occam on the Arduino

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also featuring photos by:
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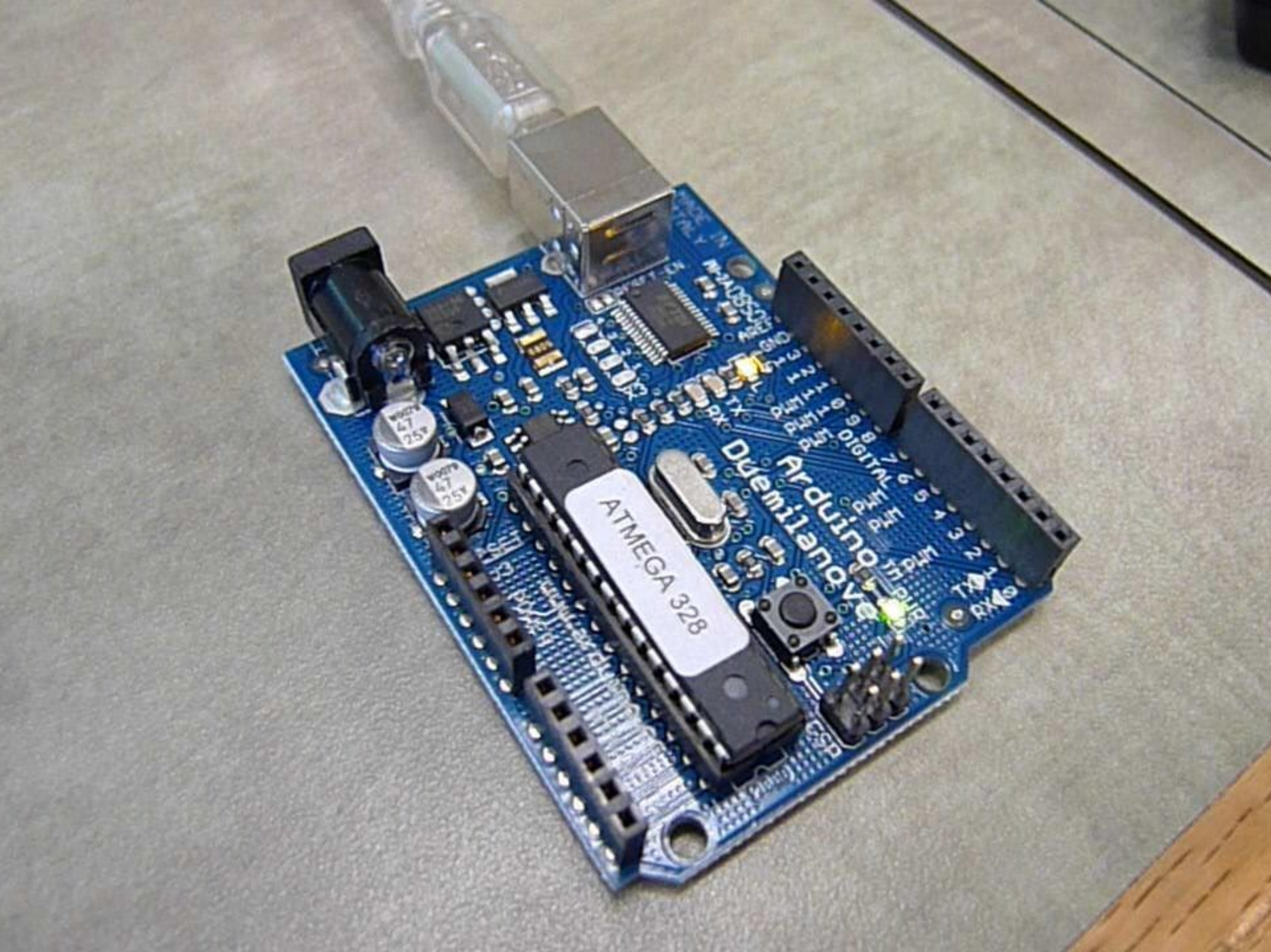
Finding a platform

- 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
Duemilanove
Arduino
DIGITAL
TX
RX

