

occam on the Arduino

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also featuring photos by:

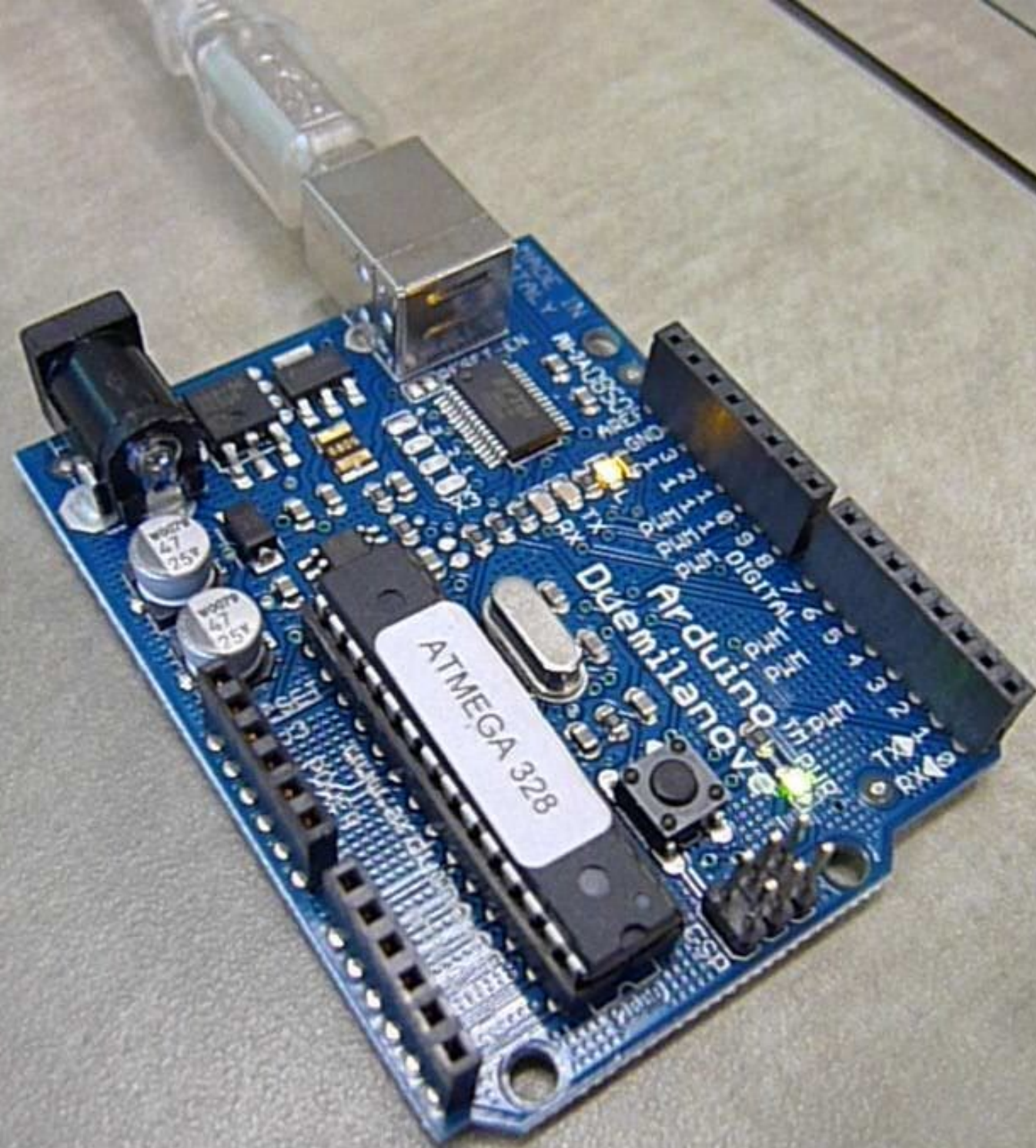
Maja Sweeny



Finding a platform

- We merged the Transterpreter into the KRoC tree a while ago, but we've only worked on one port recently – the Surveyor robot
- The Surveyor costs \$400, and is cute but not terribly robust
- Other ports we've done in the past (the Pioneer, the Lego Mindstorms, and various one-off robots) have been similarly expensive





ATMEGA 328

Arduino
Duemilanove

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47
25V

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The Arduino

- Family of AVR-based development boards
- Costs \$25
 - Cheaper in bulk
- Open-source hardware and software
 - Anyone can build their own Arduino variants – and lots of people have done
 - Simple bootloader
 - Simple IDE
- Huge community – <http://www.arduino.cc/>

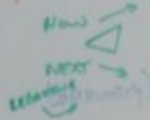


LAST MEETING: 7/20/11 / 10/20/11

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LEE MORGAN: regulation/serenity

800 (NASC): 800-331-2222
= (HOME): 410-331-1041

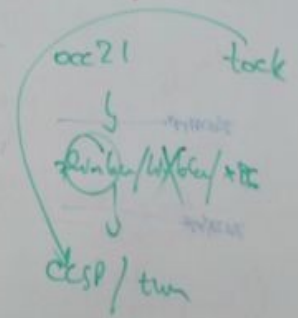
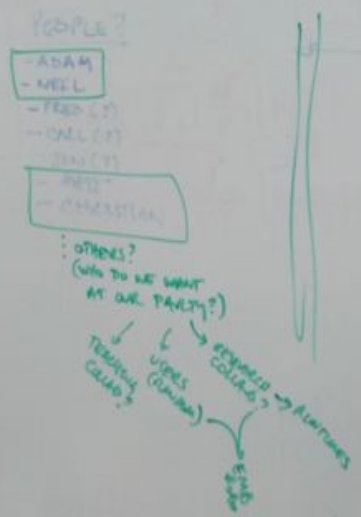


① HOW DO WE GET FROM A TO Q?

- WHAT DO WE LEARN?
- LARGER EXNS (EMG)?
- PAUL CONSTITUTIONS?
- (TEACHING VS. RESEARCH?)
- WHO IS INVOLVED - GAMES/PROJECTS

ADDITIONAL CAPTURES?
- 000001, 1000, 10000 100, etc.
000 001-031-1041

	#	Cond#	Interface	# m	# f
Open-outstop	6	B	RS-15	18	6
Upper Motor	2	B	RS-15	6	6
Printer Head	1	B	RS-15	2	2



WHAT ABOUT?

The plan

- Port the Transterpreter to the Arduino
 - ... which is really “port it to the AVR processor”
- Provide a toolkit of processes for people to build interesting things with
 - The Arduino's C++ library is called Wiring...
 - ... so our occam library is called Plumbing
- Write a book that introduces students to embedded programming with Plumbing
 - Primarily aimed at non-techies – lots of artists and musicians use Arduinos



Squeezing occam into not much space

- The ATmega328P on the Arduino is a reasonably typical low-cost microcontroller
 - 32KiB flash, 2KiB RAM
 - 16MHz, 16-bit (effectively) CPU
 - Lots of IO facilities: ports, timers, interrupts, UARTs, ADCs...
 - Just the chip costs \$4
- We use the normal occam-on-a-small-machine tricks: use 16-bit mode, disable most -pi features



Nonetheless, *we* have the will!

