of an embedded controller
  - Test Bed / Control loop
  - Control performance for software changes
- Resource usage of the embedded controller
  - RAM/ROM
  - CPU cycles

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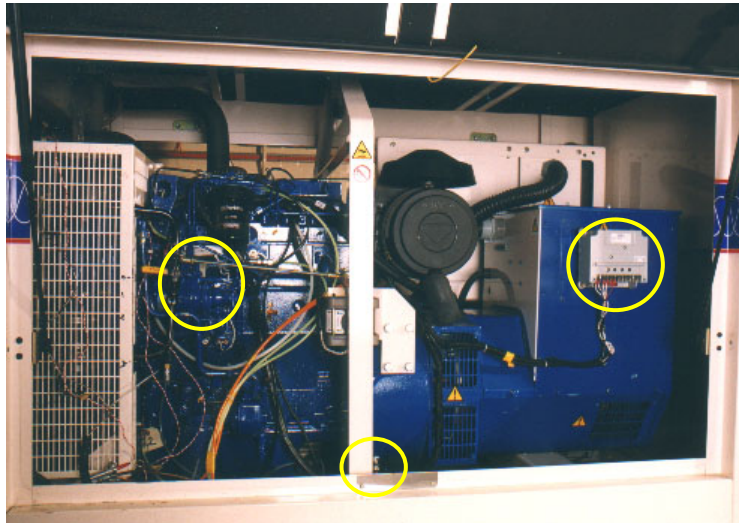
## Perkins diesel generator control loop



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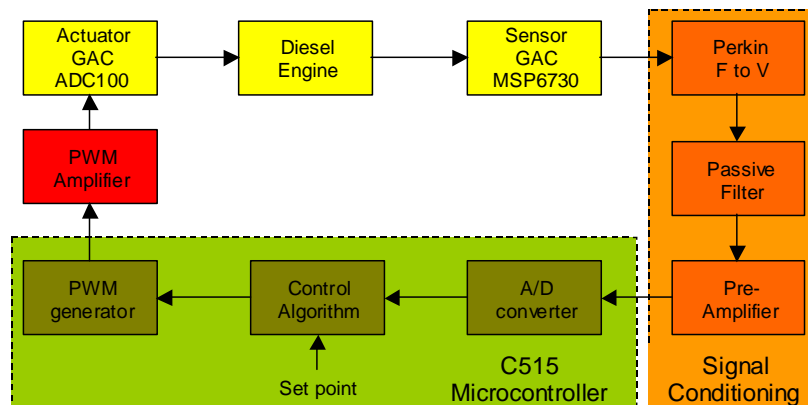
## Perkins diesel generator