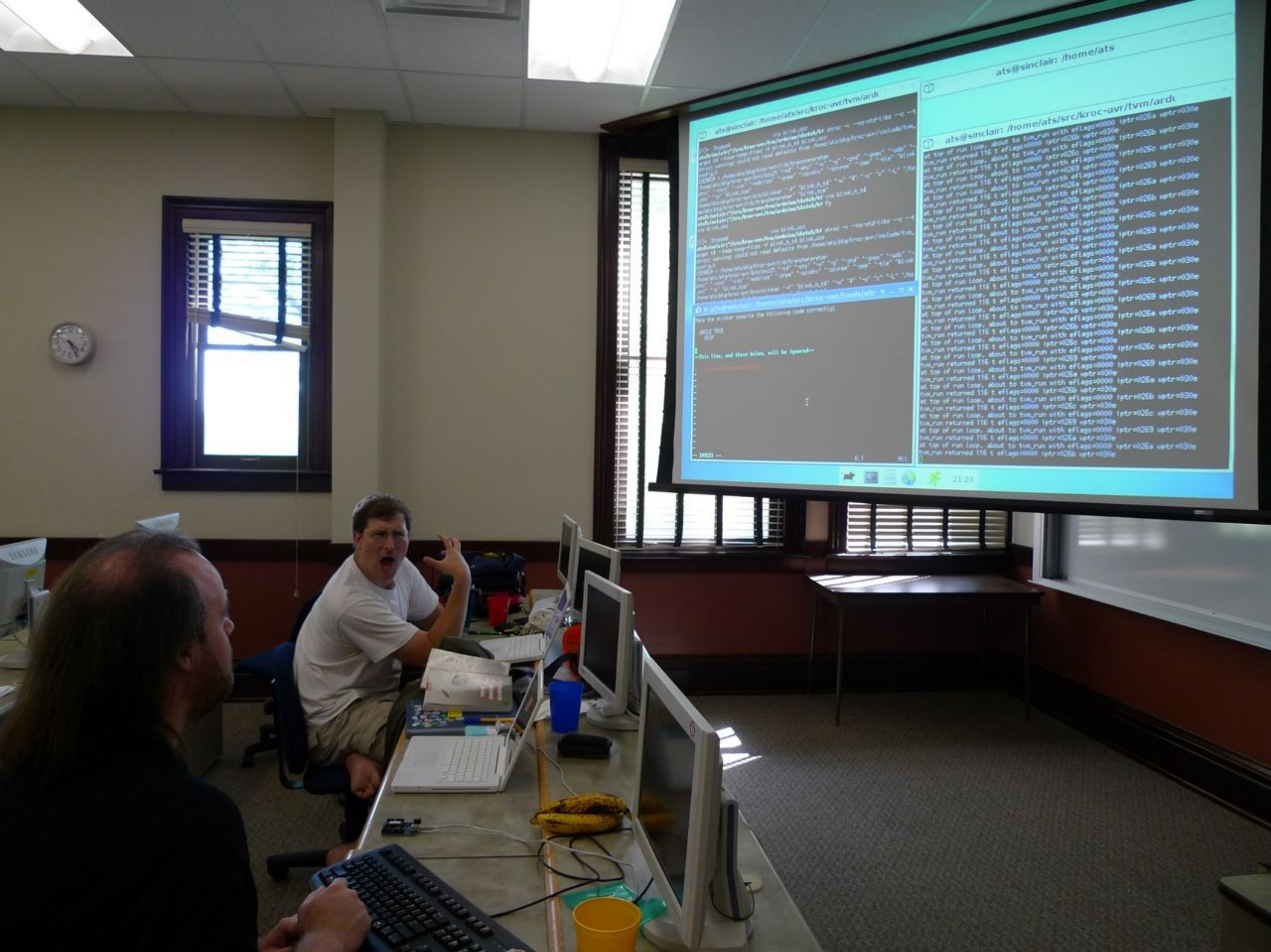
The Arduino

- 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/

HOW DO WE GET FROM A TO Q ?
PEOPLE?
ADAM
NEIL
OTHERS?
(WHO DO WE WANT AT OUR PARTY?)
Card # Interface #m #f
Stepper Motor
Printer Head
occ21
tock
CCSP / twn

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 programing with Plumbing
  - Primarily aimed at non-techies – lots of artists and musicians use Arduinos


ats@sinclair: /home/ats
ats@sinclair: /home/ats/src/kroc-avr/tvm/ardu
ats@sinclair: /home/ats/src/kroc-avr/tools/occ21
Make the blinker compile the following code correctly!
WHILE TRUE
SKIP
--this line, and those below, will be ignored--

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

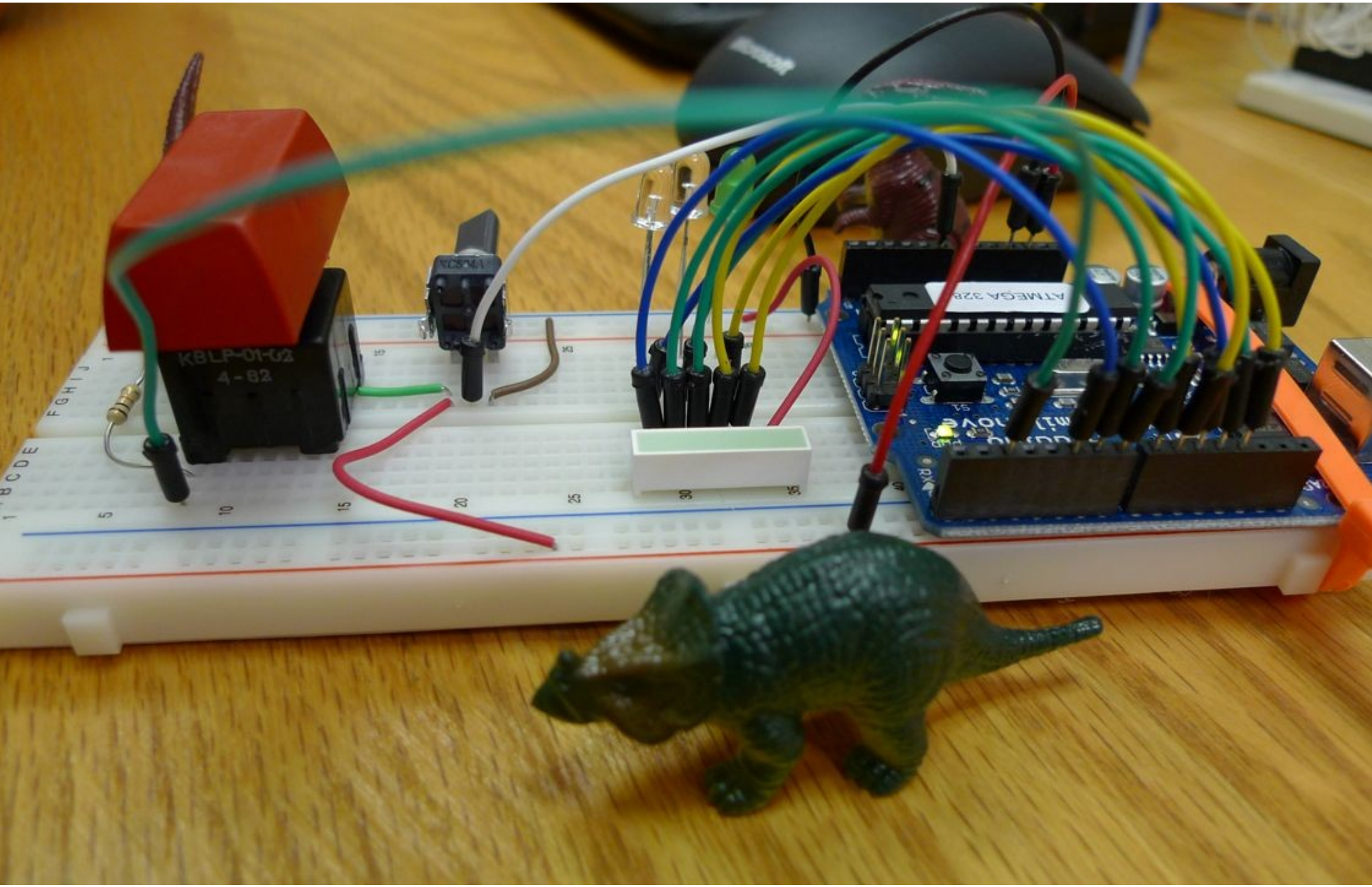
- The Arduino comes with a bootloader that lets you upload chunks of data into flash over the USB port – that's what makes it an Arduino!
- The USB interface is quite slow, so it's a pain having to upload the Transterpreter every time you change your program...
- ... so we've fixed it so you don't have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