- The AVR is a Harvard-architecture design
 - Separate address spaces for instructions and data
- By default, the AVR C compiler *copies* data from flash into RAM on startup
- We implemented a virtual memory backend for the Transterpreter so we can keep TVM bytecode in flash
 - ... and a trimmed-down bytecode loader to support it
 - Room for ~14KiB of bytecode at the moment



Loading programs

- The Arduino comes with a bootloader that lets you upload chunks of data into flash over the USB port – that's what makes it an Arduino!
- The USB interface is quite slow, so it's a pain having to upload the Transterpreter every time you change your program...
- ... so we've fixed it so you don't have to
- We use the existing bootloader; the Arduino is still an Arduino



And just about that time she calls me up

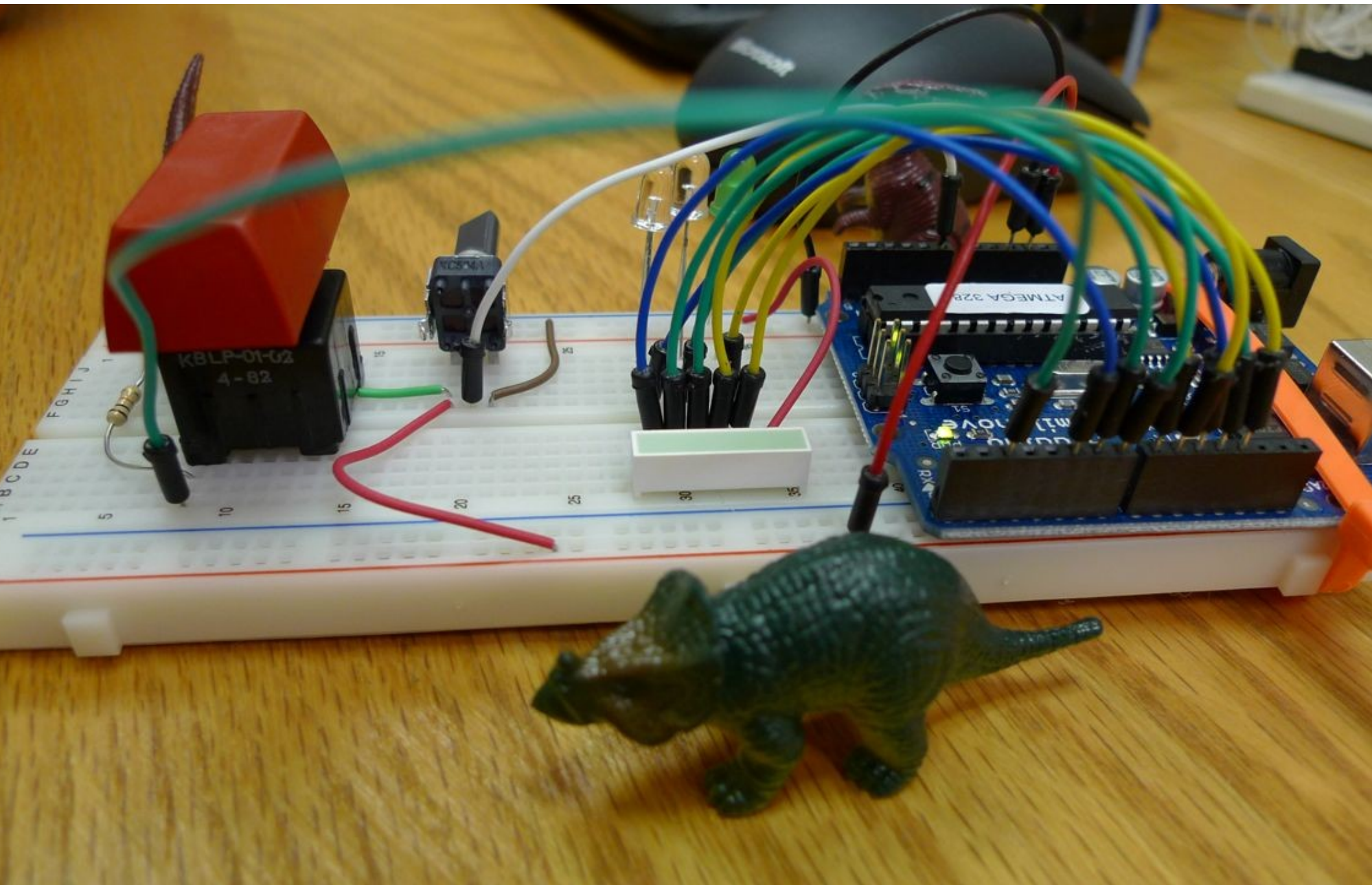
- Handling interrupts in occam is an interesting problem – but we have to do it!
- Carl and Jon had come up with a scheme to map interrupts to channels on the Surveyor that worked, but was too memory-hungry for our purposes
 - The AVR has lots of interrupts and very little RAM
- Came up with an approach that only needs two words per interrupt – works nicely
 - ... after some subtle debugging

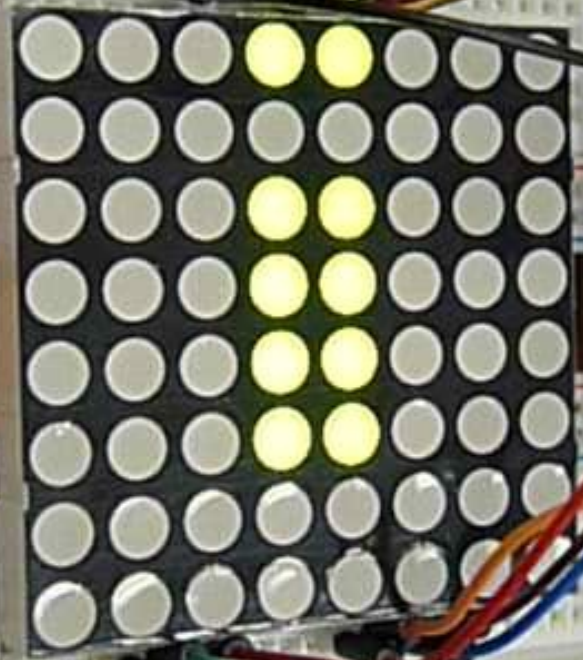
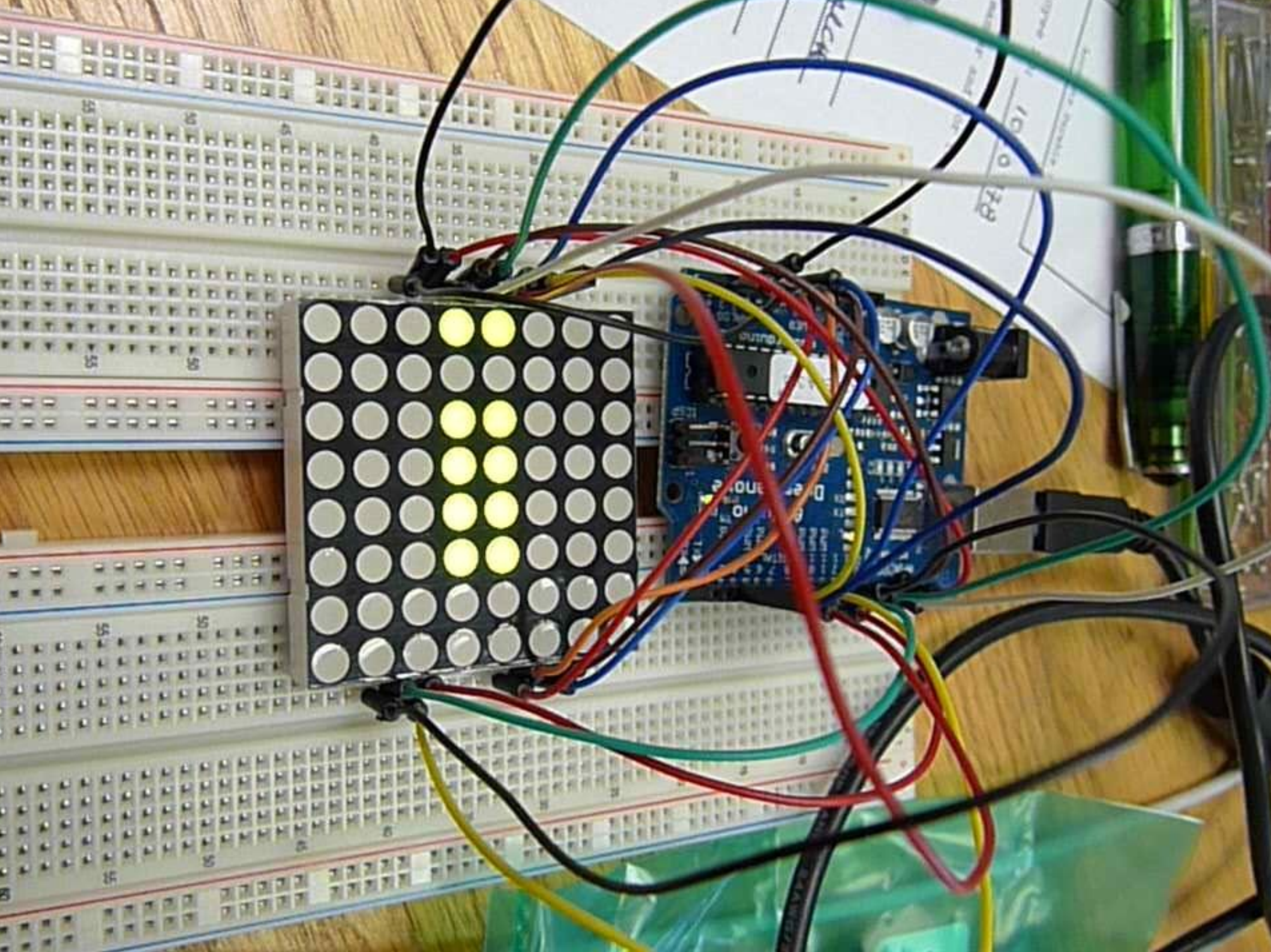


