TEAPC: Temperature Adaptive Computing in a Real PC

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TEAxx Goals

Adaptive Thermal Control for:

1. ***Workload adaptation.***
2. ***Reduced power consumption.***
3. ***Improved reliability.***
4. ***Disaster tolerance (always enabled).***
5. ***Improved performance.***
6. ***…and all in a production machine.***

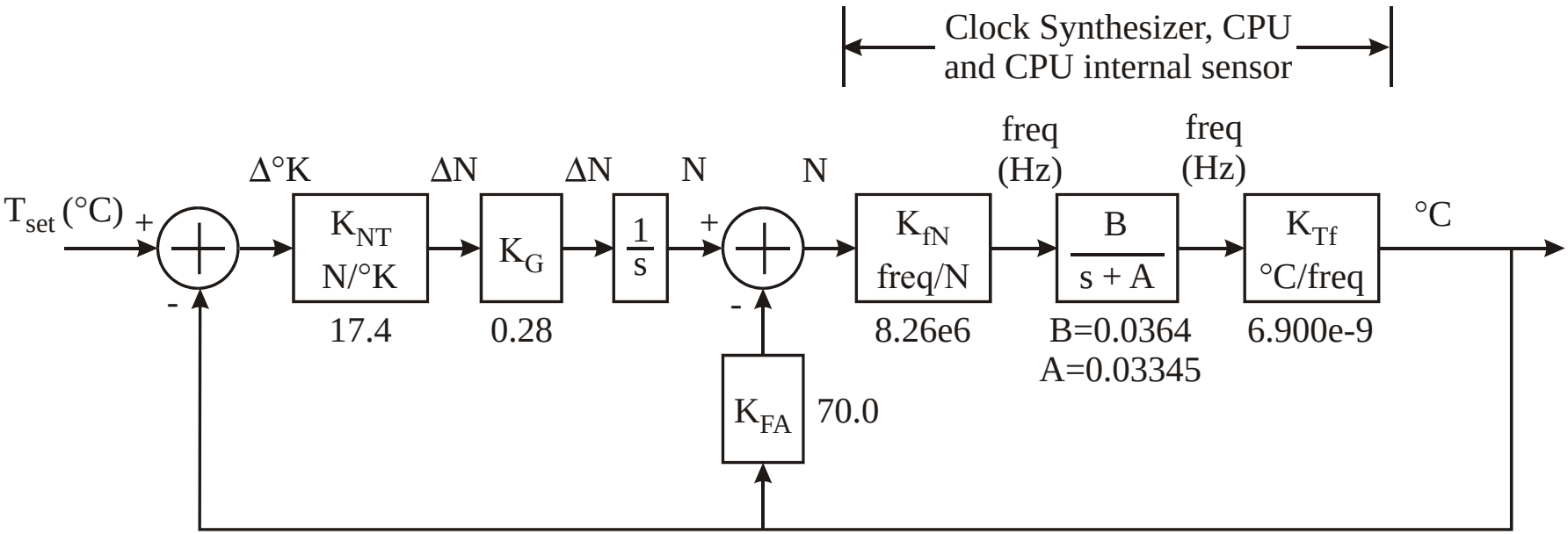
- BUT: can't redesign or build Pentium's.
- SO: use real IBM/Intel-standard PC.

Samples of Related Work

- Rohou & Smith, 1999 – temperature adaptive system
  - Adjusted temperature with frequency changes
  - BUT: required modifying OS (Linux)
  - Performance not enhanced
- Skadron *et al*, 2002 – temperature adaptive system
  - Used classical feedback control theory
  - Modeled and controlled temperatures of parts of a chip
  - Instruction-fetch toggling controlled temperature
  - Performance reduced