KBLP-01-02
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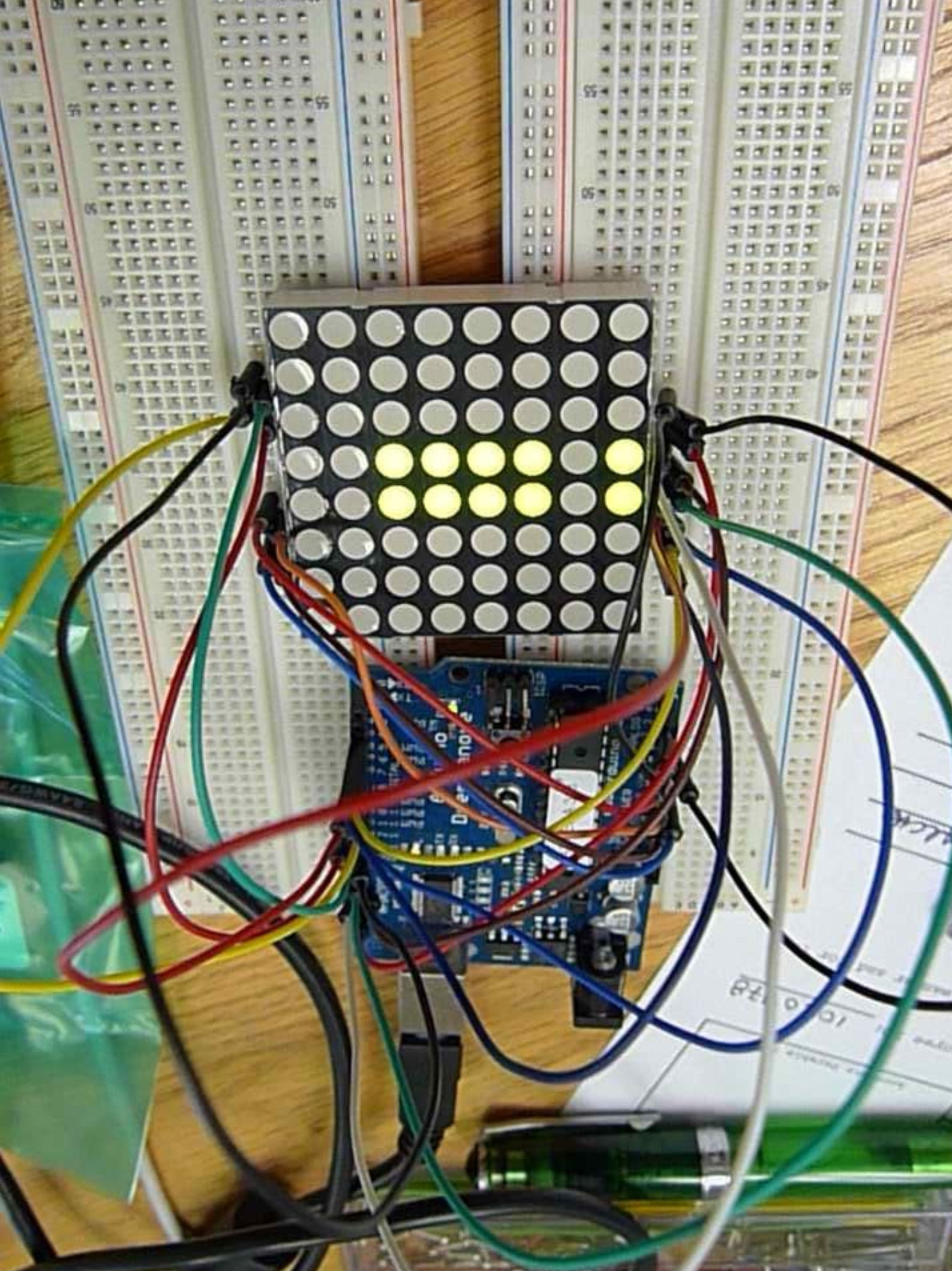
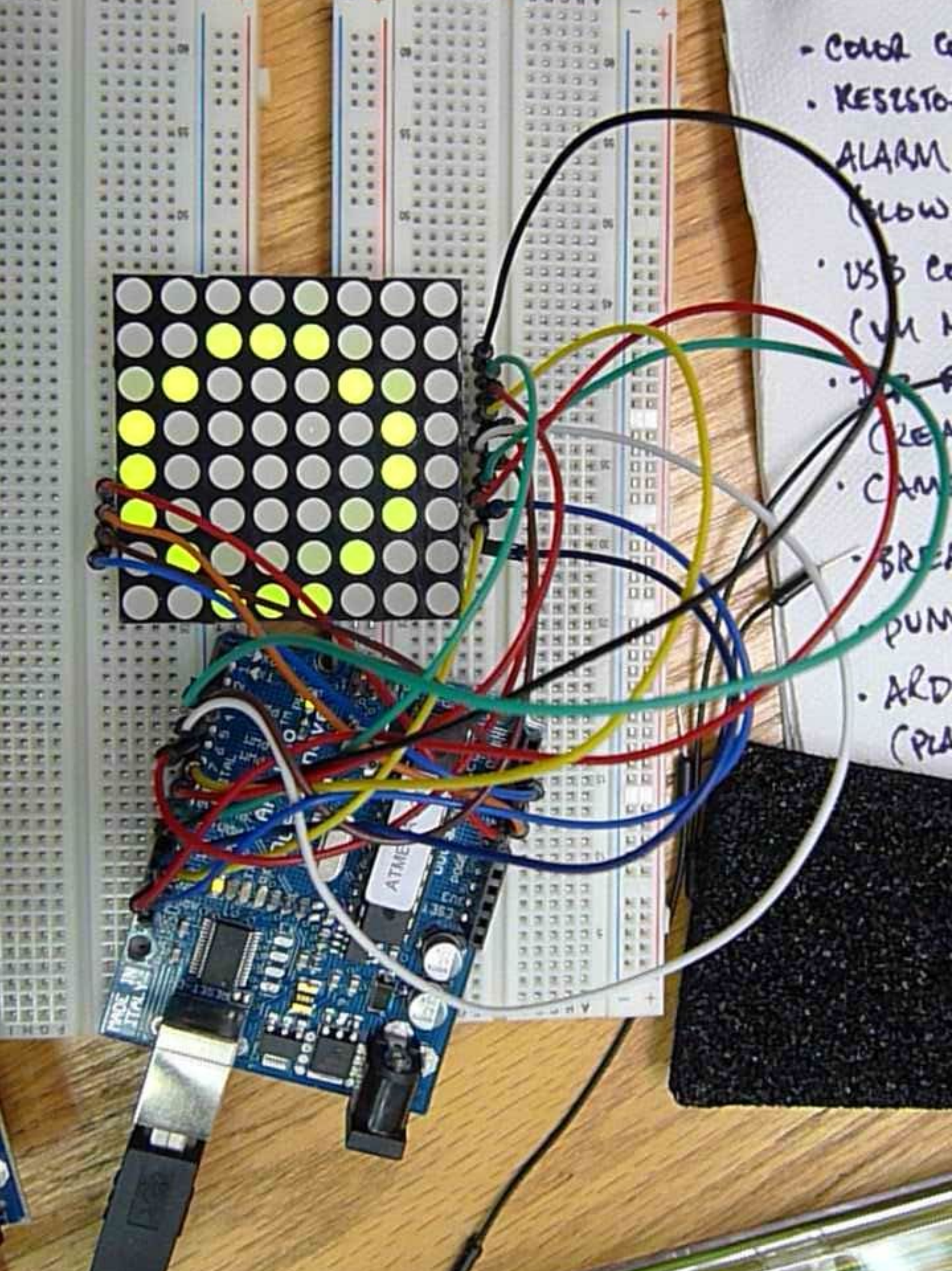
ATMEGA 328