Success!

- The traditional Arduino demo is to blink the built-in LED on and off
 - Easy to do in occam, of course...
- Of course, since this is occam, we can blink all the IO lines on and off in parallel, at different rates
 - This is extremely hard to do in C++!
- We've also done: buttons, serial communications, ADC, pin change interrupts...





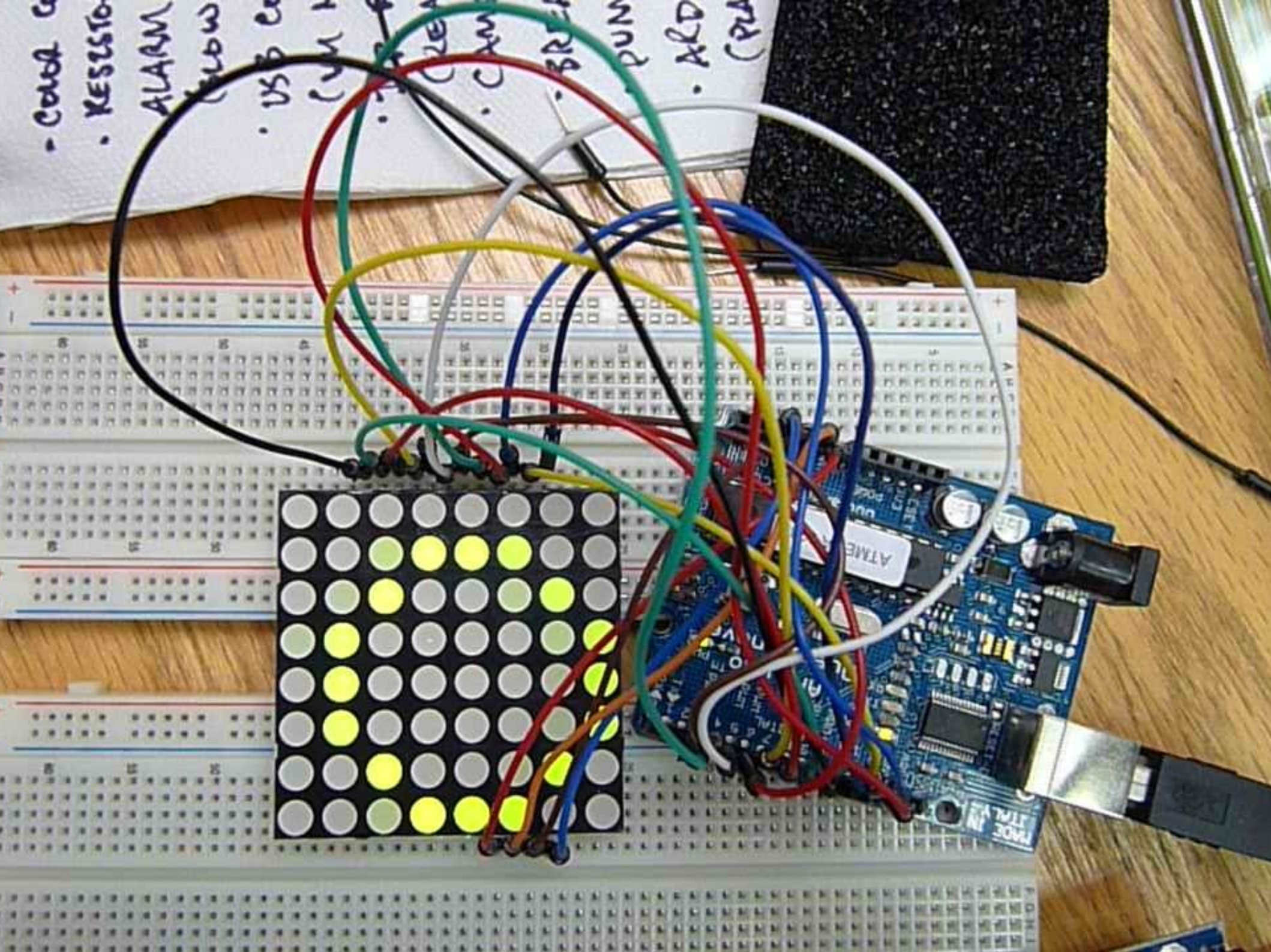


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A real application

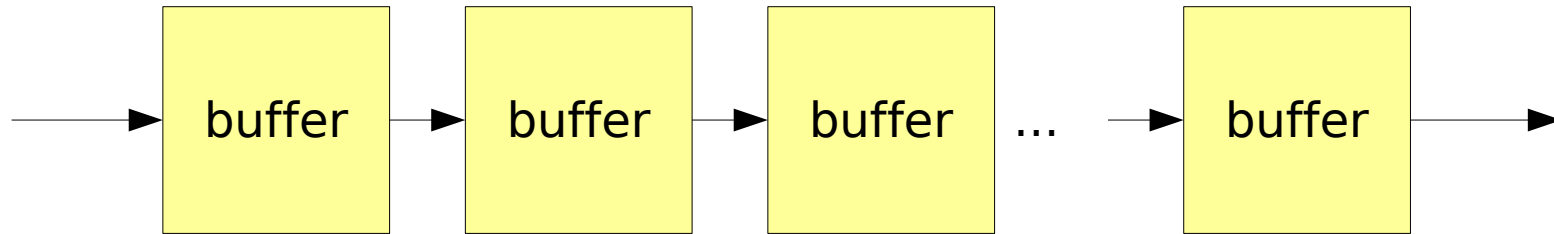
- 8x8 LED matrix
 - 8 rows and 8 columns, with an LED at each vertex
 - The AVR isn't really designed to drive that many LEDs directly off its IO pins, but it does work...
- Need to scan reasonably fast to draw graphics
- Need to buffer data as it's passed along the display