TEAPC Control System

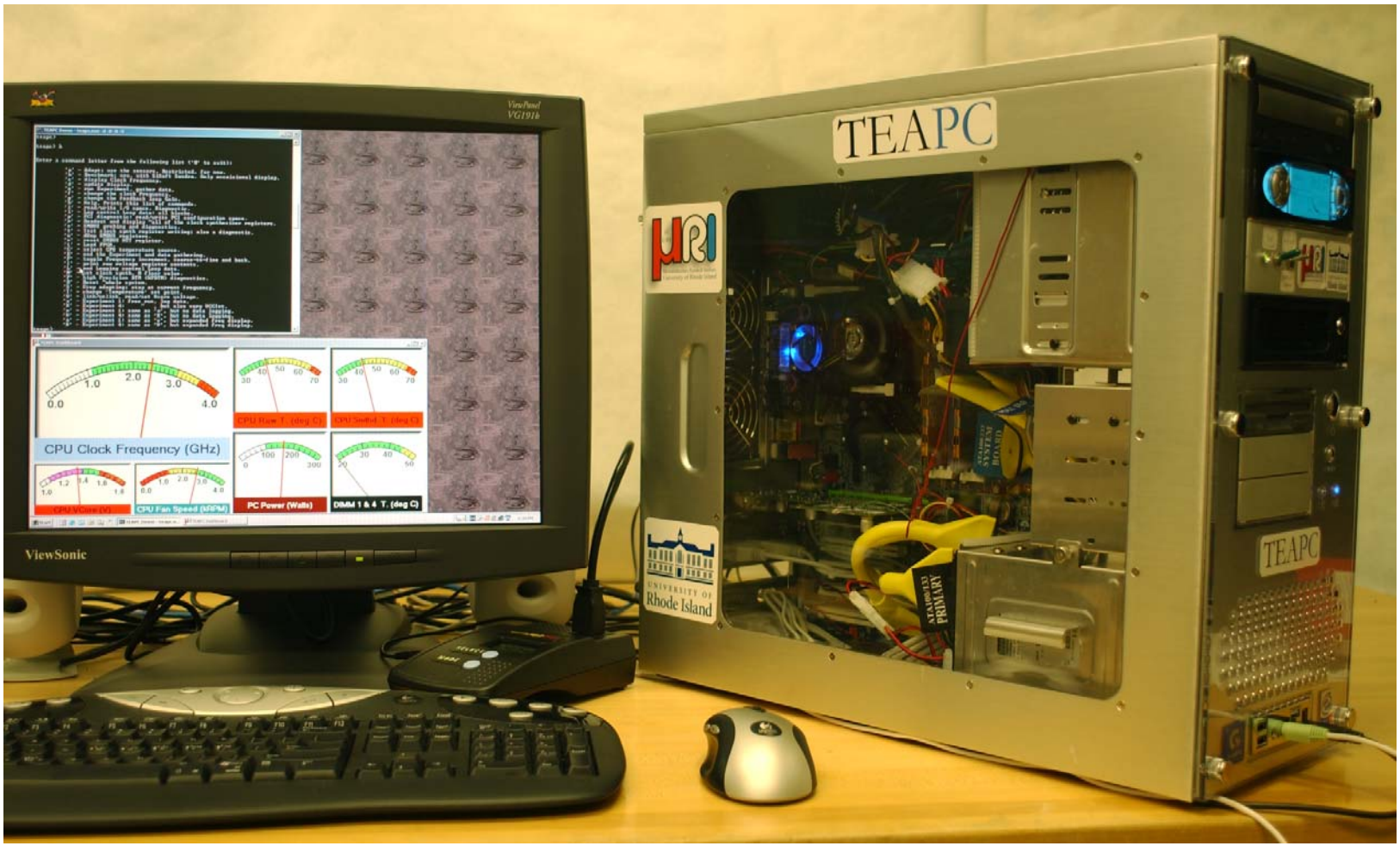
- Only sensor input is CPU temperature (feedback line)
- Primary output is CPU frequency (N) [sometimes: Vcore = *f* (N)]
- State-space discrete control system design (modern)
- Quick response