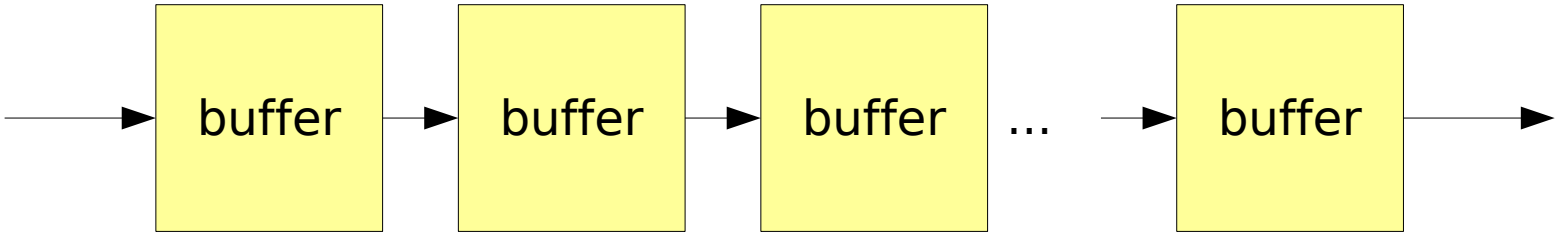


A real application

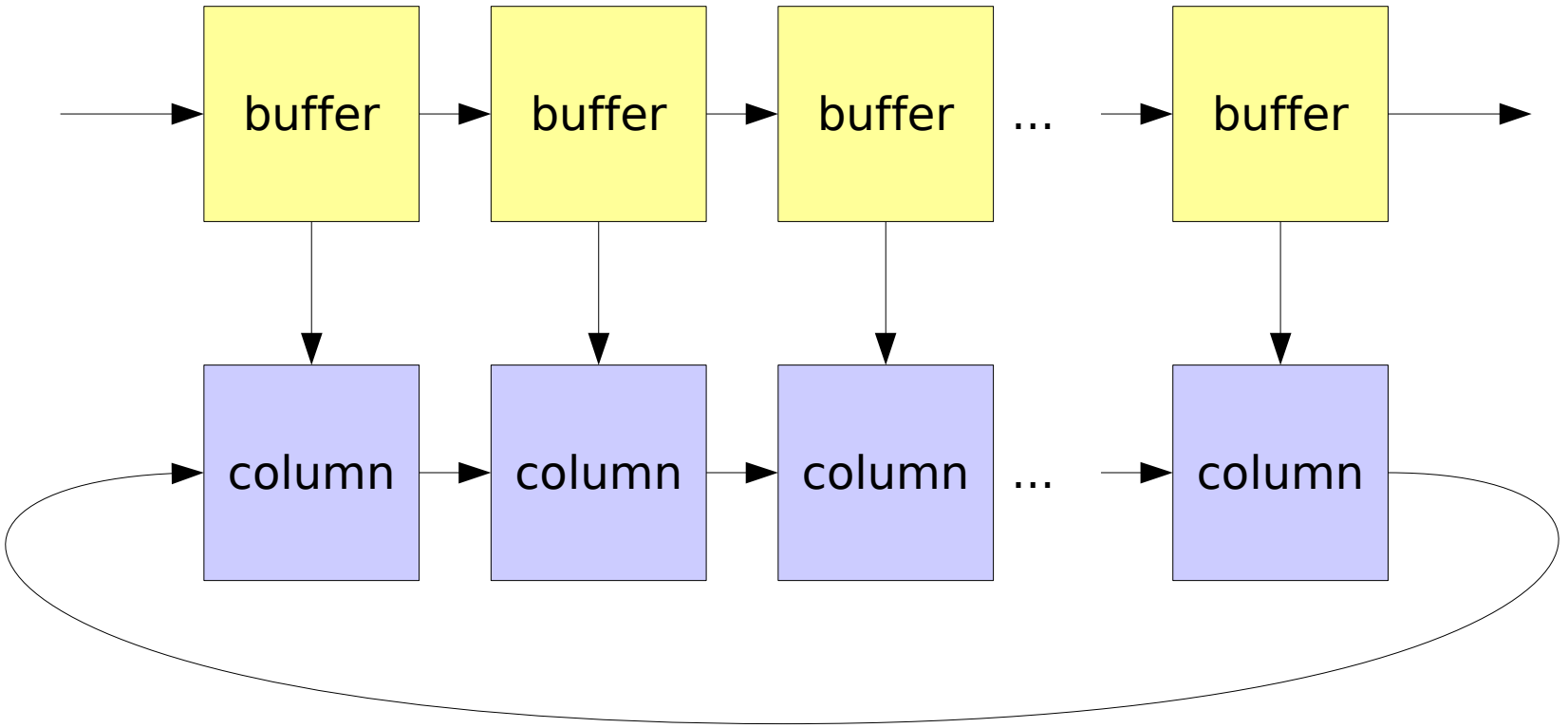
- 8x8 LED matrix
  - 8 rows and 8 columns, with an LED at each vertex
  - The AVR isn't really designed to drive that many LEDs directly off its IO pins, but it does work...
- Need to scan reasonably fast to draw graphics
- Need to buffer data as it's passed along the display