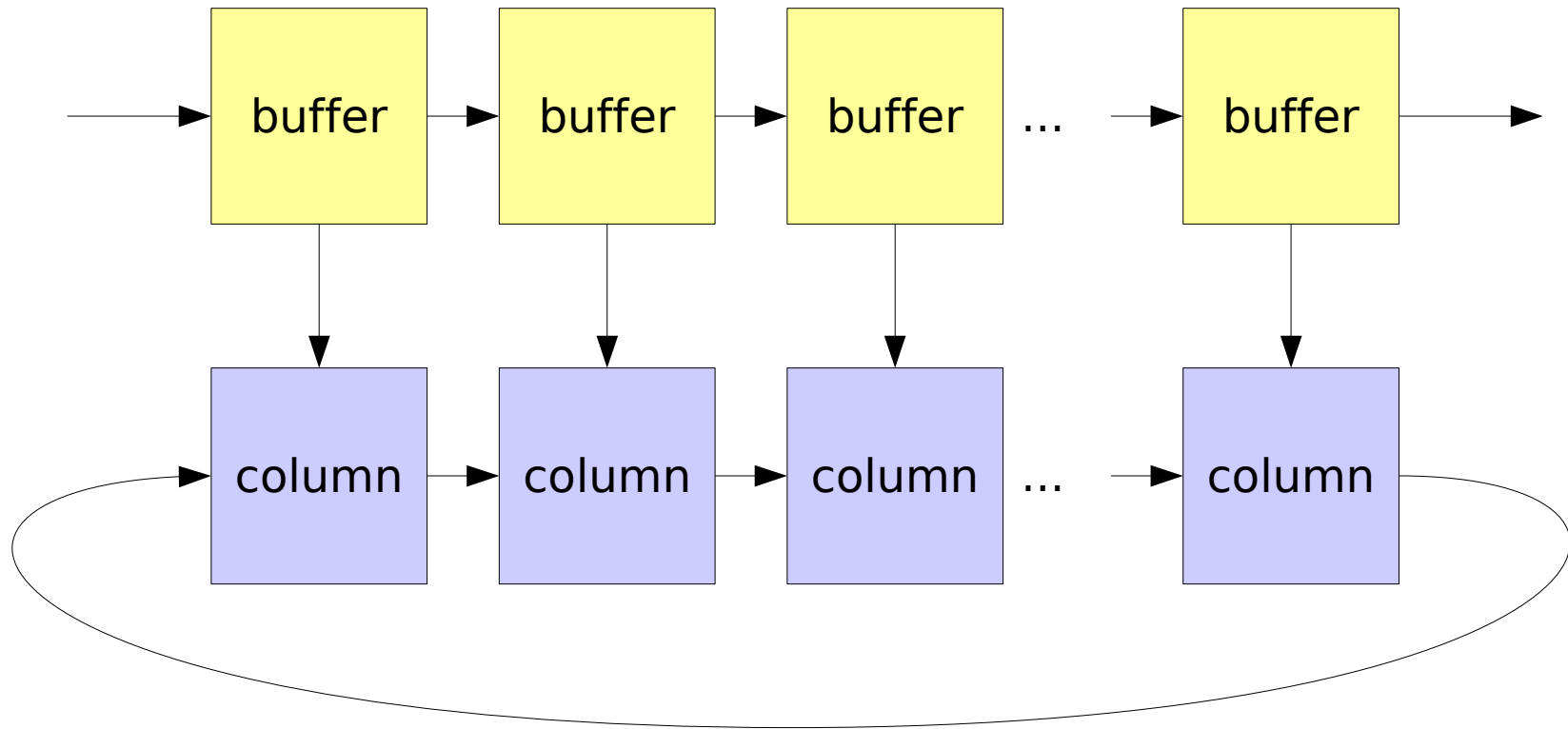


- CONTA C
- RESISTO
- ALARM
- LOW
- USB C
- CAM
- BREAD
- PUN
- ARD
- (CPLA

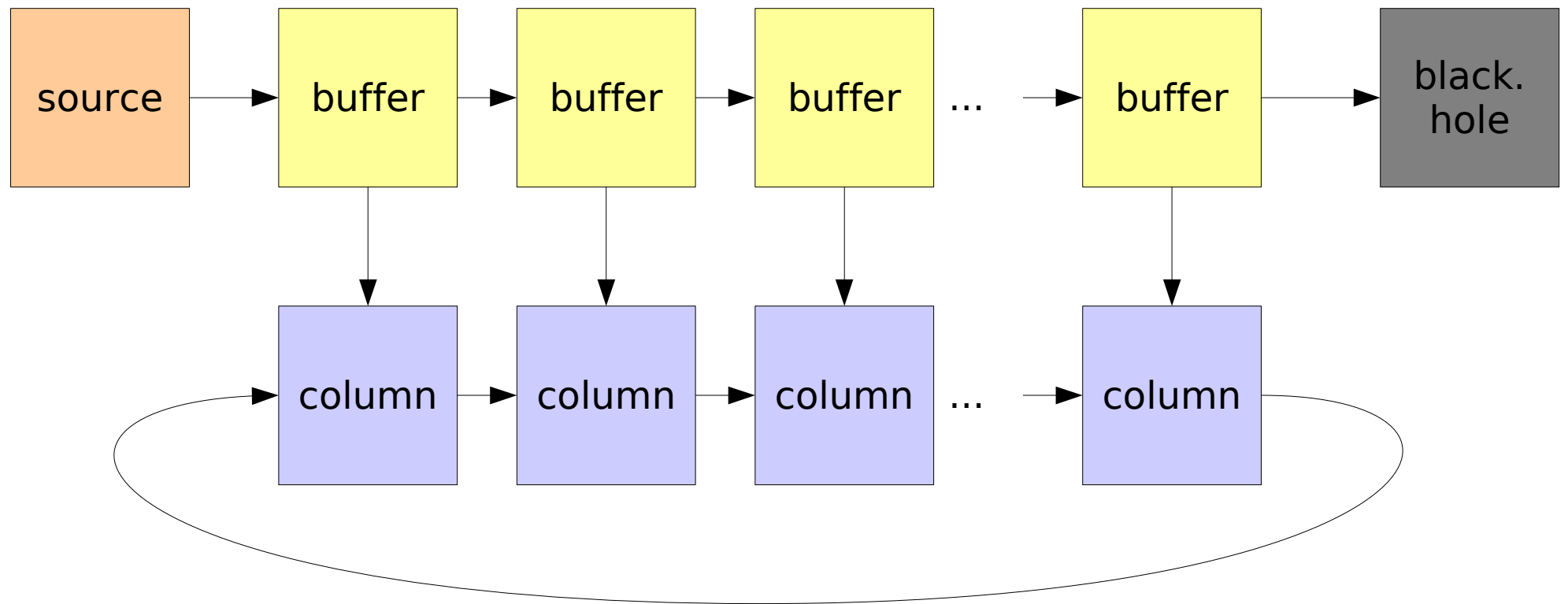
How does that work?