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## Control loop schematic

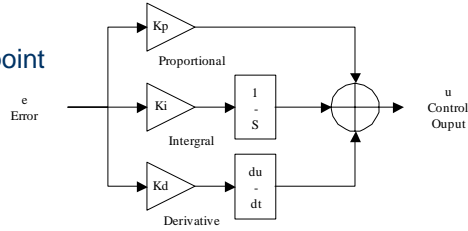


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## PID algorithm

Error = Input - Set point



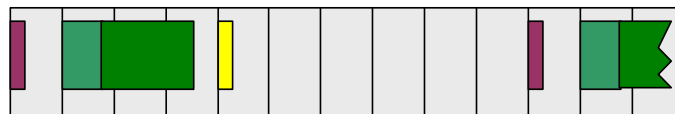
```

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

9 K J Åström and T Häggglund, PID Controllers, 2nd Edition, Instrument Society of America, 1995

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## PID algorithm scheduling



0 5 10

Time (ms)

- AD\_Sample
- PID\_Update
- PID\_Control
- PWM\_Update

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## Where does the memory go ?

- What affects memory usage?
  - Choice of programming language <sup>1</sup>
  - Choice of algorithm development
  - Choice of arithmetic

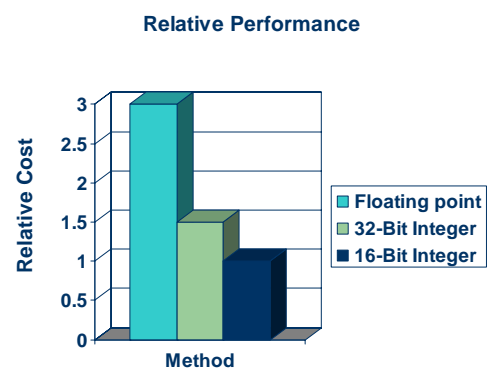
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1) Key, S.A., Pont, M.J. and Edwards, S. (2003) "Implementing low-cost TTCS systems using assembly language". Paper presented at EuroPLoP 2003 (Germany, June 2003)

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## Choice of arithmetic

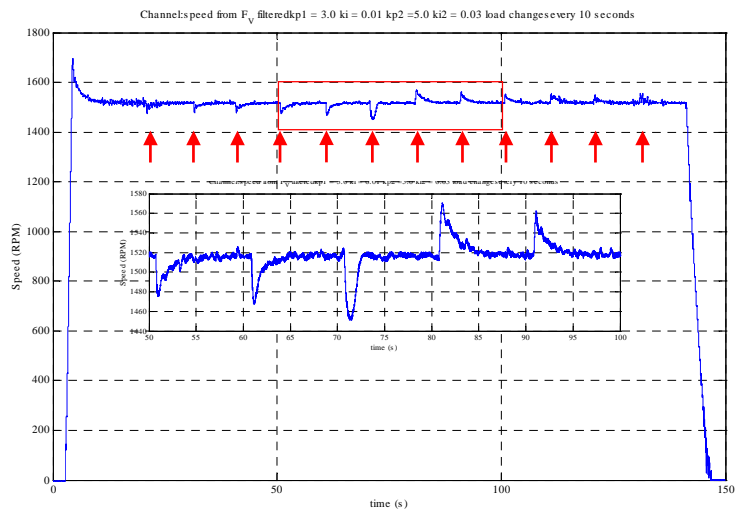
- Floating point
- 32-Bit integer
- 16-Bit integer



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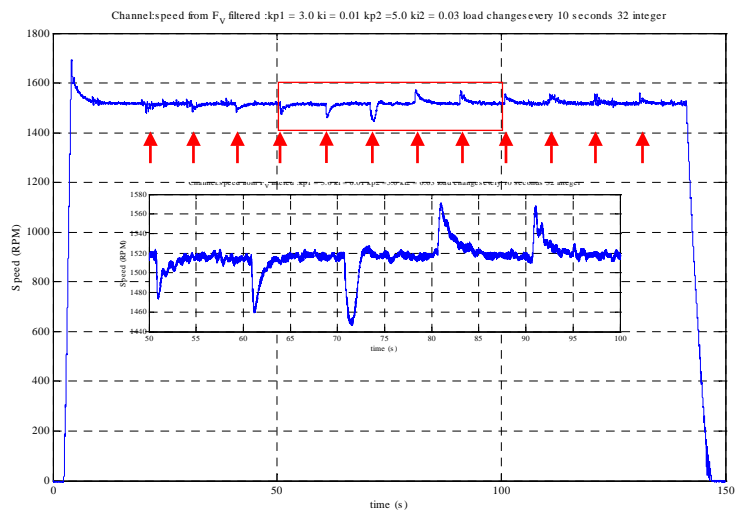