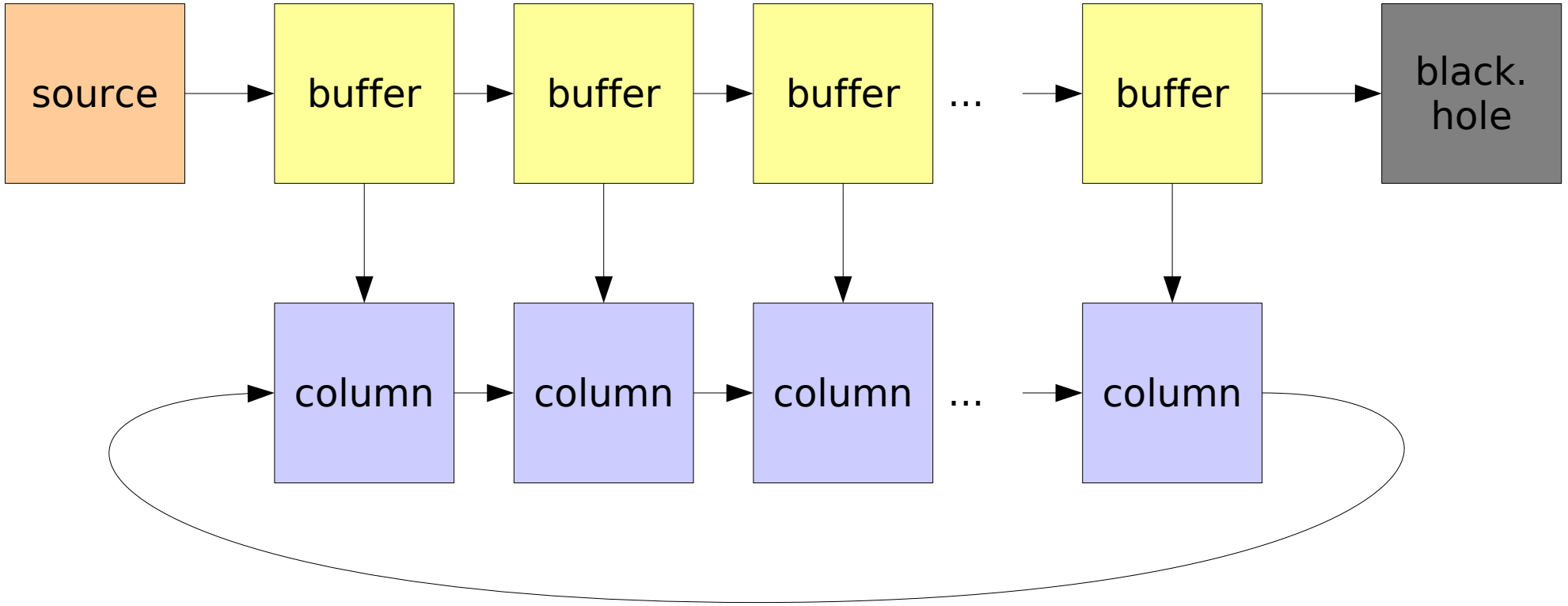
How does that work?



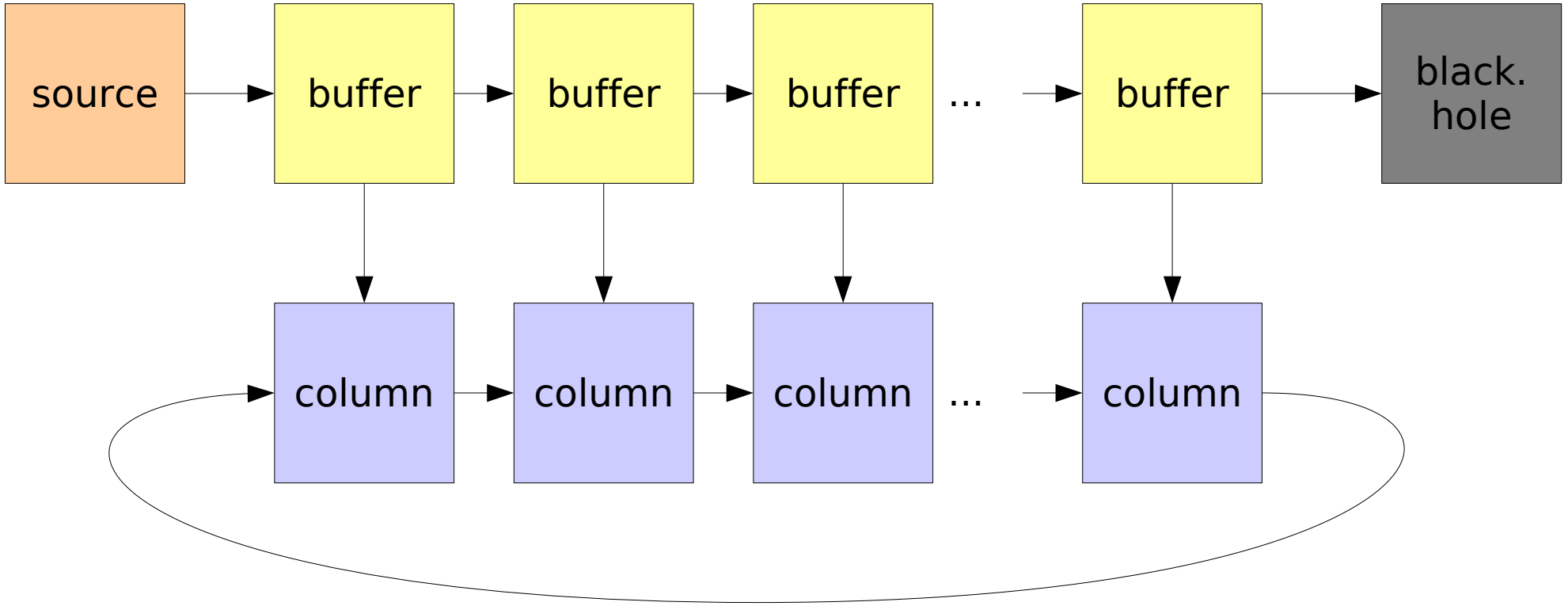
How does that work?



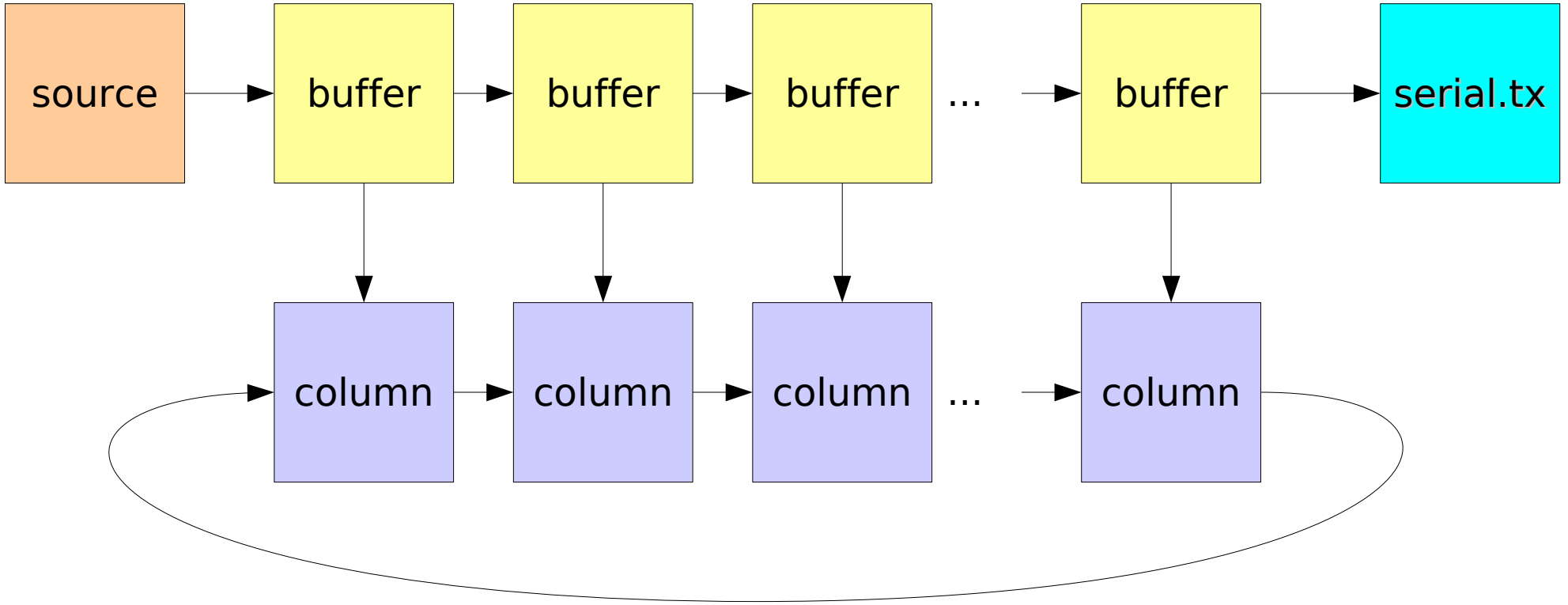
How does that work?