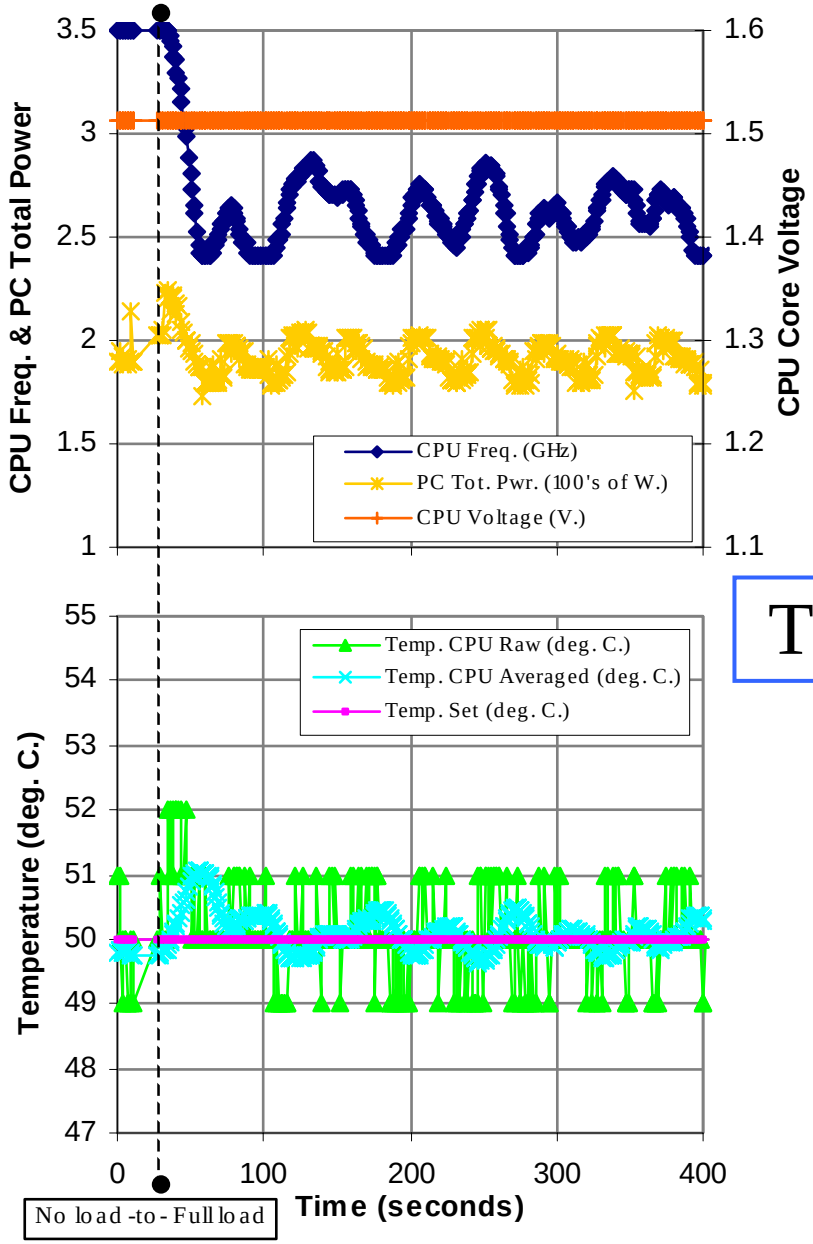
`teapc` Control Program

- Windows application – no changes to OS
- Uses x86 I/O address space to access hardware
- Small: 800 kilobytes
- Fast: < 5% CPU utilization
- Control loop updated every second
- Hard limits on max./min. frequency

Experiment Setup - Paper



freq., Vcore **un**linked < Load Adaptation > freq., Vcore linked



Freq. (GHz)

Vcore (V)

Power (100 W)