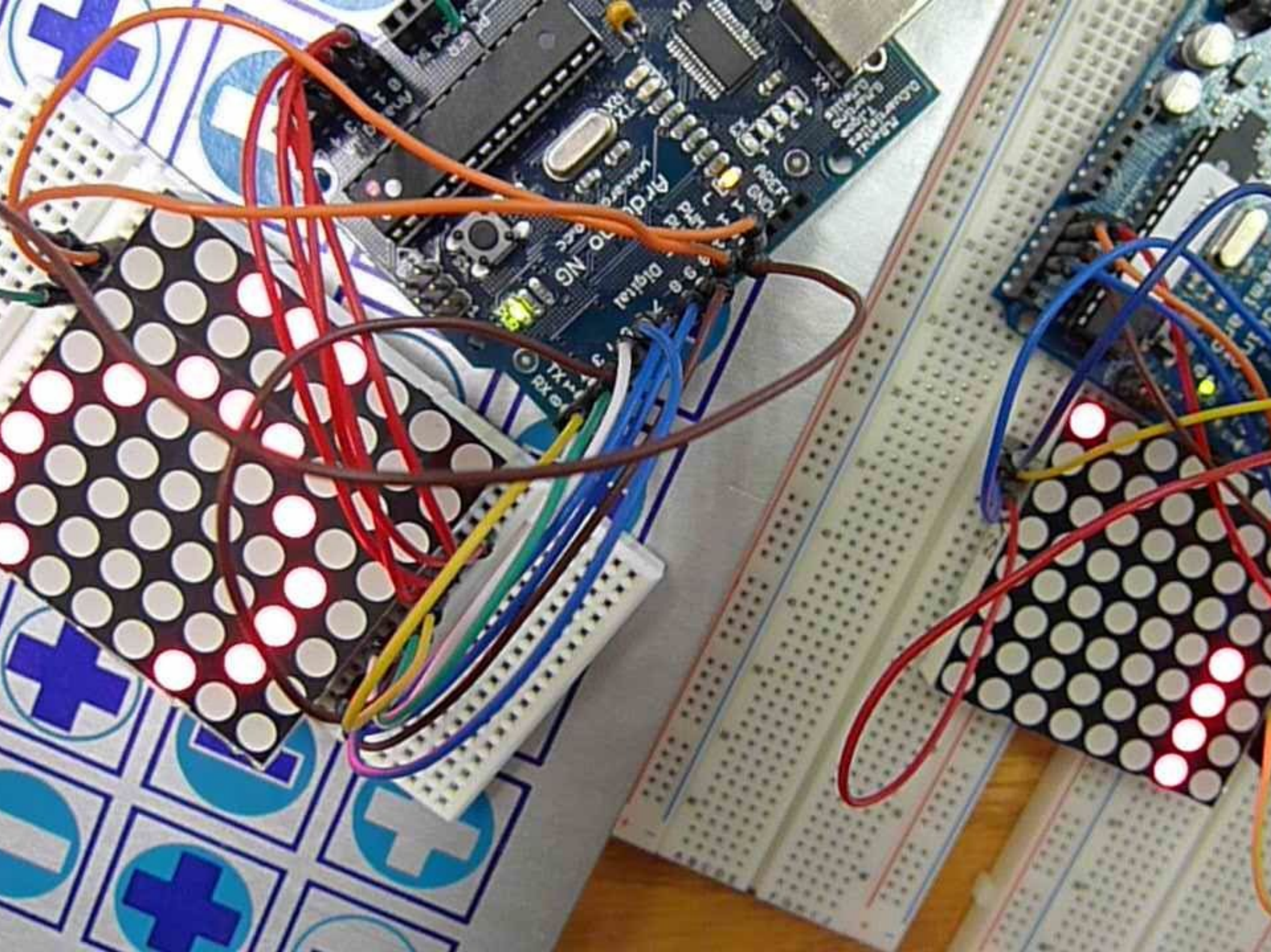


How does that work?

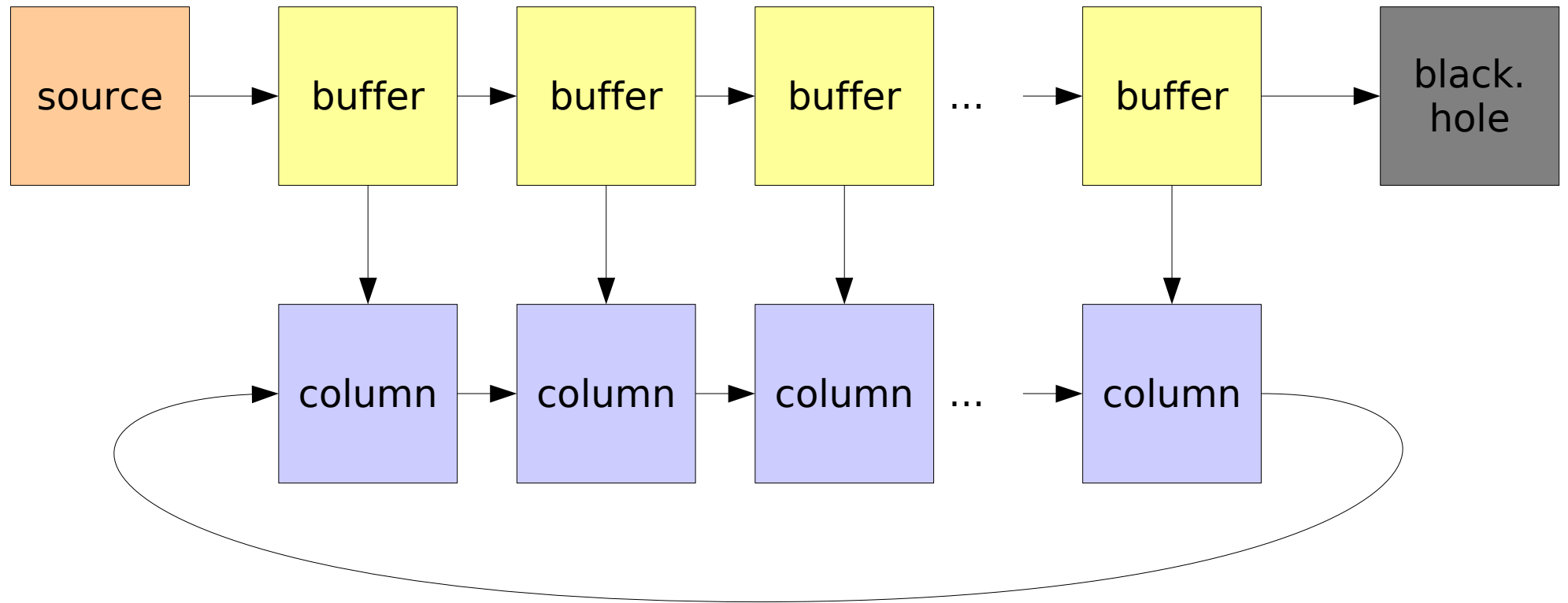


How does that work?