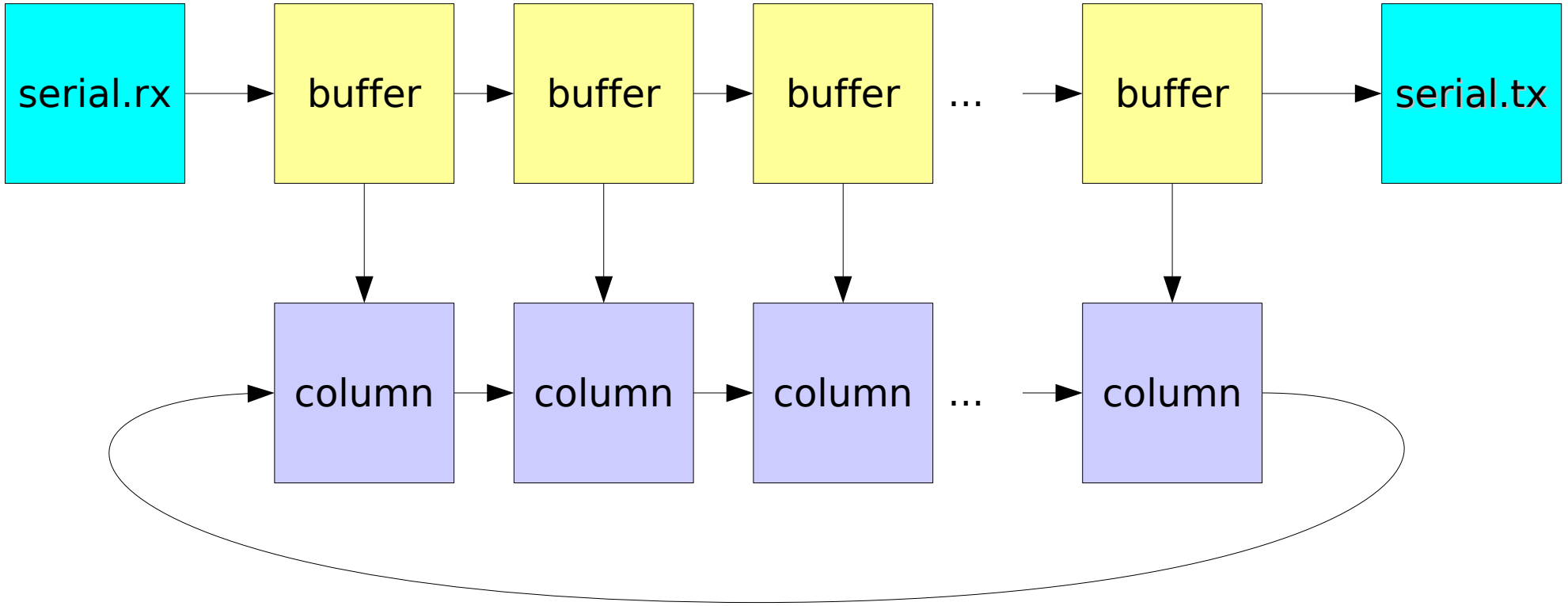
Distributed embedded system

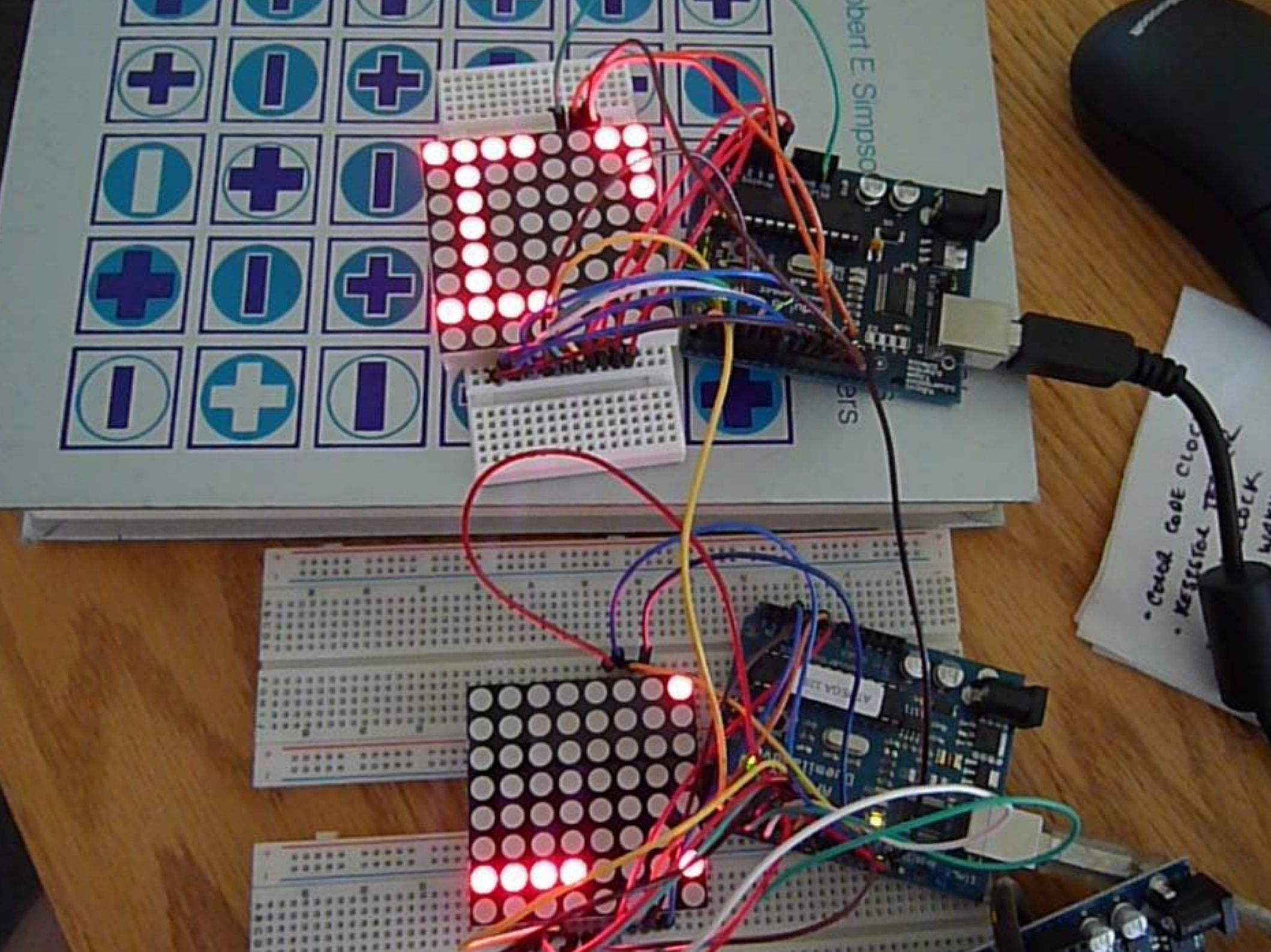


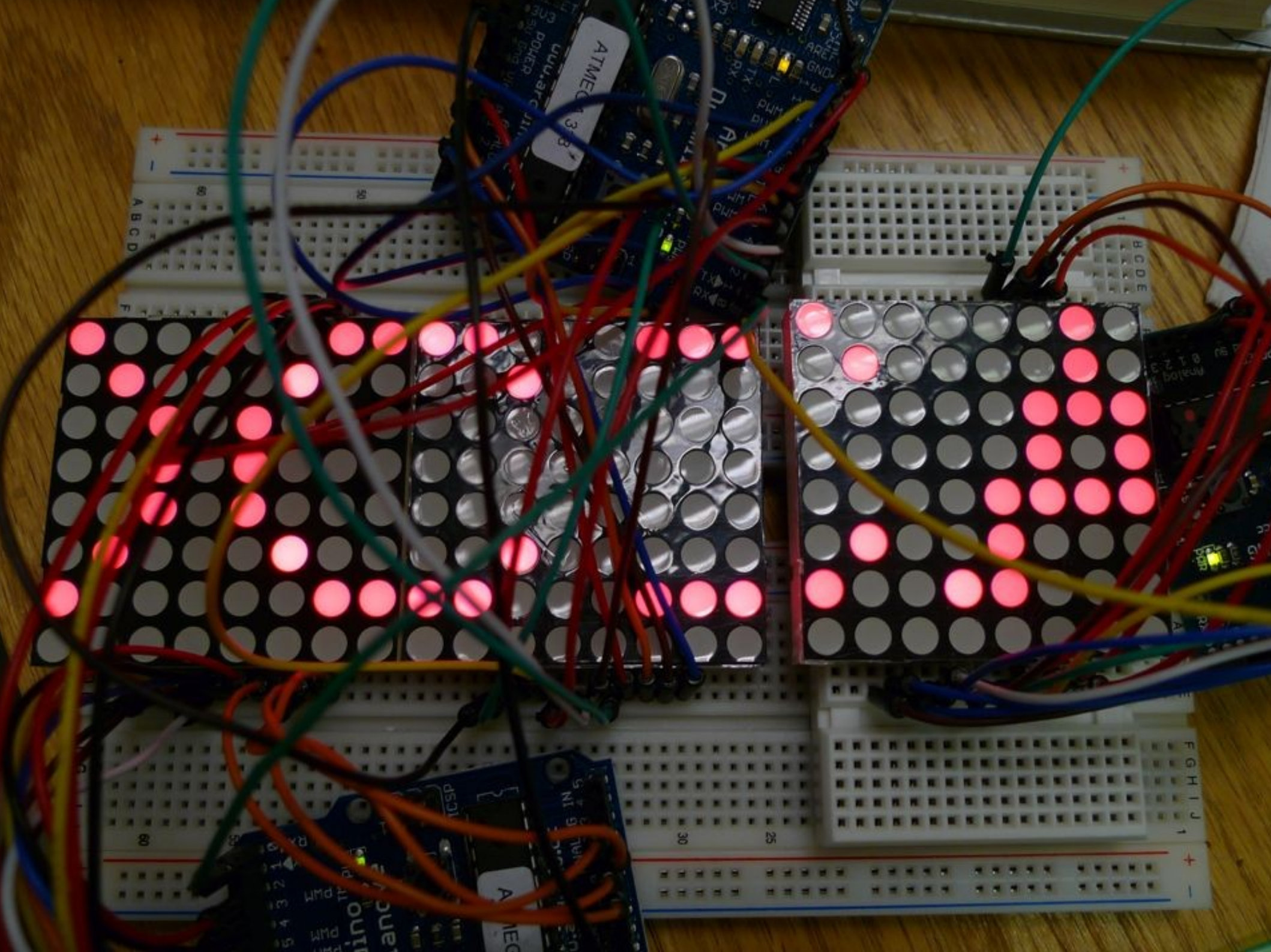
First node

