Intel Technology Symposium 2004

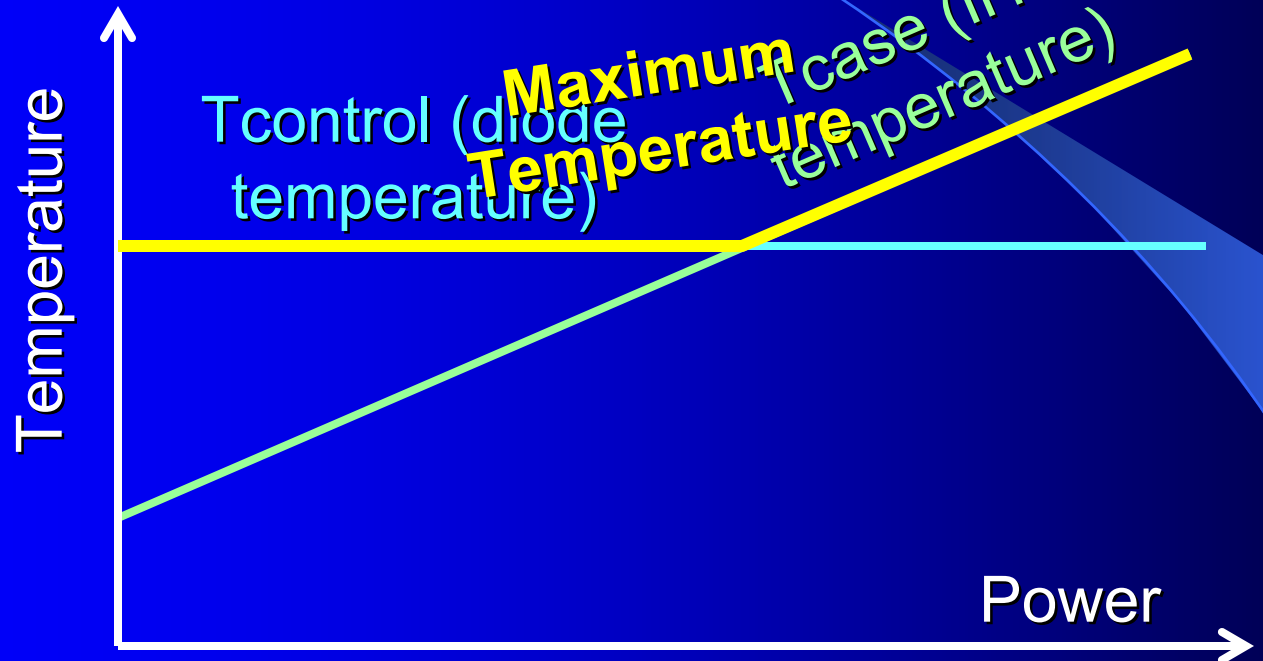
Advanced Fan Speed Control Architecture

Nick Weber
Mechanical Engineer,
Desktop Platforms Group

Agenda

- Why you need fan speed control
- Existing implementation limits
- Future fan speed control architecture overview
- Benefits of new fan speed control

