

# Embedded Systems: Timers

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# Overview

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- Embedded systems and time
  - What is “Real-time” and when do we care?
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- Clocks
- Embedded “Hello World” Revisited
  - Can we do this differently? :)
- PWM
  - Hardware to the rescue!
- PWM and relation to Analog
- Measuring inputs using timers
  - Applications?
- Q&A

# Github, Wiki

- Links posted to NYU Classes
- We have a GitHub page!
  - <https://github.com/Aghosh993/EmbeddedSystems/>
  - Code samples, snippets
  - Recitation presentations (including this one!)
  - Useful as a reference later on
- There is a Wiki!
  - <https://github.com/Aghosh993/EmbeddedSystems/wiki>
  - Basic course info
  - Office hours, availability, TA calendar links
  - Shall be appended with further info, articles, et. al. as semester progresses, so check back frequently!

# Office Hours

- Abhi: (Almost) always at LC 029 in Dibner Building
  - Technically accessible 24/7/365
  - Take stairs down to basement, make left, right, right
    - Or follow the left wall for a while...
  - Should end up at a lab full of robots
  - Highly prefer email or chat prior to meeting
    - Contact info on Wiki
- Sravani: Email to set up appointment and figure out location
  - Contact info & calendar also on Wiki

# Announcements

# Brief Intro to Git

- What is Git?
  - Trivia: Similar systems?
  - Trivia: Creator?
- Rationale for use
  - Software dev happens in teams
  - Asynchronous process
  - Need to keep different “branches” sep. and mark/tag versions
  - Rapidly view changes between versions as diffs
  - Merge codebase from different teams when ready to ship

# Brief Intro to Git (Cont'd)

- Usage
  - Linux: git is typically in package repository
    - Ubuntu: “sudo apt-get install git”
    - Arch: “pacman -Syy && pacman -S git”
    - Others: Read the man pages :)
  - Windows:
    - TortoiseGit is an excellent GUI front-end with Windows Explorer integration
    - Plenty of online installation guides
    - Git shell available for power users who want more “linux-y” experience
- To “clone” repo:
  - “git clone <repo>”
    - “git clone <https://github.com/Aghosh993/EmbeddedSystems.git>”

# Coding “Best Practices”

- 70's and earlier
  - Hardware WAS expensive, software was... unaccounted for
    - Exhibit A: Software delays in Apollo almost cost the US the race to the Moon
- Now...
  - Hardware is cheap
  - Software is the new “top expense” in projects
  - SoftEng a whole new field
- Think carefully before making extremely machine-dependent optimizations
  - Machine time = <<<\$ in extra electricity or cost of small HW upgrade
  - Programmer time = >>>\$\$\$ in misery, salary and gray hair spent debugging/porting
- Macros, #defines important
- Structuring of code into modules of source and header files very important in large projects
  - Structure code into portions that are HW-dependent and those that are HW-independent
  - HW-dependent code frequently called the HAL – Eases porting process to diff. platform
- Pick the right toolchain, optimize b/w setup time and time saved in easier usage or some other metric
- Don't listen to the bean-counters



# Coding “Best Practices” (Cont’d)

- “Everyone knows that debugging is twice as hard as writing a program in the first place. So if you’re as clever you can be when you write it, how will you ever debug it?”
  - Brian W. Kernighan (Co-author, *The C Programming Language*)
- Most mere mortals aren’t very clever...
- Comments and “good code”
  - Comments should COMPLEMENT, not REPLACE understandable code
  - “int magic, tmp, temp, foo; //These variables hold values... “
    - No...
    - Surefire way to get poor performance reviews and eventually be fired
- Unit-testing, HITL
- More advanced: Doxygen
  - Auto-generate HTML, PDF docs of software based on structured comments
- Even More Advanced(TM): Coding standards
  - MISRA, DO-178b, et. al.
  - If you’re coding to these standards, your mistakes will follow your clients to their graves :)

# Wrap-up of C programming concepts

- Bitwise math
  - AND, OR, XOR
- Two's complement, conversions of types
  - Trivia: Why do we care?
- Enums, unions re-visited
- Q&A

# Embedded systems and time

- Time is important
  - Especially so in Embedded Systems
  - Frequently a variable that actions are based on
    - Ex: Measure a sensor every X seconds and update some actuator value based on a set of calculations
- Real-time:
  - “Hard”-RT: Airliner controls, missile guidance system, car airbag deployment system
  - “Soft”-RT: Infotainment system, average user desktop
  - Everything is ultimately “hard”-RT in the sense that eventually the response characteristic will be deemed unacceptable by the user (i.e. people killed in a crash, user throwing out computer)