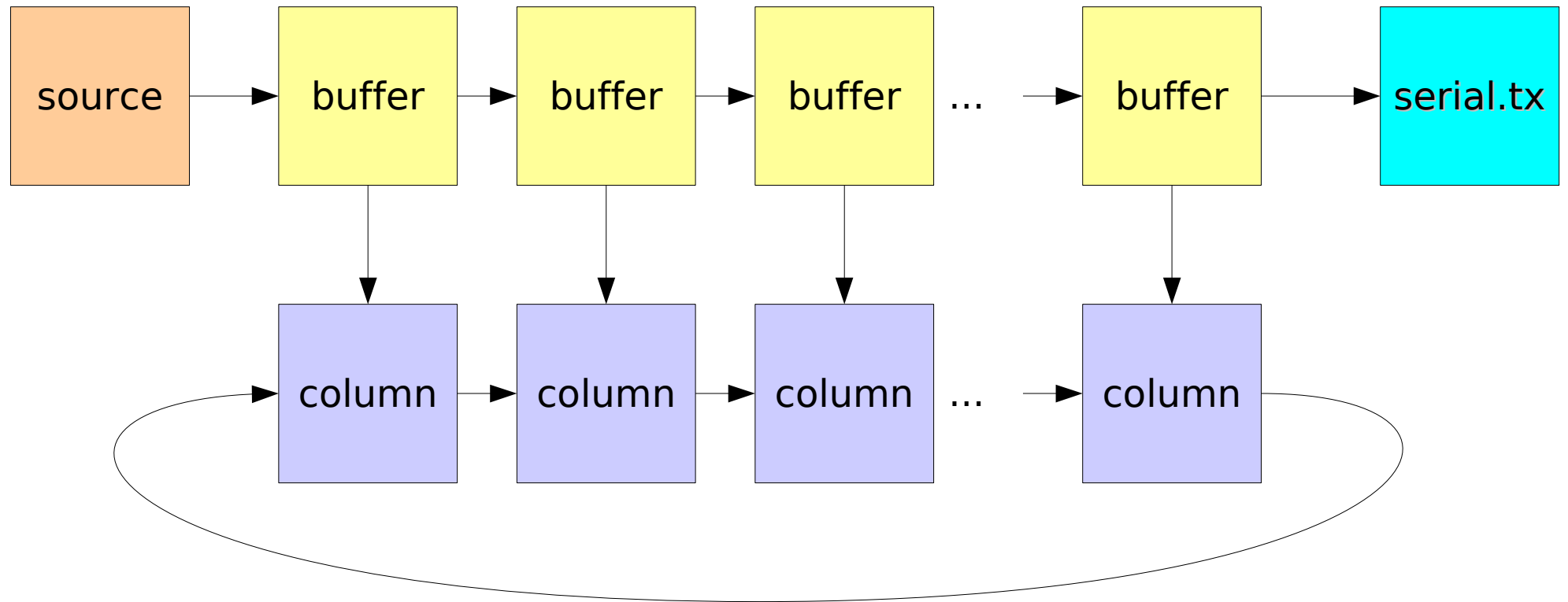




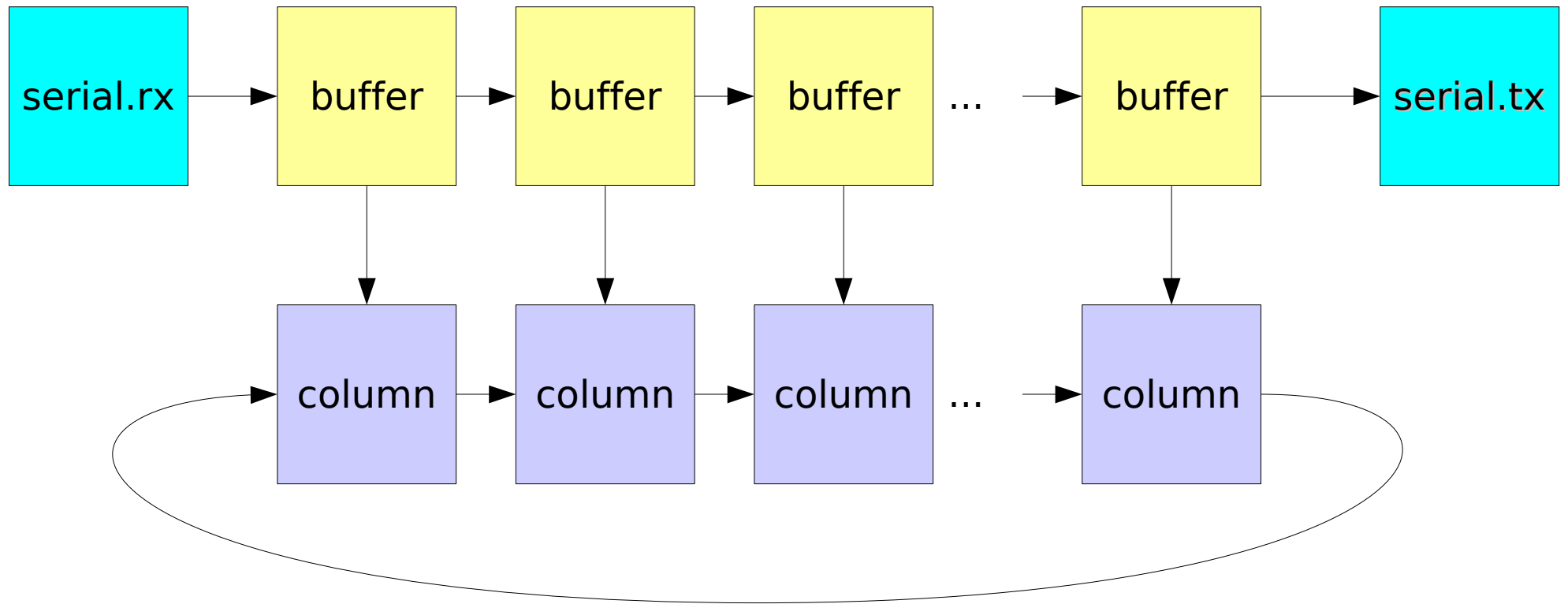
Distributed embedded system

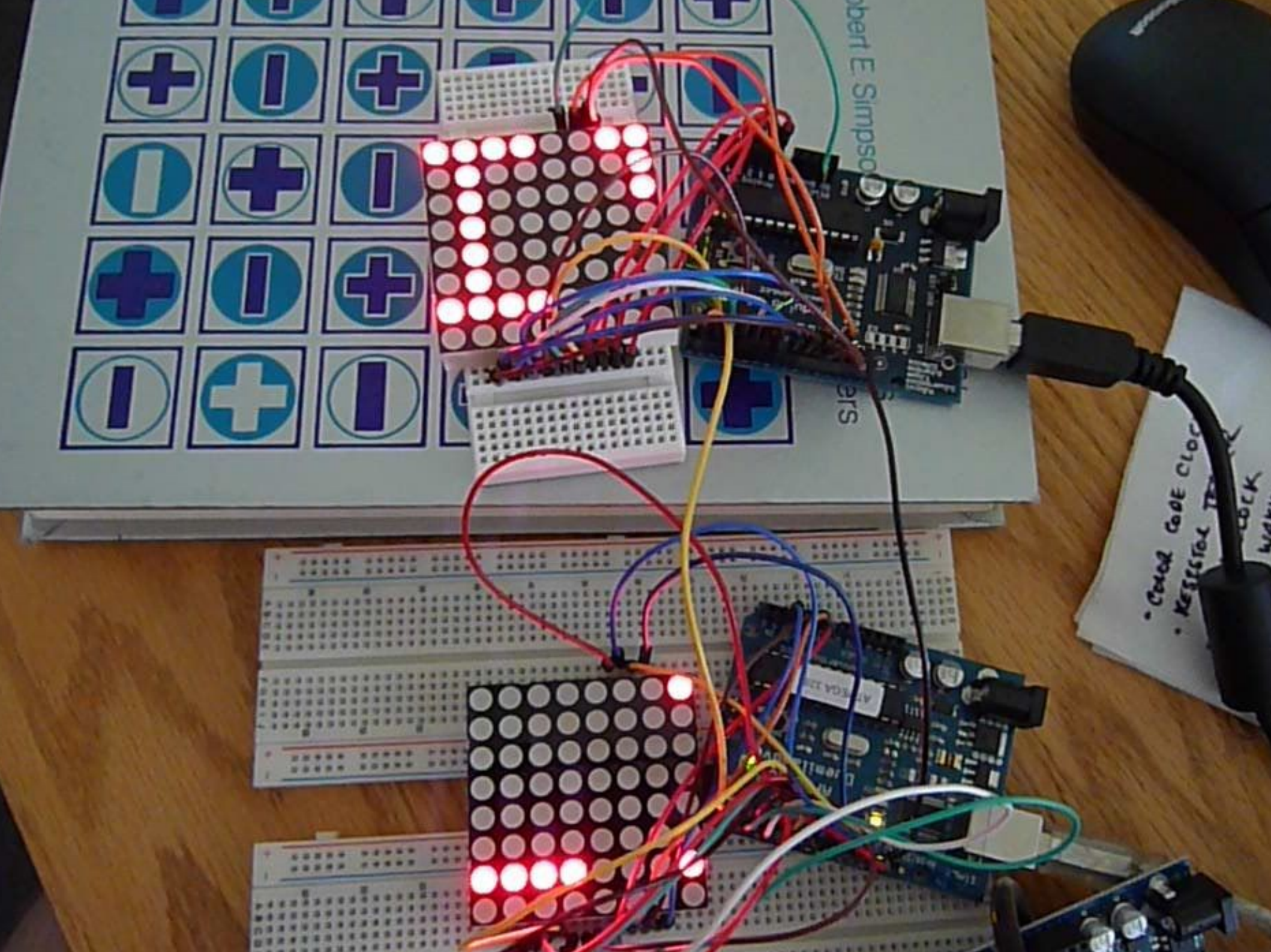


First node



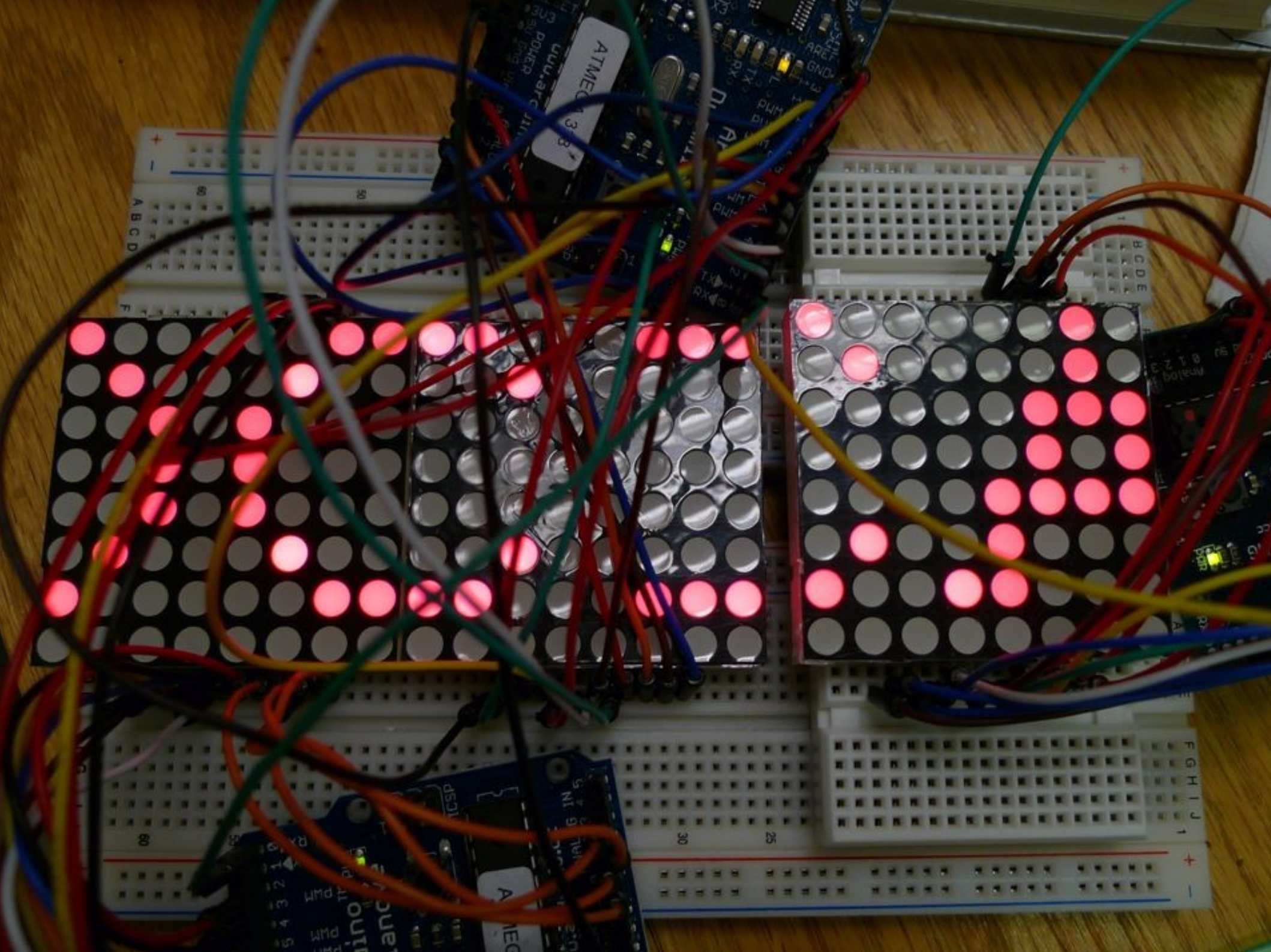
Other nodes

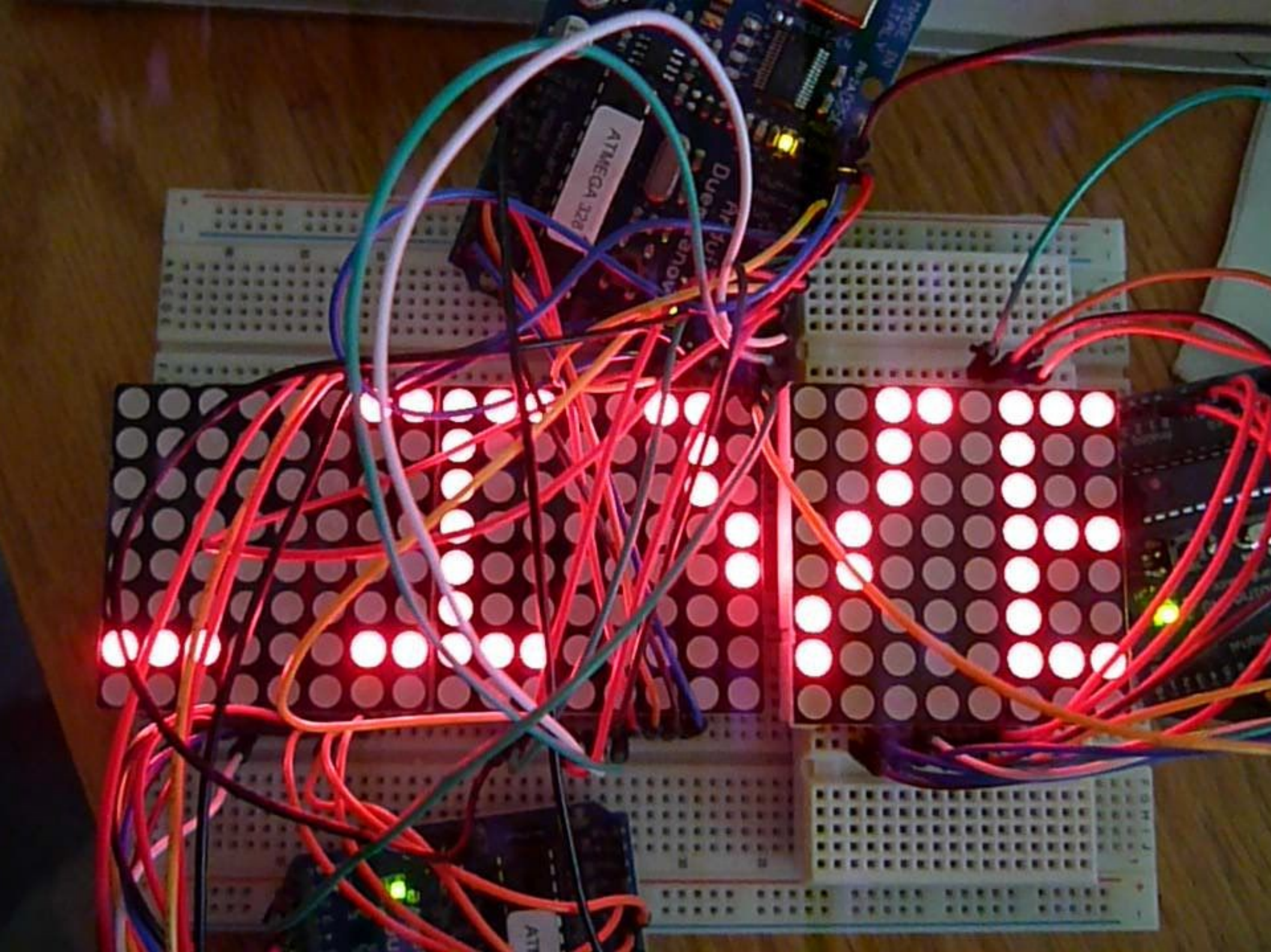