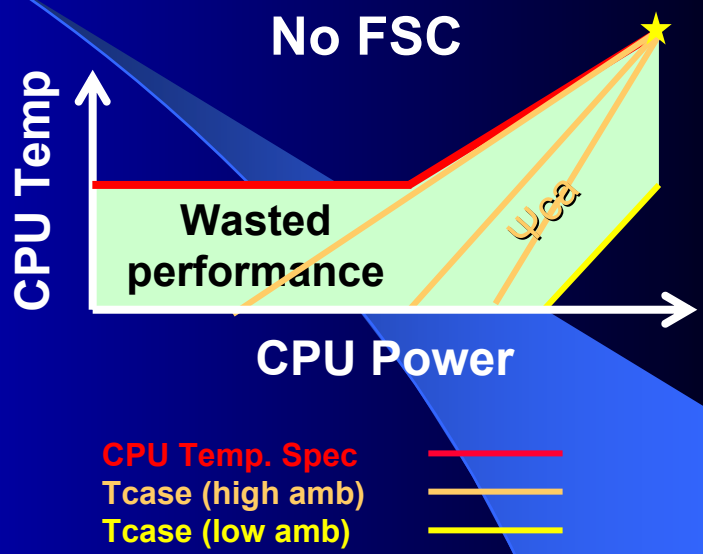
Intel CPU Thermal Specification



- Tcontrol is a register in the CPU
- If Tdiode > Tcontrol, Tcase is the limiter

Thermal Design Constraints

- Worst-case conditions
  - Maximum system power
  - External Ambient temperature of 35 °C
- Typical use conditions
  - Low system power (~2/3 max power)
  - External Ambient temperature of 23 °C

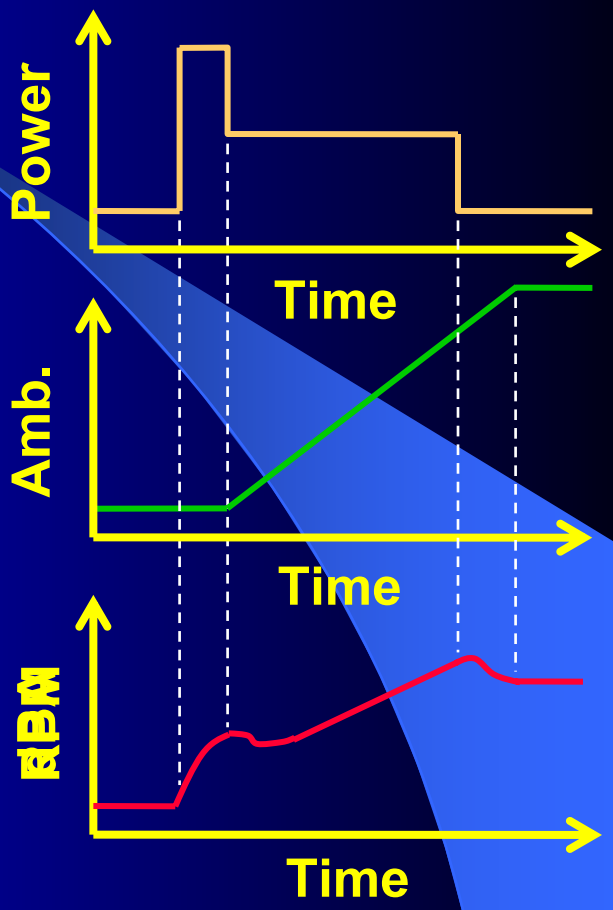


- Fans should be slowed in typical use condition
  - Slower fans = more quiet system

Intel Technology Symposium 2004

Fan Speed Control Goals

- Goals
  - Minimize fan speeds
  - Keep component temps within limits
- Optimum FSC
  - All components are constantly held at Tmax
    - Changing components' power dissipation
    - Changing local ambient temperature
    - All fans change speeds when needed
      - Damping to control sound quality
      - Only appropriate fan's speeds change