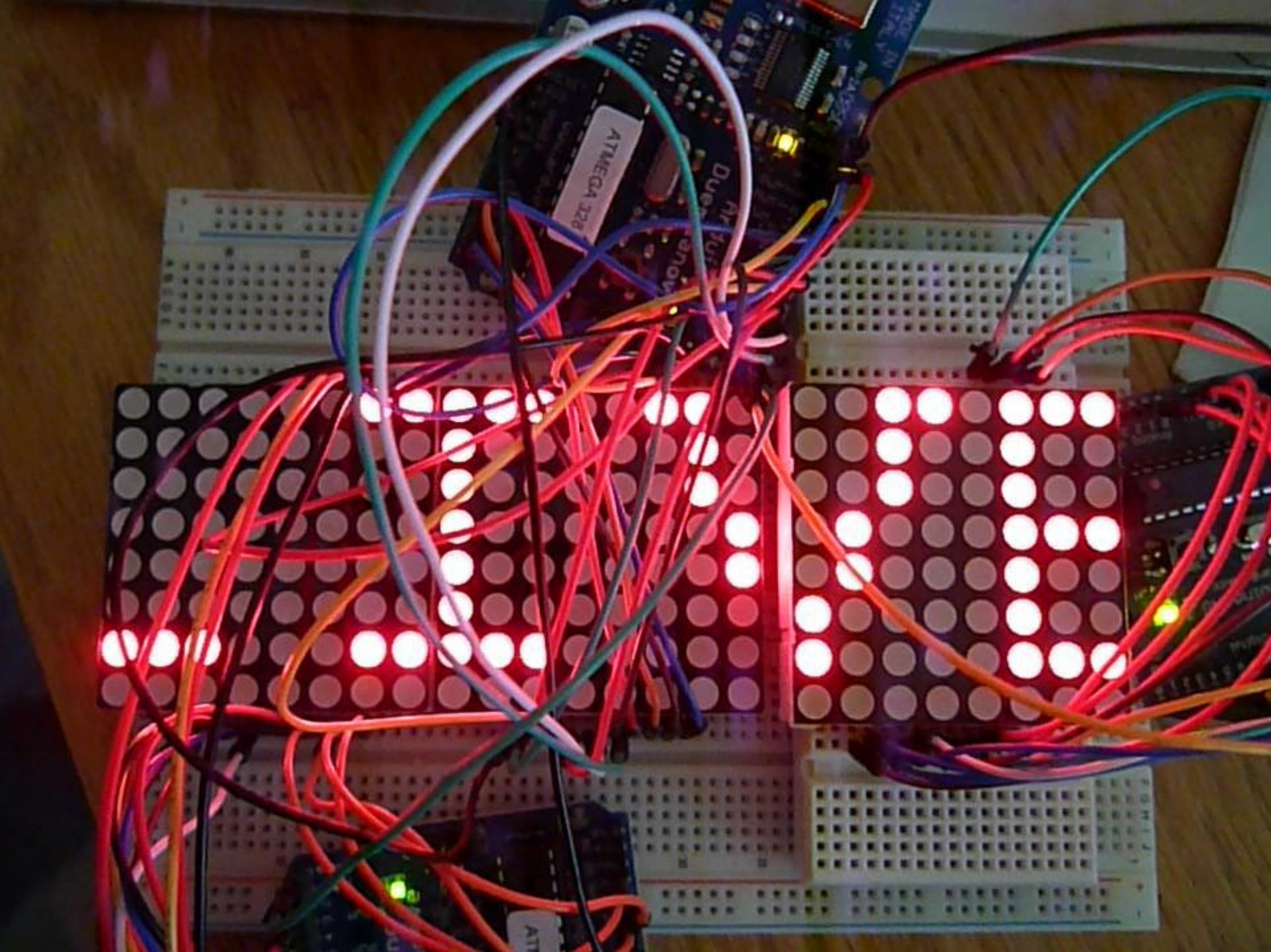

source
buffer
buffer
buffer
...
buffer
serial.tx
column
column
column
...
column

Other nodes


serial.rx
buffer
buffer
buffer
...
buffer
serial.tx
column
column