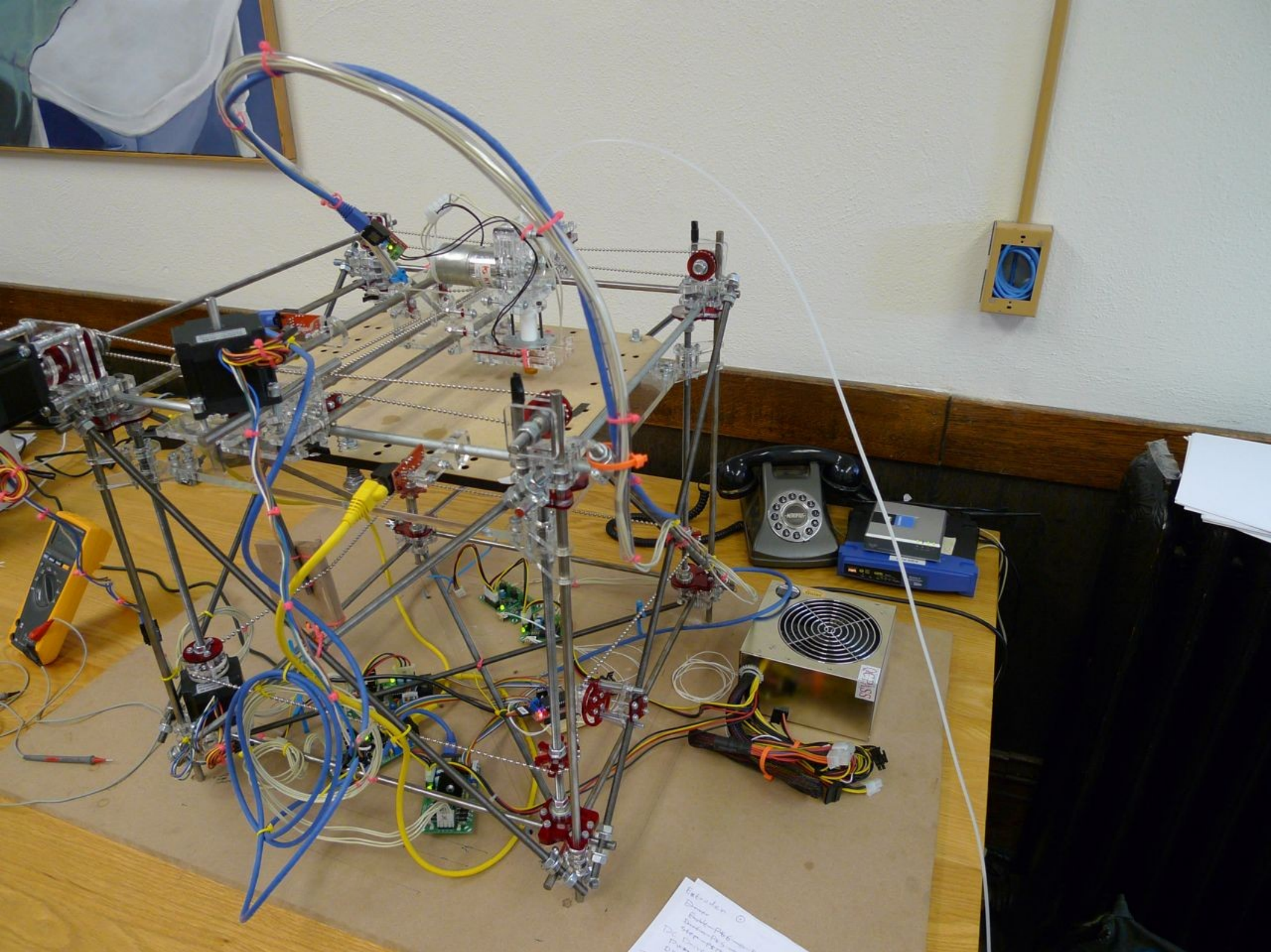


Robert E. Simpson
ERS

• Control CODE CLOCK
• REGISTER TRIGGER
• CLOCK







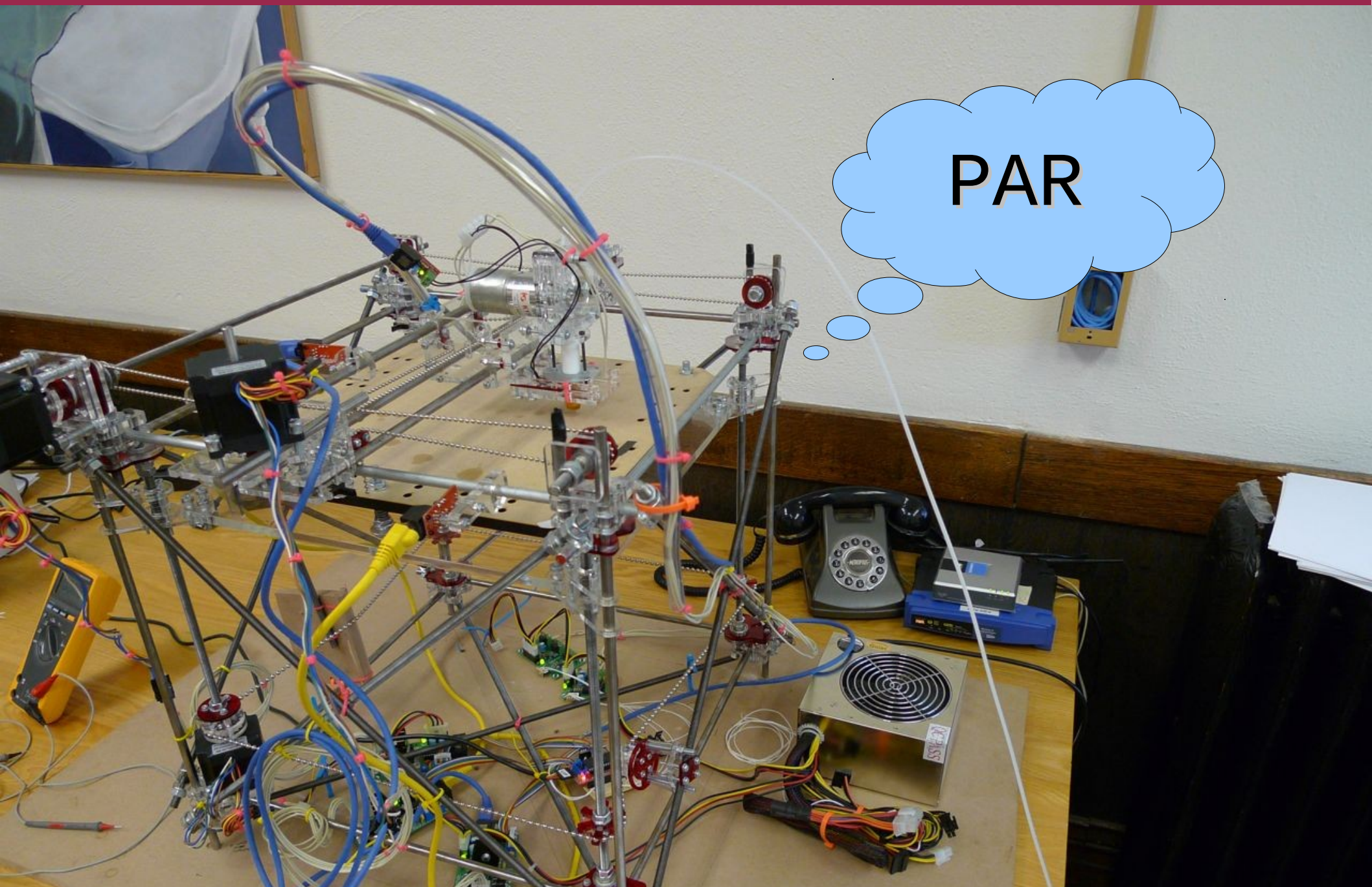
Exercises
Date: _____
Author: _____
Version: _____
Copyright: _____
D. _____

The RepRap

- Homebrew 3D printer
 - Builds up 3D models layer by layer in ABS plastic
- Controlled by an Arduino board
- The existing firmware is complete rubbish
- Matt plans to get a student to reimplement it in occam using the Transterpreter...



Any questions?



PAR