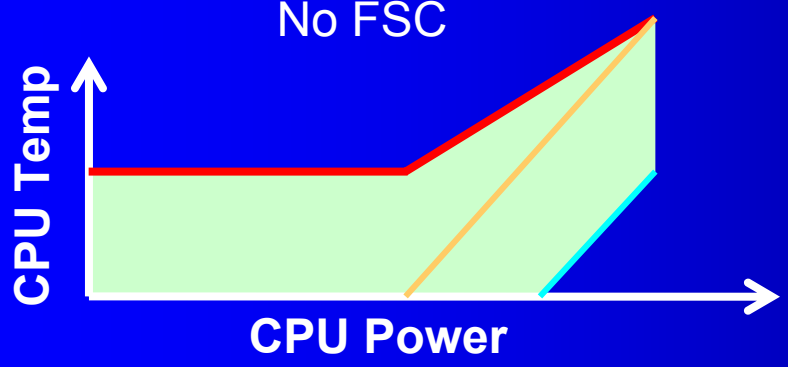


Optimize Acoustics and Thermals

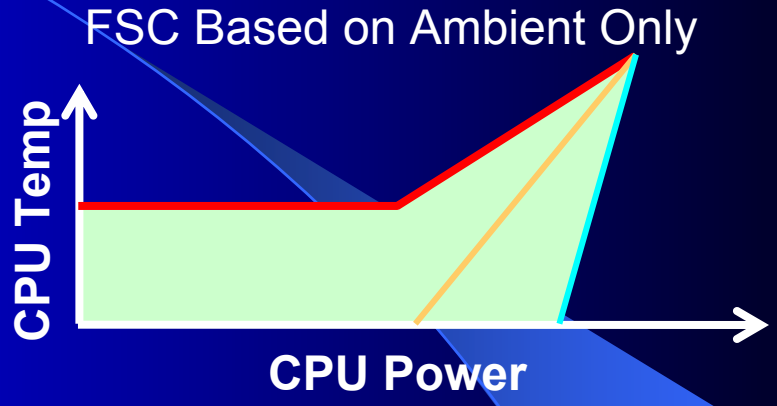
Intel Technology Symposium 2004

Levels of FSC
Steady State Responses

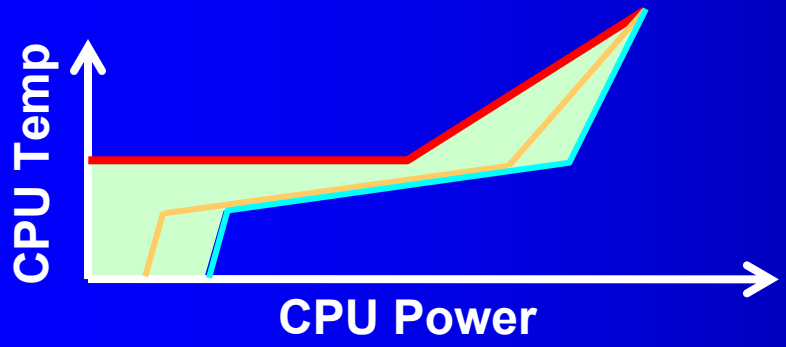
No FSC



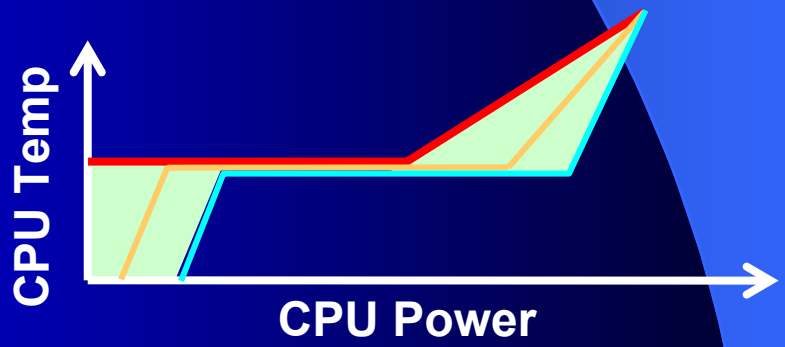
FSC Based on Ambient Only



Linear + Ambient FSC



New FSC Architecture

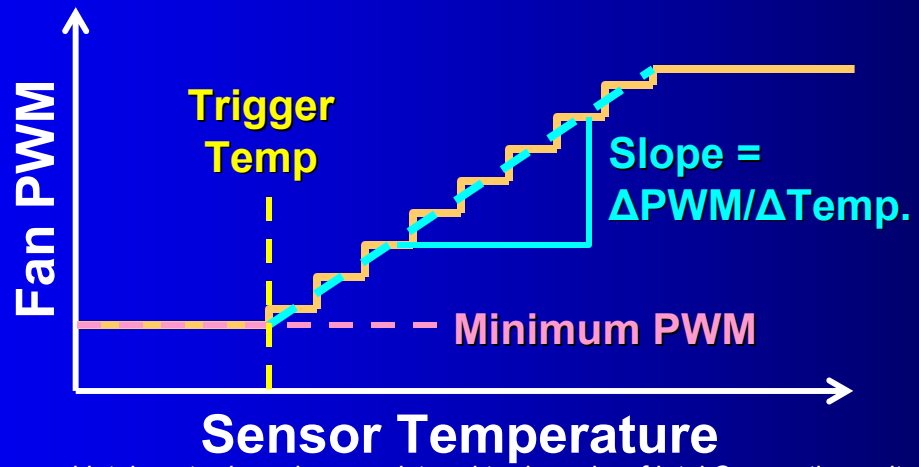


CPU Temp Spec
Tcase (high amb)
Tcase (low amb)