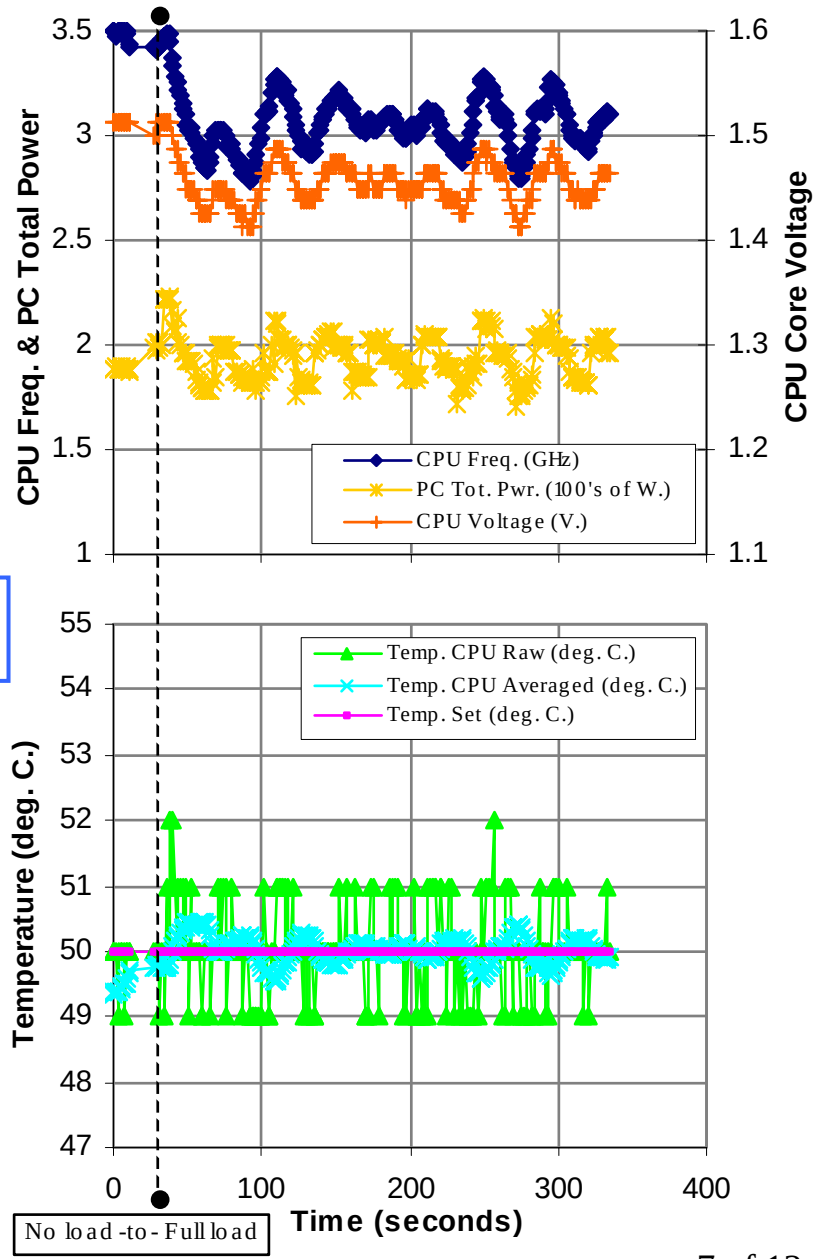
TEAPC

Tset

Traw

Tavg

(all deg. C)



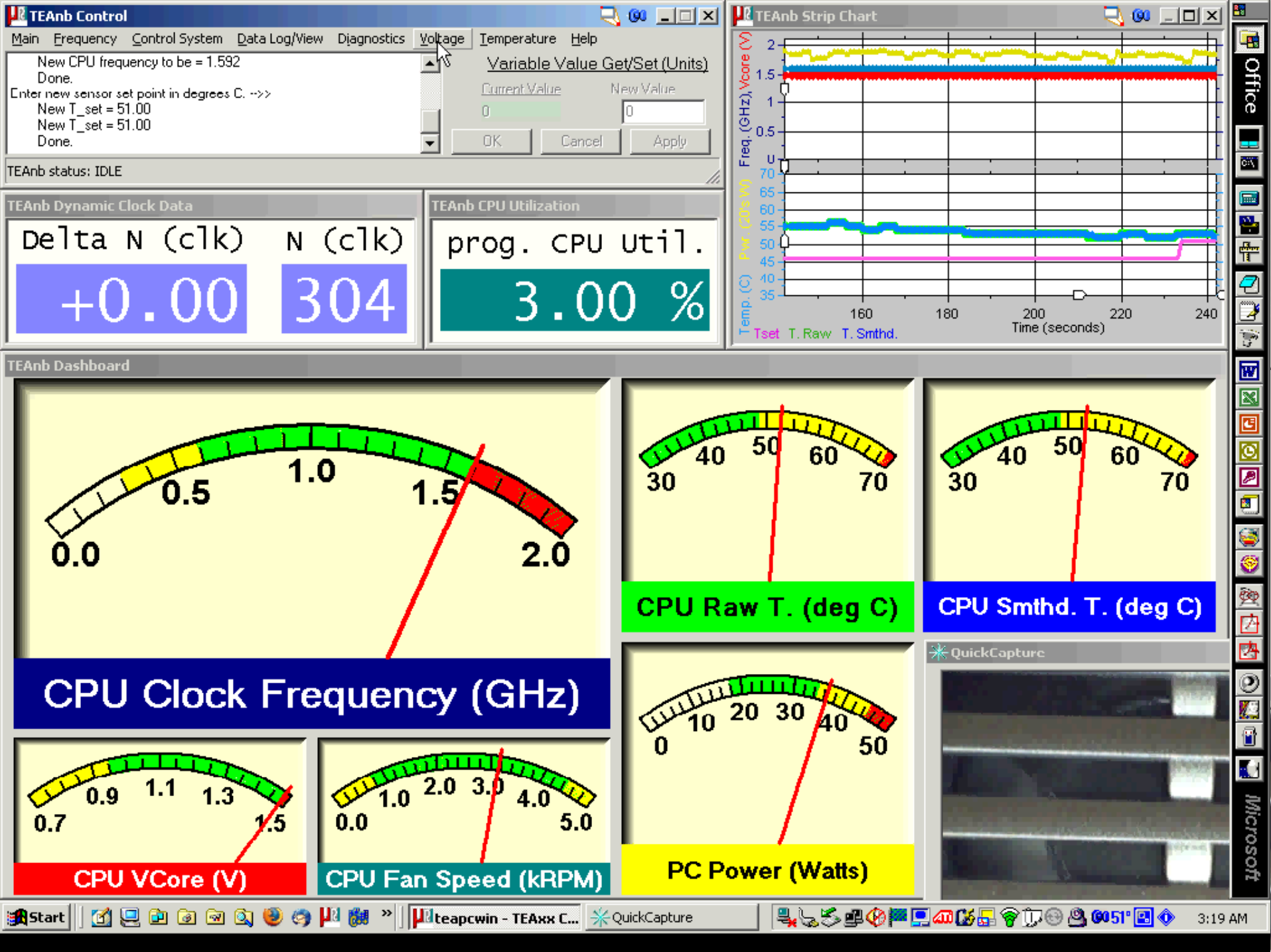
…and now it's time for the:

Video Demo: *TEAnb*

(*TEAnb*: *notebook PC, or "note bene"*)

Clip 1: *Basic Operation*

Clip 2: *Disaster Tolerance*


TEAnb Control
Main
Frequency
Control System
Data Log/View
Diagnostics
Voltage
Temperature
Help
New CPU frequency to be = 1.592
Done.
Enter new sensor set point in degrees C. -->>
New T_set = 51.00
New T_set = 51.00
Done.
Variable Value Get/Set (Units)
Current Value
New Value
0
0
OK
Cancel
Apply
TEAnb status: IDLE
TEAnb Strip Chart
Freq. (GHz), Vcore (V)
Temp. (C) Pwr (Watts)
Tset
T. Raw
T. Smthd.
Time (seconds)
TEAnb Dynamic Clock Data
Delta N (clk)
N (clk)
+0.00
304
TEAnb CPU Utilization
prog. CPU Util.
3.00 %
TEAnb Dashboard
CPU Clock Frequency (GHz)
CPU Raw T. (deg C)
CPU Smthd. T. (deg C)
CPU VCore (V)
CPU Fan Speed (kRPM)
PC Power (Watts)
QuickCapture
Office
Microsoft
Start
teapcwin - TEAxx C...
QuickCapture
3:19 AM