# The Humble Timer

- Variety of ways to create delays, keep track of time
  - Why not just a busy loop?
  - External time reference? Trivia!
- Timers to the rescue!
  - Processors already use some kind of timebase, known as crystal or oscillator
  - Timer uses the transitions in the waveform of oscillator/other clock source to increment a counter
  - Since timebase (crystal, oscillator, et. al.) has a well-defined period, the counter will also count up/down at a very well-defined rate
    - We can use this in our app!
  - Many HW methods to take various actions based on counter and a few other regs
    - Toggle a pin
    - Take some user-defined action
    - Sample a pin and use it to trigger reset/stop of counter

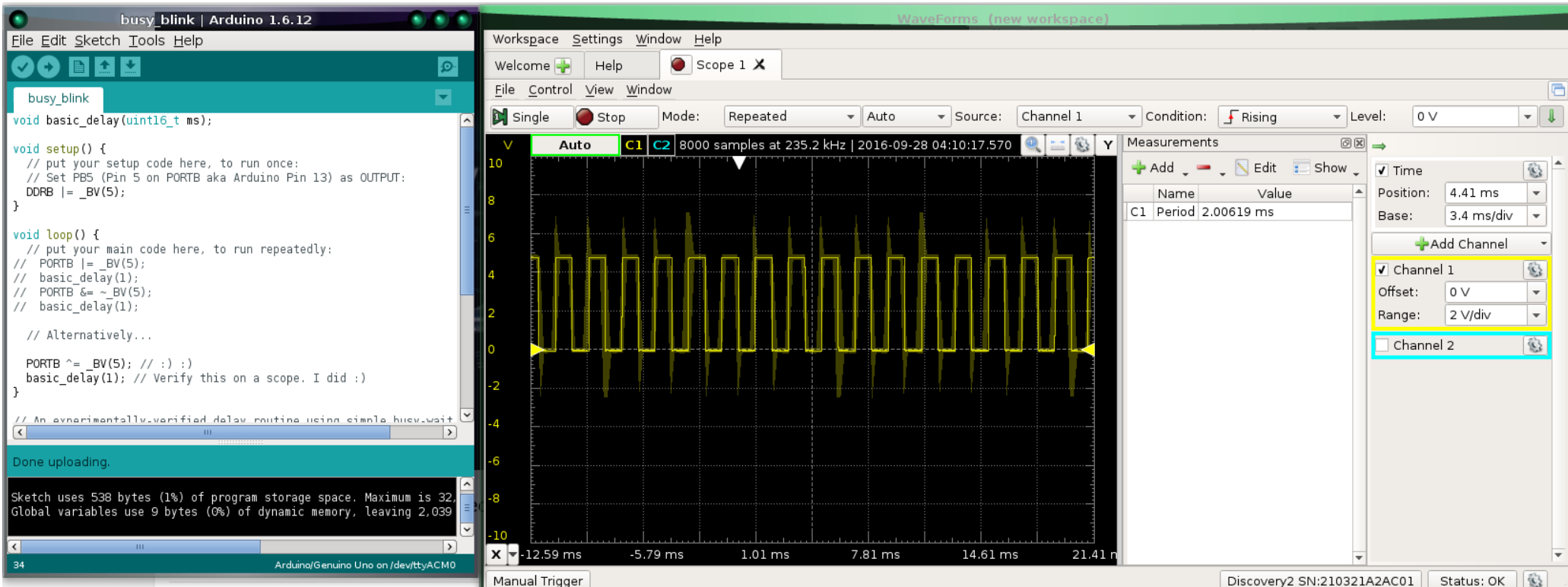
# Clocks

- Commonly some kind of quartz crystal that oscillates at a VERY consistent frequency
  - Consistency/accuracy often given by the manufacturer as PPM (parts per million) or max % deviation
  - Often temperature-sensitive
    - Is this an issue in some apps? Trivia!
  - Might need to consider crystal drift in some apps...
    - Trivia: Where might there be an immediate issue?
- Clock source can also be some other logic circuit
  - Free lunch/dinner for any ideas/circuit names that do this :)
    - Cannot use crystal/anything besides transistor-based ICs, resistors, capacitors

# Clocks (Cont'd)

- Problem: We don't just want to count at  $1/\text{CLK}$ 
  - Prescalers
  - What else can be done? Trivia!

# Embedded Hello World Revisited



Trivia: Any idea why the scope shot has artifacts?