Area represents wasted thermal performance

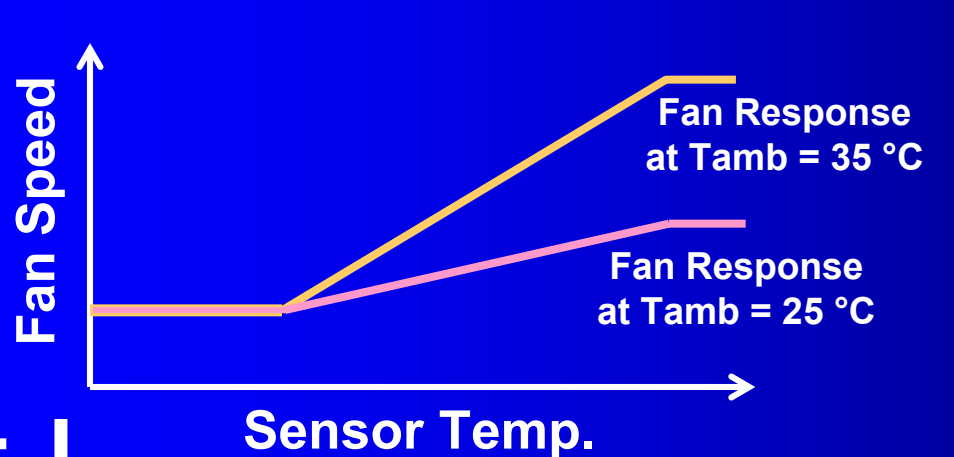
Current Fan Speed Control

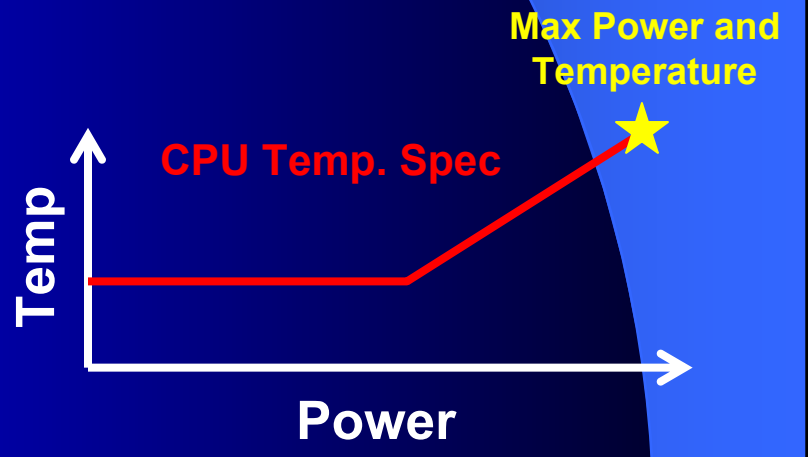
- Linear control based on sensor temperatures
  - Variables
    - Minimum fan PWM (max is 100%)
    - Slope – provides stability
    - Trigger temperature



