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- Measuring performance:
  - **Throughput** or **bandwidth**: the total amount of work done in a given time.
  - **Execution time** or **response time** or **elapsed time** or **wall clock time**: the time between the start and completion of a task.
  - **CPU execution time** or **CPU time**: the actual time the CPU spends computing for a specific task.
  - **User CPU time**: the CPU time spent in a program itself.
  - **System CPU time**: the CPU time spent in the operating system performing tasks on behalf of the program.
- **Clock cycles**: the discrete time intervals in the hardware.
  - **Clock period**: the length of each clock cycle.
  - **Clock rate**: the inverse of the clock period.
- **Clock cycles per instruction (CPI)**: average number of clock cycles per instruction for a program or program fragment.
- **Instruction count**: the number of instructions executed by the program.
- **CPU time** = instruction count × CPI × clock period = instruction count × CPI / clock rate.
- Source of energy consumption:
  - *Dynamic energy* (major): energy that is consumed when transistors switch states from 0 to 1 and vice versa.
  - *Static energy_* or *leakage*: leakage current that flows even when a transistor is off.
- **Dynamic energy**: power (watts) $\propto$ capacitive load × voltage^2 × frequency switched.
- Further lowering of the voltage appears to make the system unstable and make the transistors too leaky.
- The computer is evaluated using a set of **benchmarks**-programs specifically chosen to measure performance.
- **SPEC (System Performance Evaluation Cooperative)**: *CPU benchmark* & *power benchmark*.
- A CINT2006 or CFP2006 summary measurement is obtained by taking the *geometric mean* of the SPEC ratios.
- **Power benchmark**: overall ssj_ops per watt = $(\sum_{i=0}^{10} \text{ssj\_ops}_i) / \sum_{i=0}^{10} \text{power}_i$
- Fallacies and pitfalls:
  - Expecting the improvement of one aspect of a computer to increase overall performance by an amount proportional to the size of the improvement.

    - Computers at low utilization use little power.
    - Designing for performance and designing for energy efficiency are unrelated goals.
    - Using a subset of the performance equation as a performance metric.
- **MIPS (millions of instructions per second)** = clock rate $\times 10^{-6}$ / CPI does not take into account:
    - Differences of ISAs between computers.
    - Differences of complexity between instructions.
- The execution time of the program a er making the improvement is given by the following simple equation known as **Amdahl's Law**.
- Execution time is the only valid and unimpeachable measure of performance.