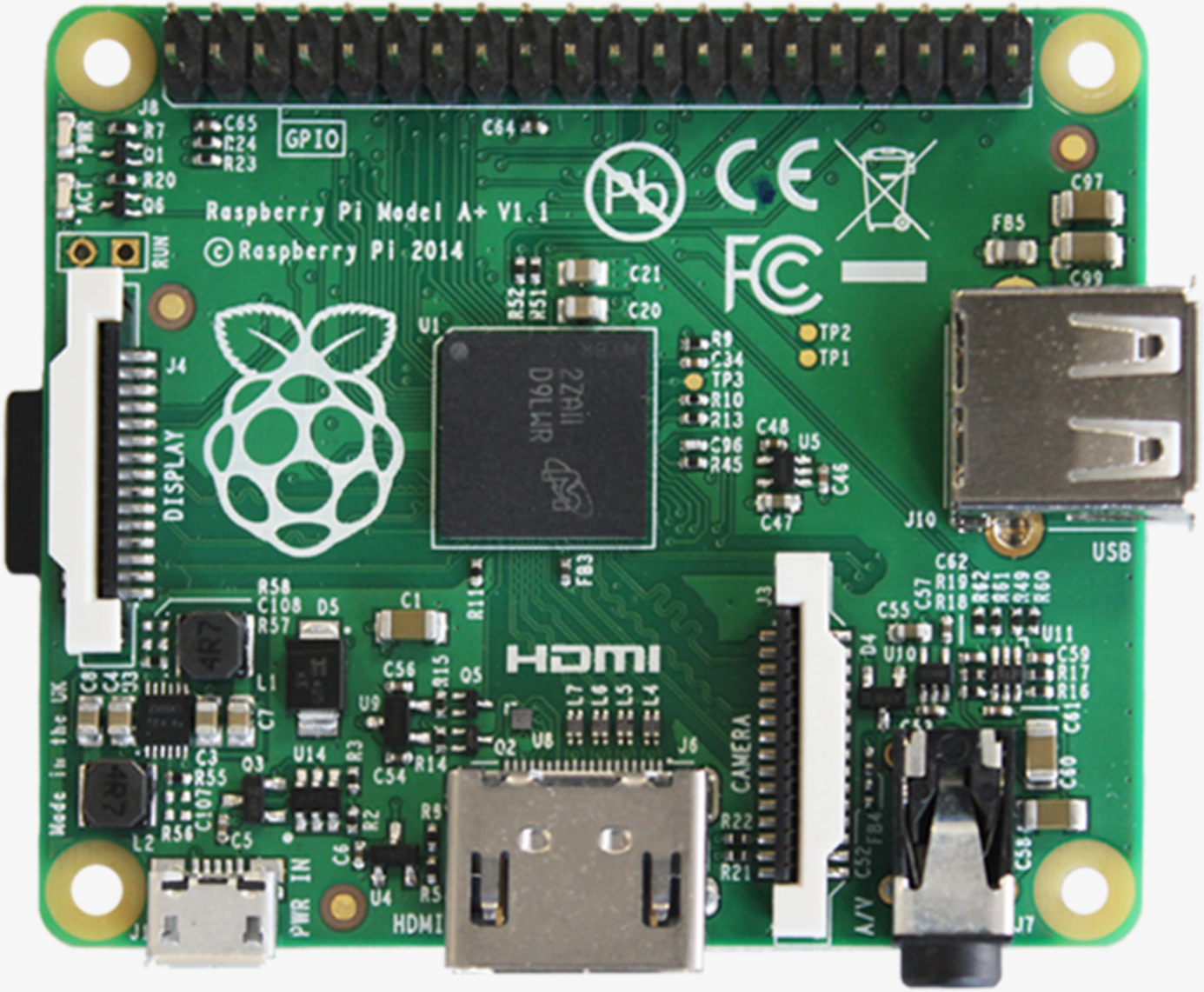

PRODUCTION
CS107e
Computer Systems
from the Ground Up
SCENE
Wrap Party
TAKE
11
DIRECTOR
Chris, Phil, Liana, Anna, Matt, and Maria
CAMERA
DATE
Autumn 2021