Controlling for Low Ambient

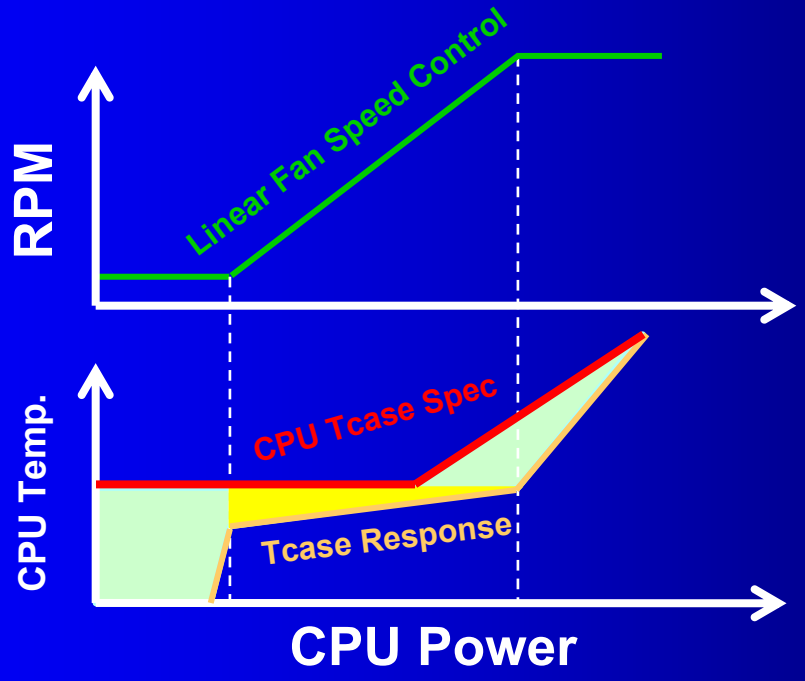
- CPU allowable Temperature is relaxed at high power
- Thermal sensors measure temperature only
  - Max fan speed is capped at low ambient
  - If Tdiode - Tamb is large, then power must be high
  - Currently this is implemented by a hub-mounted thermistor in the fan





Linear FSC Limitations

- Linear control can take advantage of the relaxed thermal limit at high power
- The linear response is not optimal
  - Slope must be too flat

