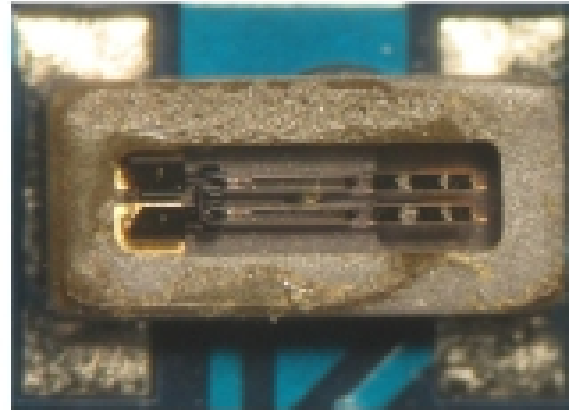




EECS 373

Design of Microprocessor-Based Systems

Thomas Schmid
University of Michigan



Lecture 8: Timers: count, compare, capture, PWM
September 28, 2010

<http://home.nccorm.com/~avensant/science.html>

1



Minute Quiz...

2

Announcements



- Homework 1 posted on website
 - Due date October 7th

4



Where do we use time in an embedded system?

5

Why do we need accurate time?



- Scheduling of computation
 - Scheduler in operating systems
 - Real time operating systems
- Signal sampling
 - Audio sampling at 44.1 kHz
 - Sampling CCD at 30 fps
- Signal generation
 - 120 Hz TV refresh rate
 - Pulse Width Modulated (PWM) signals
- Communication
 - Media Access Control (MAC) protocols
 - Modulation
- Navigation
 - GPS
- Coordination

6

ABB Motion Control



7

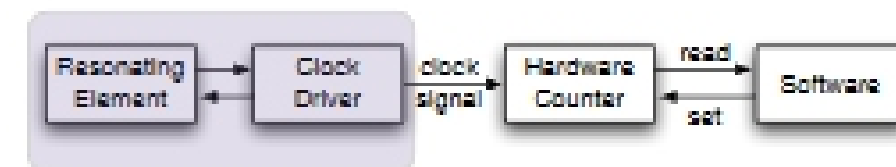
Time in Embedded Systems



- Time is kept by a hardware counter, updated by a clock signal
- The clock signal increments the counter every $1/f$ seconds (resolution)
- The counter reads $c(t) = \lfloor f \cdot t \rfloor \bmod 2^n$
 - n : size of counter
- Smallest increment at which software can read counter: **precision**
- How close is timer to UTC: **accuracy**

8

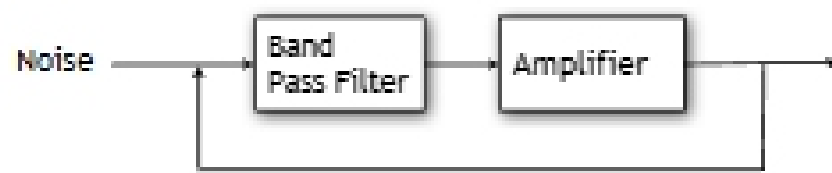
Resonator Technology



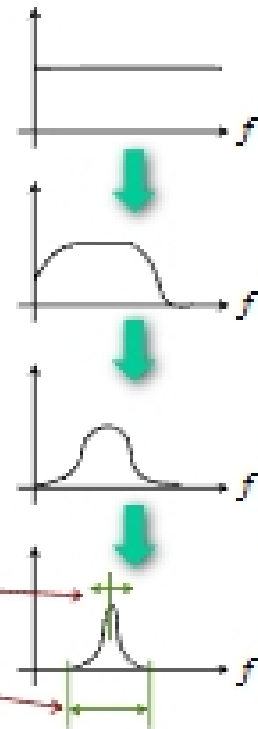
- LC/RC Circuits
- Inverter Ring
- Quartz Crystal
- MEMS Resonators
- Atomic Clock: Hydrogen Maser
- Others: Cesium, Rubidium, Ceramic, Bulk Acoustic Wave, Surface Acoustic Wave, Opto-electronic Oscillator, etc

9

Resonator As Filter

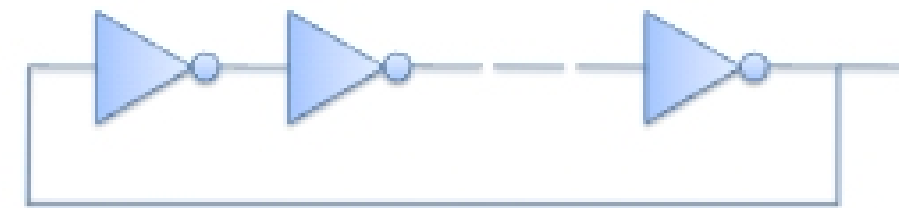


- **Barkhausen Criteria:**
 - For a positive feedback system, oscillation will occur when loop gain (product of forward gain and feedback gain) has zero phase shift and a magnitude greater than unity.
- **Performance Metrics**
 - Quality or Q factor: measure of energy loss within resonating structure.
 - Frequency Stability: How much the center of the peak moves (longer term).
 - Phase Noise: Energy around the peak (short term).