## Floating-point performance



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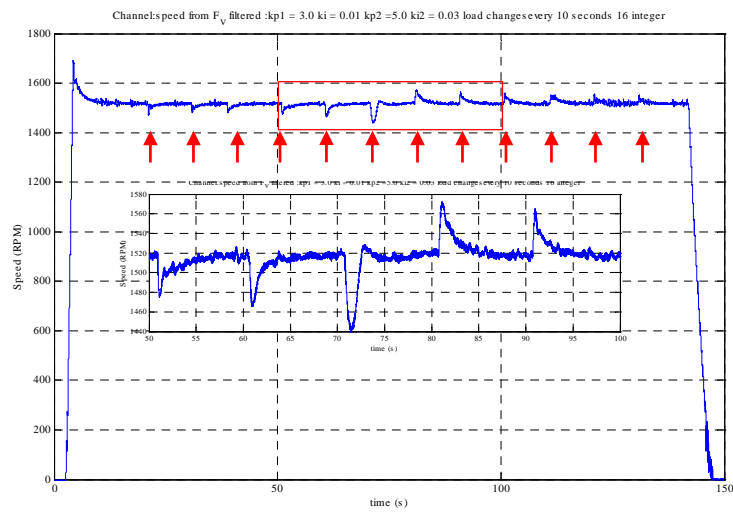
## 32-bit integer performance



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## 16-bit integer performance



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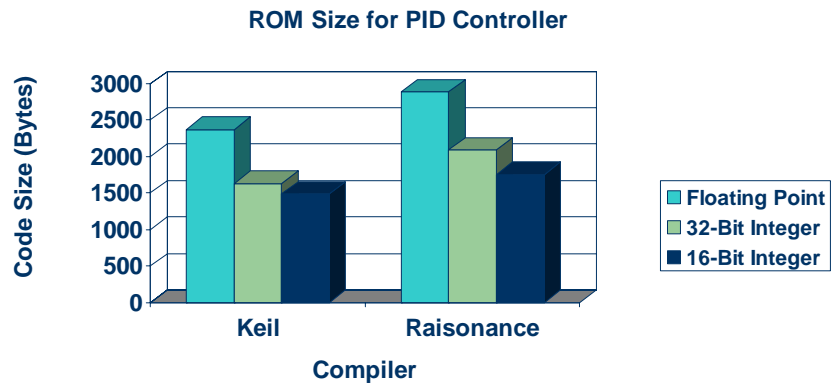
## Overview

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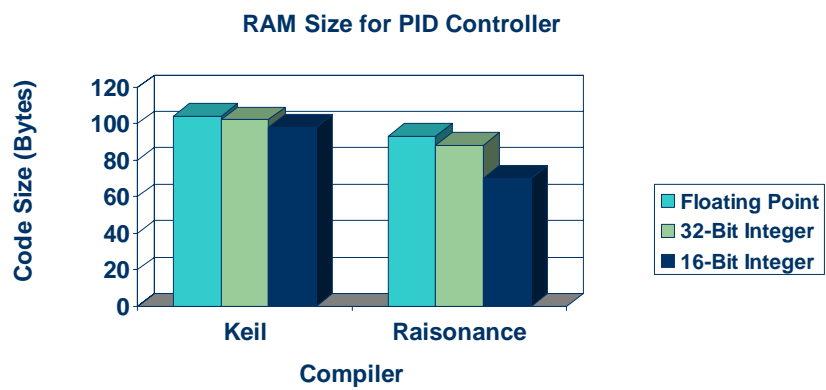
## PID ROM memory requirements



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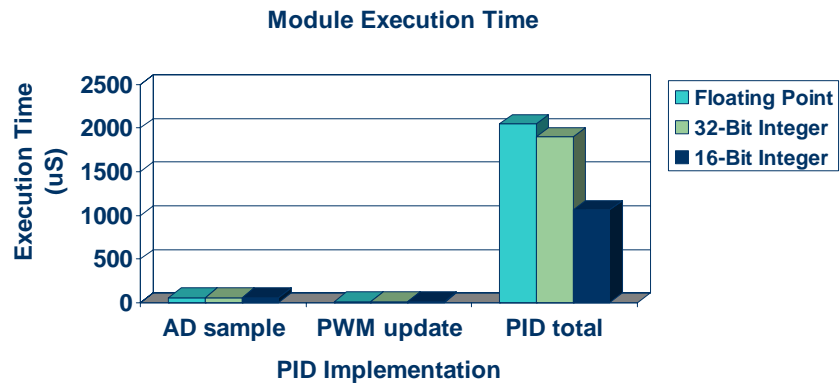
## PID RAM memory requirements



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## PID CPU requirements



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## Summary

- Motivation ✓
- Control performance of an embedded controller ✓
- Resource usage of the embedded controller ✓

### Cheapest solution

- 8 bit microcontroller
  - 10 bit A/D converter
  - 16 bit PWM
  - 16 bit arithmetic
- Cost ~ £5.00

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## Conclusion

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- Resource limited controllers can
  - Achieve adequate control performance
  - Achieve significant cost savings

## Concluding Remarks

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Further information available on the  
Embedded Systems Laboratory website  
<http://www.le.ac.uk/eg/embedded>  
[sak15@le.ac.uk](mailto:sak15@le.ac.uk)