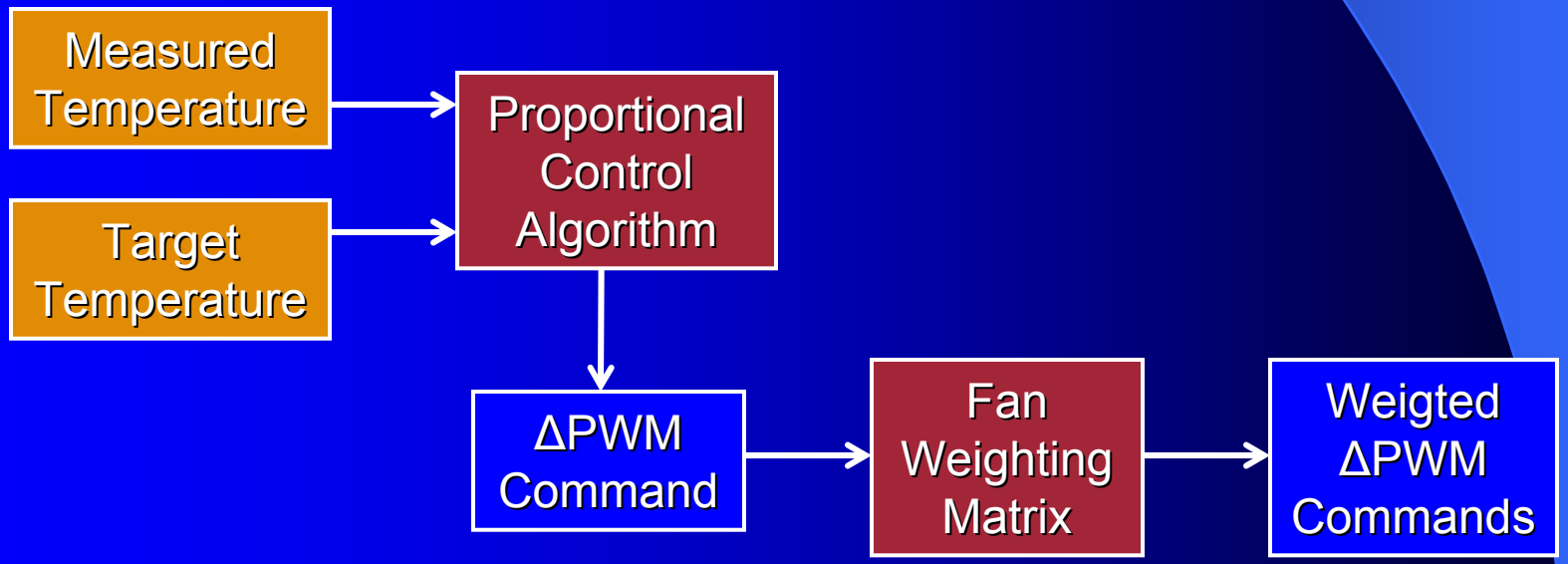


Potential Steady-State Improvement

Currently Fans Run Faster Than Necessary

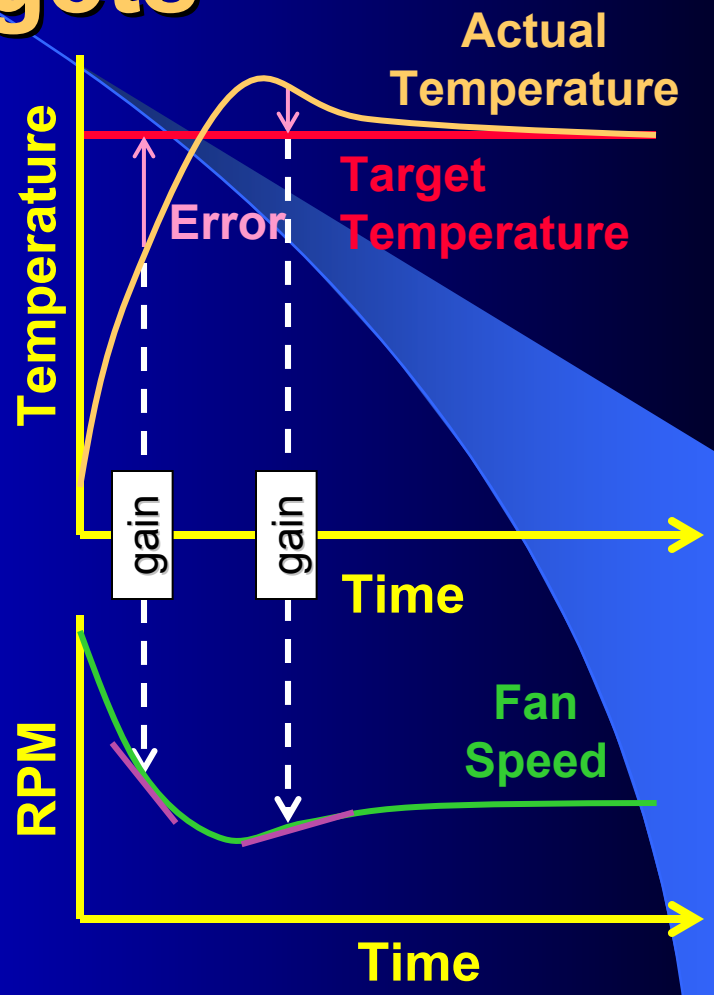
New FSC Architecture

- Each temperature sensor in the system has a target temperature
  - Reflects the limit temperature for a given component
  - Example: CPU Tcontrol
- New Architecture changes the fans' speeds to meet these target temperatures



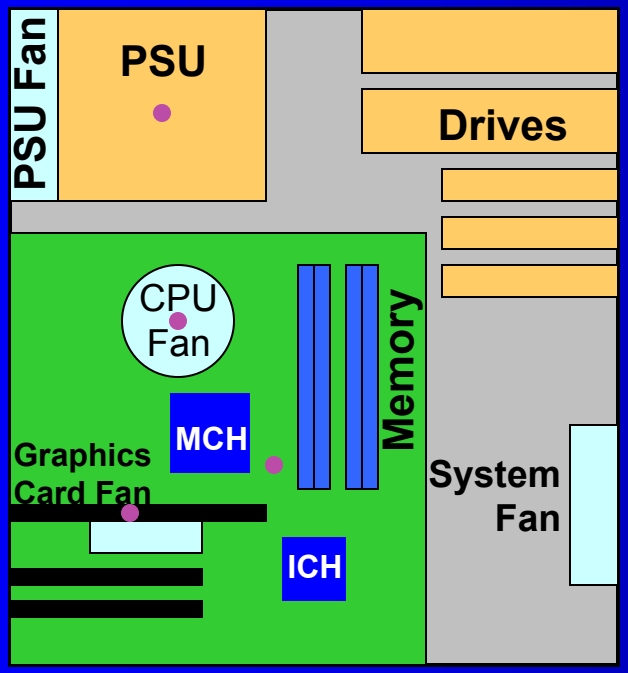
Proportional Control to Temperature Targets

