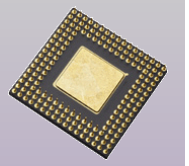

Timers and Counters

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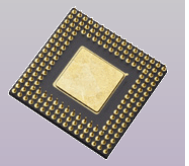
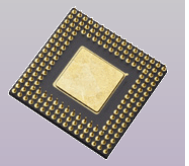


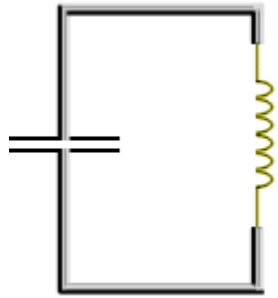
Timers and Counters

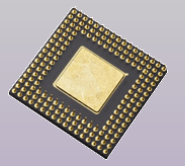
- Devices to keep track of recurring events
  - Time
  - Elapsed time
  - Delays
  - Time-outs
  - Scheduling
- Types of timers in embedded systems
  - Oscillators
  - Counters
  - Real-time clock
  - Watchdog



Oscillators

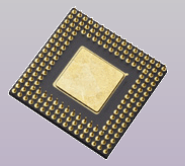
- Basic structure
  - A charged capacitor connected to an inductor
  - The capacitor starts to discharge through the inductor
    - At the same time, the inductor creates a magnetic field
  - Once the capacitor discharges, the inductor will try to keep the current in the circuit, so it will charge up the other plate of the capacitor
  - Once the inductor's field collapses, the capacitor has been recharged (but with the opposite polarity), so it discharges again through the inductor





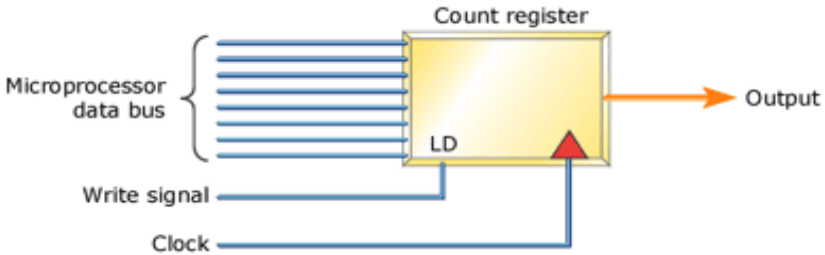
Clock Generator

- A clock generator is a kind of oscillator in which the frequency is controlled by a piezoelectric crystal
- The clock of a timer can be shared with or scaled from the processor's clock
  - Clock divisor (e.g. counter)
  - Clock multiplier (e.g. pll)

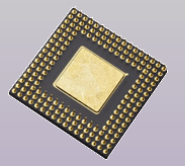


A Basic Timer

- Basic structure
  - Loadable count register
  - Input clock signal
    - Triggers count operations
  - Output signal
    - Indicate counting events

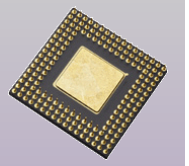


- Operation
  - Counter is loaded with an initial value
  - Each subsequent clock transition increments (decrements) the counter
  - When the counter overflows (zeroes), the output signal is asserted
    - Can be driven to an interrupt request line or an I/O port for polling



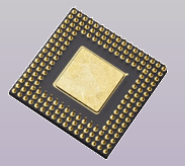
Timer Programming

- Transition trigger
  - Level, rising edge, falling edge
- Initial values
  - Setable, reloadable
- Precision of count registers (bits)
- Resolution (in hertz)
- Input frequency
  - Divisors
- Operations
  - Overflow, compare match, input capture



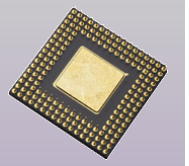
Real-time Clock

- A real-time clock (RTC) is a battery-powered counter that keeps track of time
- Example: Motorola MC-146818 (PC RTC)
  - Keeps track of time and date
    - Different registers for second, minute, hour, day, etc.
  - ~1Mhz resolution
  - BCD or binary format
  - Interrupt generation
    - Like a timer on clock and counter transitions
    - Like an alarm with a predefined time