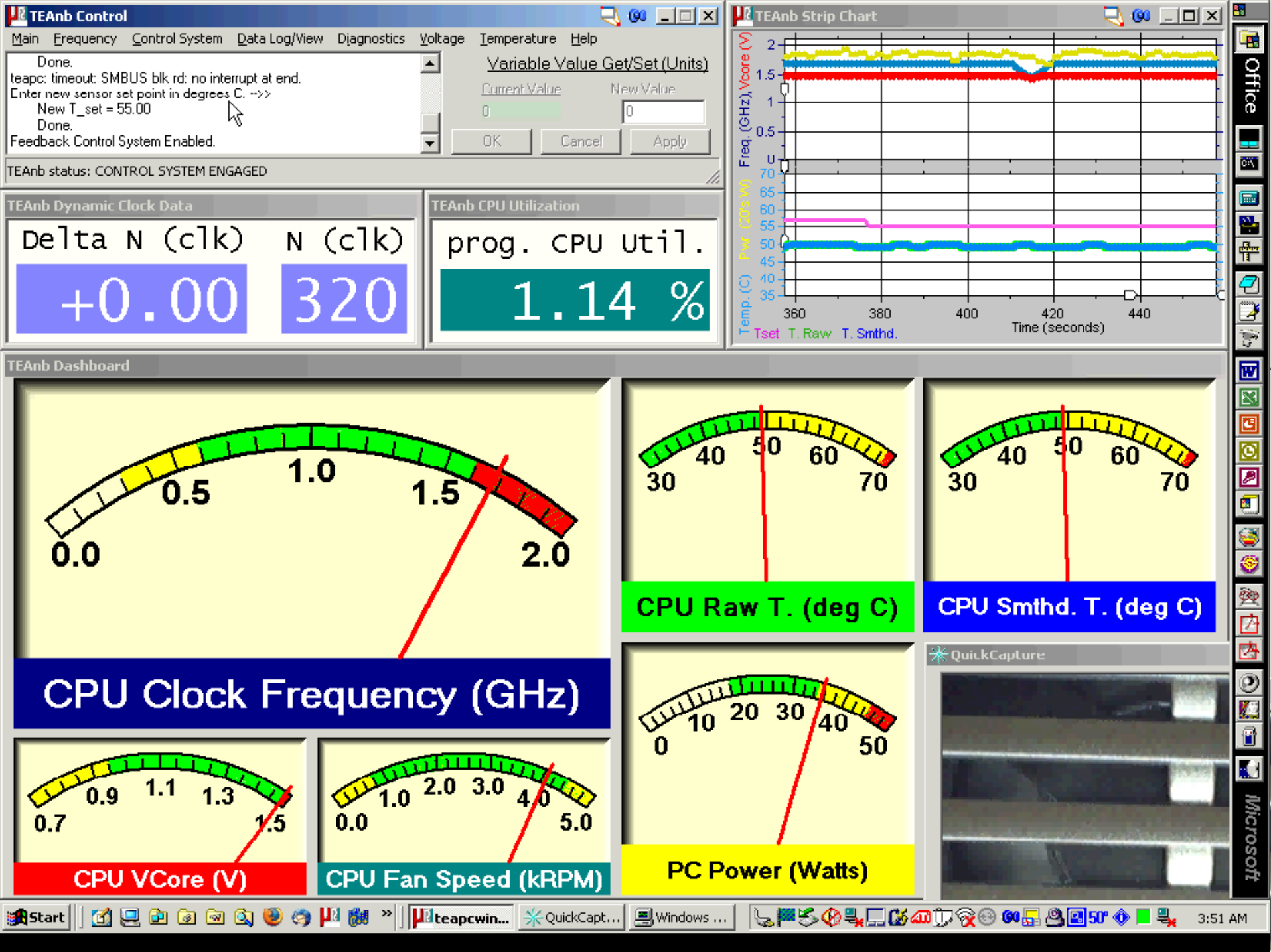
…and now it's time for the:

Video Demo: *TEAnb*

(*TEAnb*: *notebook PC, or "note bene"*)

Clip 1: *Basic Operation*

Clip 2: *Disaster Tolerance*


TEAnb Control
Main Frequency Control System Data Log/View Diagnostics Voltage Temperature Help
Done.
teapc: timeout: SMBUS blk rd: no interrupt at end.
Enter new sensor set point in degrees C. -->>
New T_set = 55.00
Done.
Feedback Control System Enabled.
Variable Value Get/Set (Units)
Current Value
New Value
OK
Cancel
Apply
TEAnb status: CONTROL SYSTEM ENGAGED
TEAnb Strip Chart
Freq. (GHz), Vcore (V)
Pwr (Watts)
Temp. (C)
Time (seconds)
Tset T. Raw T. Smthd.
TEAnb Dynamic Clock Data
Delta N (clk)
+0.00
N (clk)
320
TEAnb CPU Utilization
prog. CPU Util.
1.14 %
TEAnb Dashboard
CPU Clock Frequency (GHz)
CPU Raw T. (deg C)
CPU Smthd. T. (deg C)
CPU VCore (V)
CPU Fan Speed (kRPM)
PC Power (Watts)
QuickCapture
Office
Microsoft
Start
teapcwin...
QuickCapt...
Windows ...
3:51 AM

Summary

- TEAxx realize:
  1. ***Thermally Adaptive*** operation to both environment and/or loading.
  2. Low-power, high-reliability operation.
  3. Better-than-worst-case performance.
  4. Disaster tolerance.
- Feedback-control great for a system, too.
- ***It Works!!***

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