- Target temperatures are assigned for each sensor
- Fan speed control system will increase or decrease fan speeds based on error
  - Error = Ttarget-Tactual
  - If error is positive ⇨ decrease fan speeds
  - If error is negative ⇨ increase fan speeds
- Rate of change of fan speed is proportional to magnitude of the error
  - ΔPWM = Error X Gain



Fan Weighting

- Fan/sensor weighting controls how each fan responds to each sensor
  - Optimize thermal/acoustic response
  - If a fan's speed change has a large impact on a sensor, it receives a higher weighting

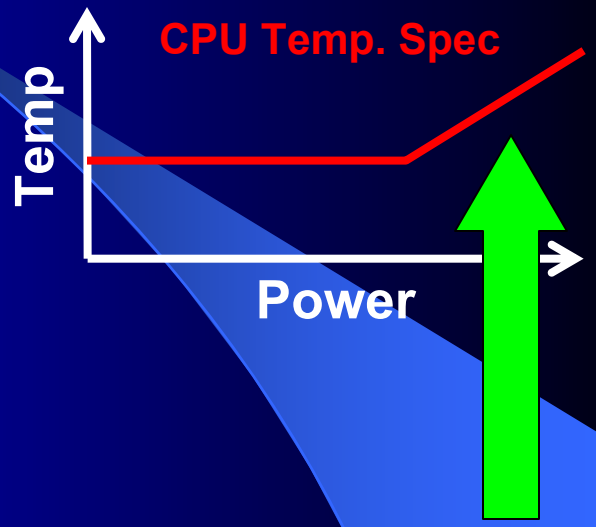


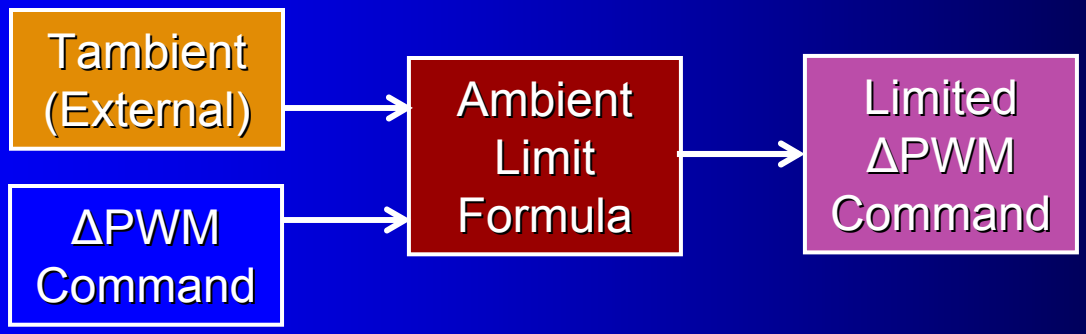
Sensor	Fan	Weight
CPU	CPU	100%
	System	50%
	PSU	20%
	Graphics	0%
System	CPU	50%
	System	50%
	PSU	50%
	Graphics	10%

Additional Sensors Can Be Used

Ambient Limit Algorithm

- Ambient limit algorithm caps the CPU cooling at low ambient
  - Affects CPU cooling only
  - Take advantage of relaxed thermal spec at high power