10

Inverter Ring



- An odd number of inverters arranged in a ring produce a frequency

$$f(T) = 1 / 2N \cdot t_{pd}(T)$$

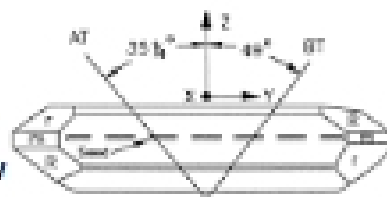
- Inverter propagation delay has strong temperature dependence, leading to frequency drift.
- Advantages:
 - Very high frequencies possible (tpd < 10ps for 90nm technology), high integration, almost zero cost when building a large chip, nearly arbitrary frequency choice.
- Disadvantages:
 - Very low Q-factor, very low stability $\approx 10^8$ ppm (affected by temperature and voltage), very high phase noise.

11

Quartz Crystal

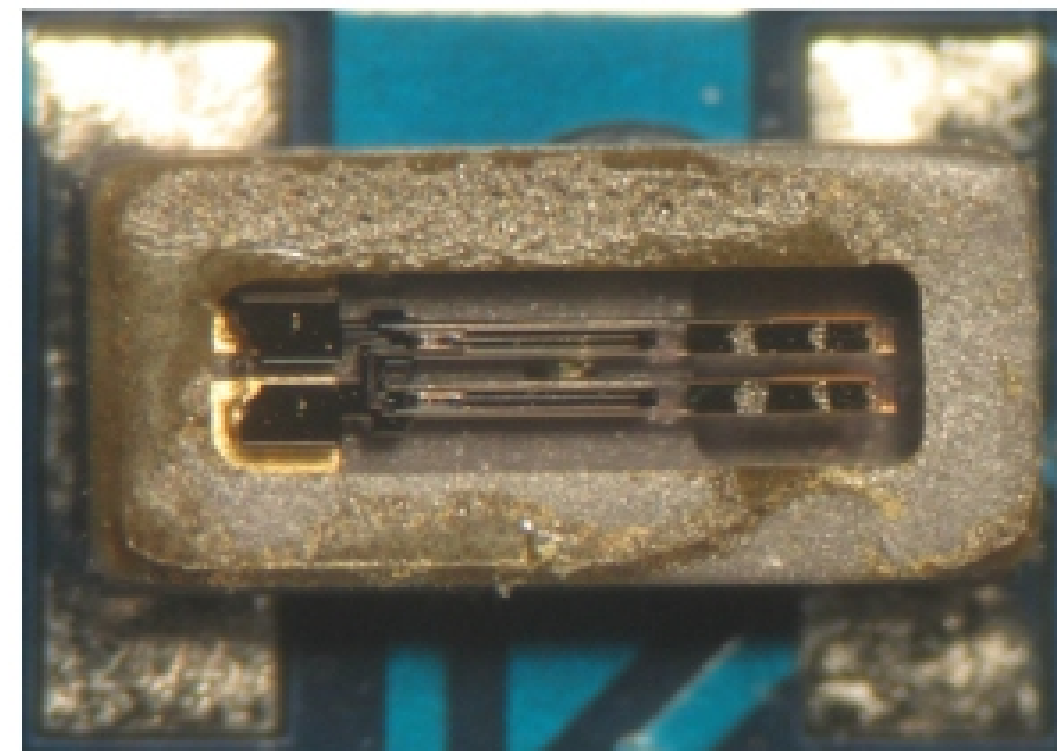


- Chemically, quartz is Silicon Dioxide and displays the Piezoelectric effect.
 - When a crystal of quartz is properly cut and mounted, it can be made to bend in an electric field.
 - When the field is removed, the quartz will generate an electric field as it returns to its previous shape.
- The resonance frequency of a quartz crystal depends on its length, thickness and angle of cut with respect to the crystallographic axes.
- Some angles have high immunity to temperature variations.
- Advantages:
 - Very high Q factor $\approx 10^6$, high stability $< 10^2$ ppm, low phase noise.
- Disadvantage:
 - Expensive, precision engineering, not all frequencies possible with all cuts.



12

Tuning Fork Crystal (magnified view)



13