Introduction to Embedded Systems Research
Midterm Exam

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Closed book. Closed notes. No calculators or other computers. No network.
If you write lightly with pencil, I may not see your answers or work.

Printed name: _____

Sign below to acknowledge the Engineering Honor Code: "I have neither given nor received aid on this examination, nor have I concealed a violation of the Honor Code."

_____

[5] 1. Specification. What can data-flow graphs express that cannot be expressed using control-flow graphs? Use at most three words.

_____

[5] 2. Optimization. Fill in the boxes in the first column with the best matches from the second column.

- [ ] Genetic algorithms
- [ ] Simulated annealing
- [ ] Greedy descent
- [ ] Tabu search
- [ ] Approximation algorithm

A. Can be proven to produce solutions that deviate from optimal cost by some bound.

B. Uses Boltzmann trials to determine which solutions will survive into future generations.

C. Uses a list to avoid recently-considered solutions.

D. Allows sub-solutions to be traded among solutions that exist simultaneously during optimization.

E. May be prone to becoming trapped in local minima.

Answers: D, B, E, C, A.

5 3. Memory hierarchy. What does a memory management unit provide that a memory protection unit does not provide? Use at most two words.

Answer: Virtual Memory

5 4. Real-time systems. Mark the features that substantially complicate real-time scheduling.

- ◯ Cache.
- ◯ Scratchpad memory.
- ◯ Using multiple processors or processor cores with shared communication buses.
- ◯ Dynamic voltage and frequency scaling.
- ◯ Memory protection.

Answers: Cache, Using multiple processors..., Dynamic voltage and frequency scaling

5 5. Power, energy, and temperature. Other than switching power consumption, what type of power consumption is largest in most applications and modern microcontrollers?

- ◯ Gate leakage.
- ◯ Photon conversion.
- ◯ Subthreshold leakage.
- ◯ Quantum jitter.
- ◯ Short circuit power consumption.

Answer: Subthreshold leakage

5 6. Reliability, testing, and formal methods. Using at most one sentence, indicate why testing sequential system hardware is generally harder than testing combinational system hardware.

Answer: The state space is large due to dependence on internal state, not just inputs.

5 7. Consider L. Yang, R. P. Dick, H. Lekatsas, and S. Chakradhar, "High-performance operating system controlled on-line memory compression," *ACM Trans. Embedded Computing Systems*, vol. 9, no. 4, pp. 30:1–30:28, Mar. 2010. In what way did the PBPM algorithm differ from a conventional dictionary compression algorithm. Use at most one sentence.

Answer: It allowed partial matches with dictionary entries.

5 8. Consider E. A. Lee, "The past, present and future of cyber-physical systems: A focus on models," *Sensors*, Feb. 2015. Indicate three main topics considered in this paper, using at most three words for each topic.

Answers: Many answers were taken here. Here are some examples: Model determinism, Timing and synchronization, PRET machines, Modeling time, Superdense time, Ptides.

10 9. Consider L. Zhang, B. Tiwana, Z. Qian, Z. Wang, R. P. Dick, Z. M. Mao, and L. Yang, "Accurate online power estimation and automatic battery behavior based power model generation for smartphones," in *Proc. Int. Conf. Hardware/Software Codesign and System Synthesis*, Oct. 2010, pp. 105–114. Consider the embedded system characterized by the following state-based power consumption table.

Component	Off (mW)	Sleep (mW)	Active (mW)
CPU	n.a.	10	70
Vibration sensor	0	n.a.	50
Wireless transceiver	0	10	100

If the CPU spends 90% of its time asleep and 10% of its time active, the vibration sensor spends 100% of its time active, and the wireless transceiver spends 90% of its time off, 5% of its time asleep, and 5% of its time active, what is the average power consumption of the system?

Answer: 71.5 mW

A new vibration detector component might be added to the system to enable the vibration sensor to spend more time in sleep mode. The vibration detector would spend 100% of its time in a state with 1 mW power consumption and would enable the vibration sensor to spend 95% of its time off and 5% of its time active. After this change, what would the power consumption of the system be?

Answer: 25 mW

5 10. Consider T. Trippel, O. Weisse, W. Xu, P. Honeyman, and K. Fu, "WALNUT: Waging doubt on the integrity of MEMS accelerometers with acoustic injection attacks," in *Proc. European Symp. on Security and Privacy*, Apr. 2017. Using at most one sentence, indicate a software-only change that would prevent the attack described in this paper.

Answer: Sampling at random times or changing sample phase.

5 11. Consider J. Polastre, R. Szewczyk, A. Mainwaring, D. Culler, and J. Anderson, "Analysis of wireless sensor networks for habitat monitoring," in *Wireless Sensor Networks*, C. S. Raghavendra, K. M. Sivalingam, and T. Znati, Eds. Springer US, 2004, ch. 18, pp. 399–423. Was the system described in this paper a cyber-physical system? ◯ Yes. ◯ No.

Answer: No.

5 12. Consider S. Roundy, P. K. Wright, and J. Rabaey, "A study of low level vibrations as a power source for wireless sensor nodes," *Computer Communications*, vol. 26, pp. 1131–1144, Oct. 2003. Which of the following sources of power considered by Roundy et al. had the highest power density?

- ◯ Solar (indoors)
- ◯ Vibrations (electrostatic conversion)
- ◯ Acoustic noise
- ◯ Temperature gradient
- ◯ Vibrations (piezoelectric conversion)

◯ Shoe inserts

Answer: Shoe inserts.