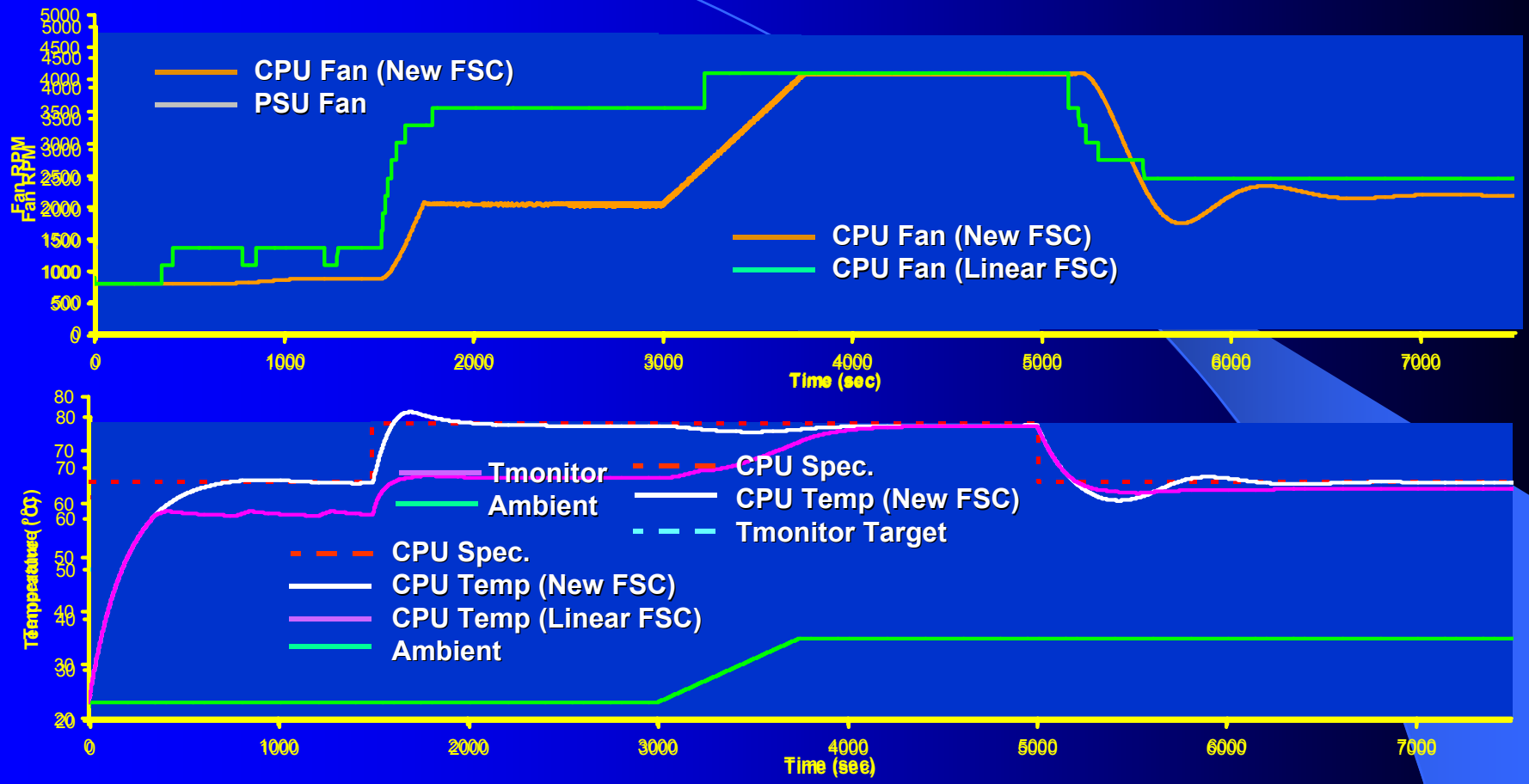
Proportional Control with Fan Weighting

Using the new FSC

- Easy to Implement
  - For each sensor
    - Target value
      - based on thermal limits of components
      - Simulation/experimentation to correlate component/sensor temperatures
    - Gain
      - Depends on thermal solution time constant
  - For each fan
    - Minimum PWM
      - Lowest speed for which the fan can operate reliably
    - Sensor weighting
      - Simulation/experimentation to determine

Response Curves – BTX Model

Intel Technology Symposium 2004



Easier and Quieter than Linear Control

Summary

- Optimize acoustics and thermals
- Currently fans run faster than necessary
- Proportional control with fan weighting
- Easier and quieter than linear control

Look for Hardware Implementation Soon