column
...
column



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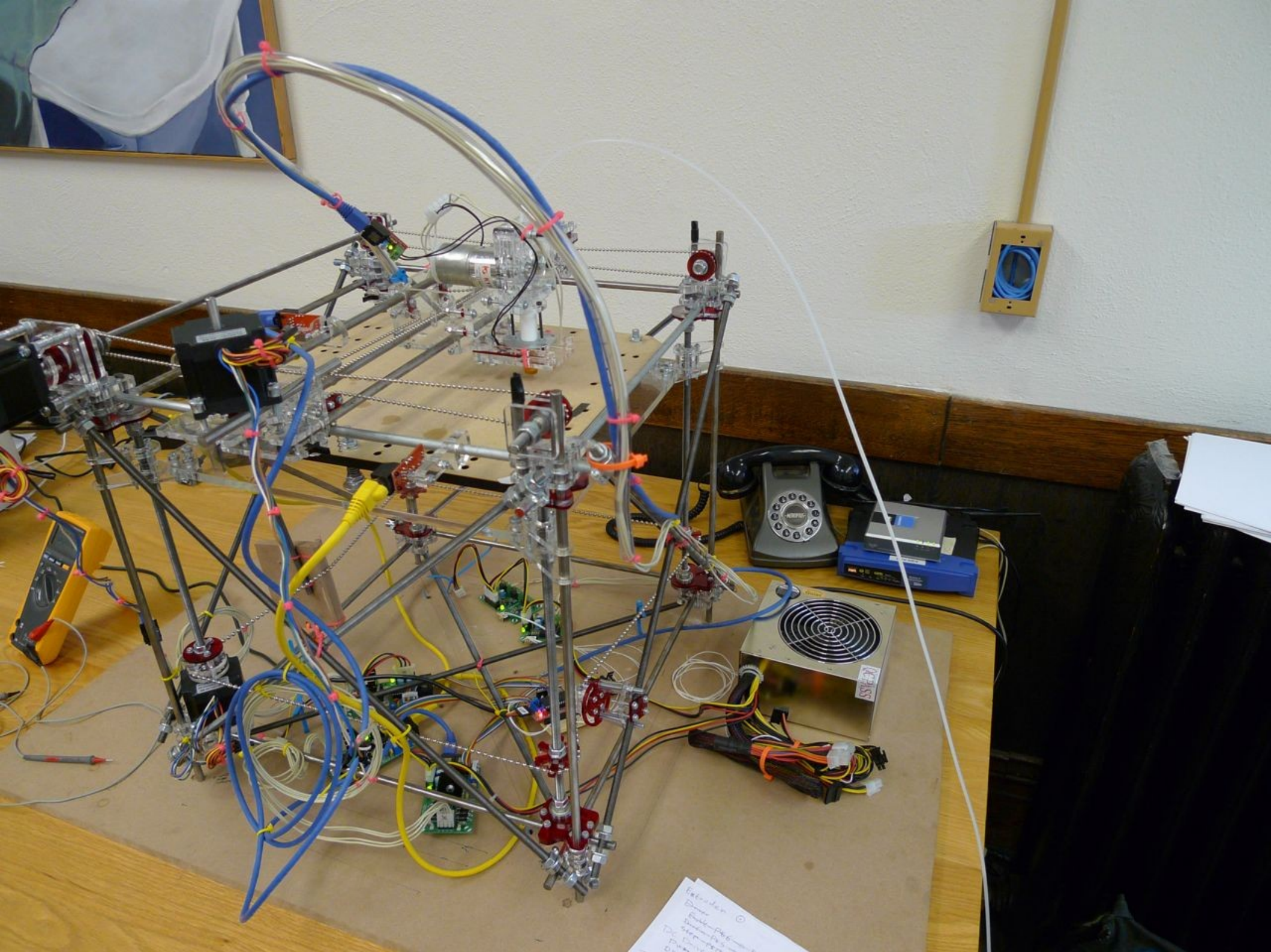

The RepRap

- 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?