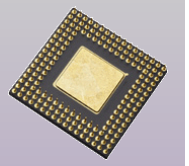
Watchdog Timer

- Hardware
  - A counter with the output signal wired to the circuit's reset
  - Initiated with a certain value that is constantly decremented
  - Must be reinitialized before reaching zero
- Software
  - Sets the count to its original value often enough to ensure that it never reaches zero
  - If it does reach zero, it is assumed that the software has failed in some manner and the WDT “bites” the processor, forcing the system to reinitialize itself



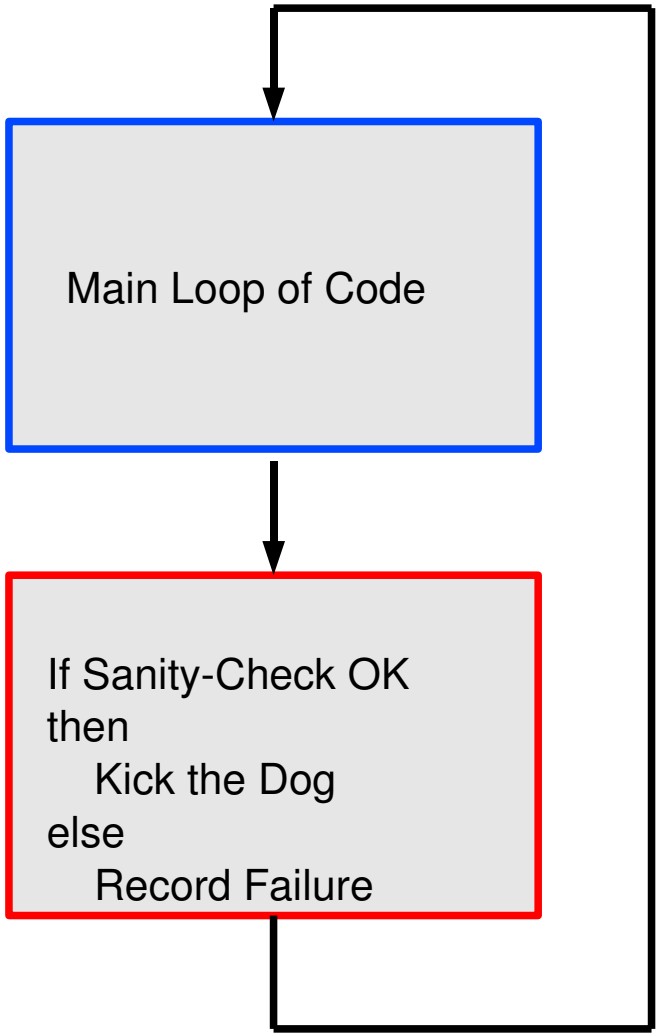
Watchdog Timer Use Cases

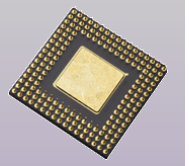
- In electrically noisy environments, a power glitch may corrupt the program counter, stack pointer, or data in RAM
  - The software would crash almost immediately, even if the code is completely bug free
- Bugs in software can also cause the system to hang, if they lead to an infinite loop, a lost pointer, or a dead-lock condition
- Periodically “kicking the dog” ensures that the software is running properly



Watchdog Timer: “kicking the dog”

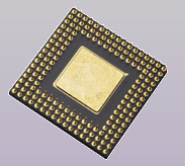
- Kick the dog at the end of every main program loop iteration
- Kick the dog only after the system has passed sanity checks
  - Stack depth
  - Number of buffers allocated
  - Status of some mechanical component
  - Status of system flags ...





Case Study: AVR General Purpose Timers

- 8- and 16-bit timers
  - Input frequency prescaled from the system clock
- Watchdog Timer
  - Separate, prescalable 1 Mhz oscillator
- Timer events
  - Overflow
  - Compare match
  - Input capture
- Interrupt-based event notification
  - Overflow, compare and input capture interrupts
  - Controlled by a timer interrupt mask register



Case Study: AT90S Timers Operation

- Timer input clock configured by registers
  - Divided from the system clock
- 8-bit timer (Timer0)
  - Only Overflow Interrupt
- 16-bit timer (Timer1)
  - Overflow, Compare and Input Capture Interrupts
- Timer value available and settable through registers