http://quinndunki.com/blondihacks/?p=1347

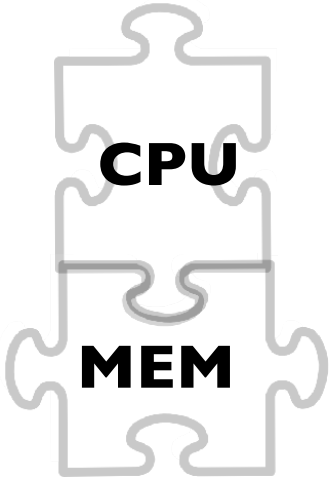
Goal 1

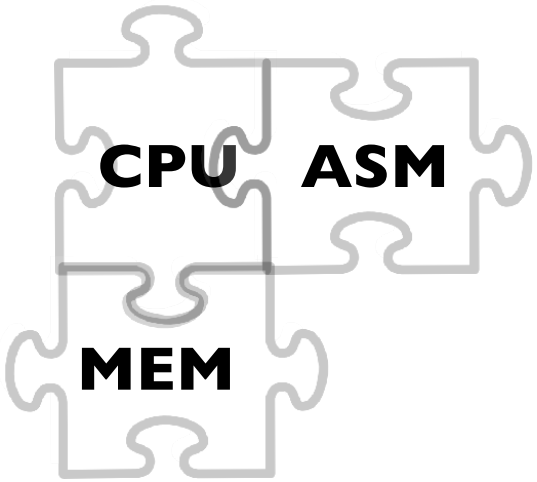
Understand How Computers Work

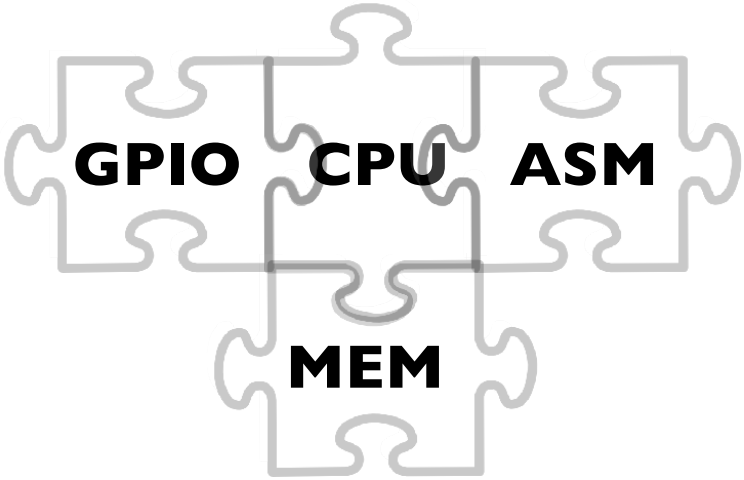
Computer Systems from the Ground Up



Bare Metal on the Raspberry Pi


CPU
MEM


CPU
ASM
MEM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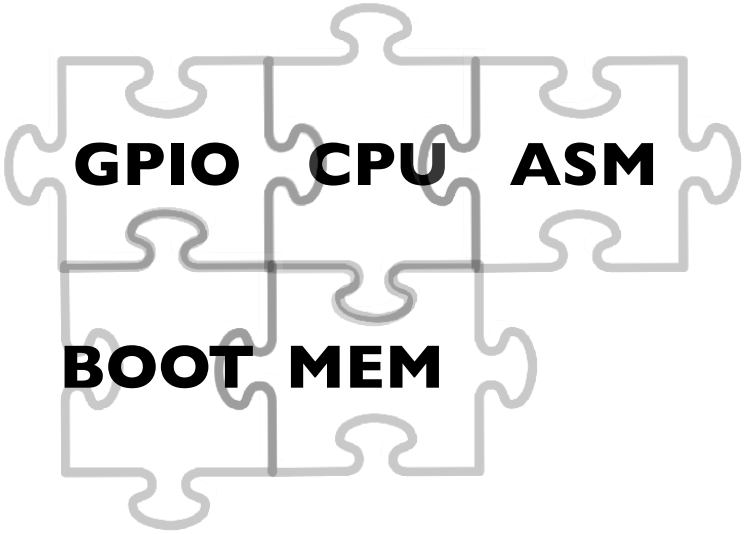
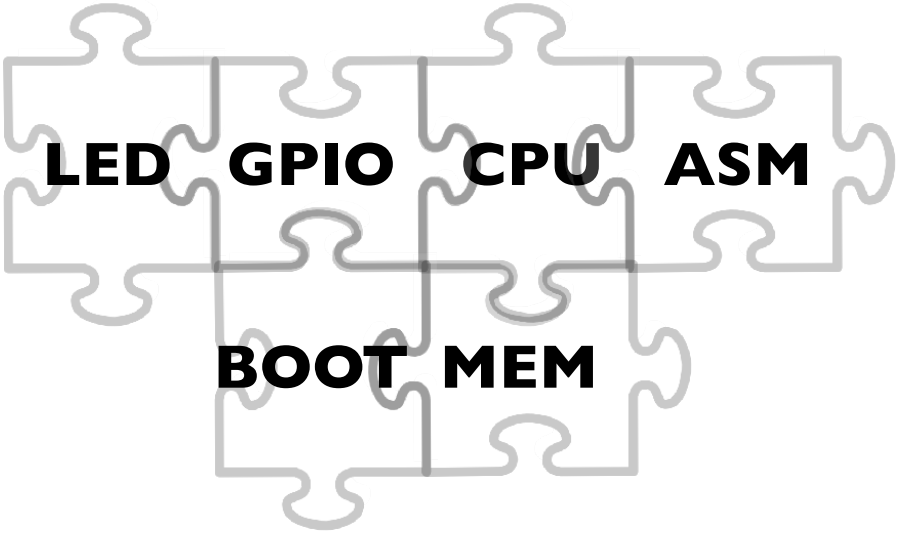
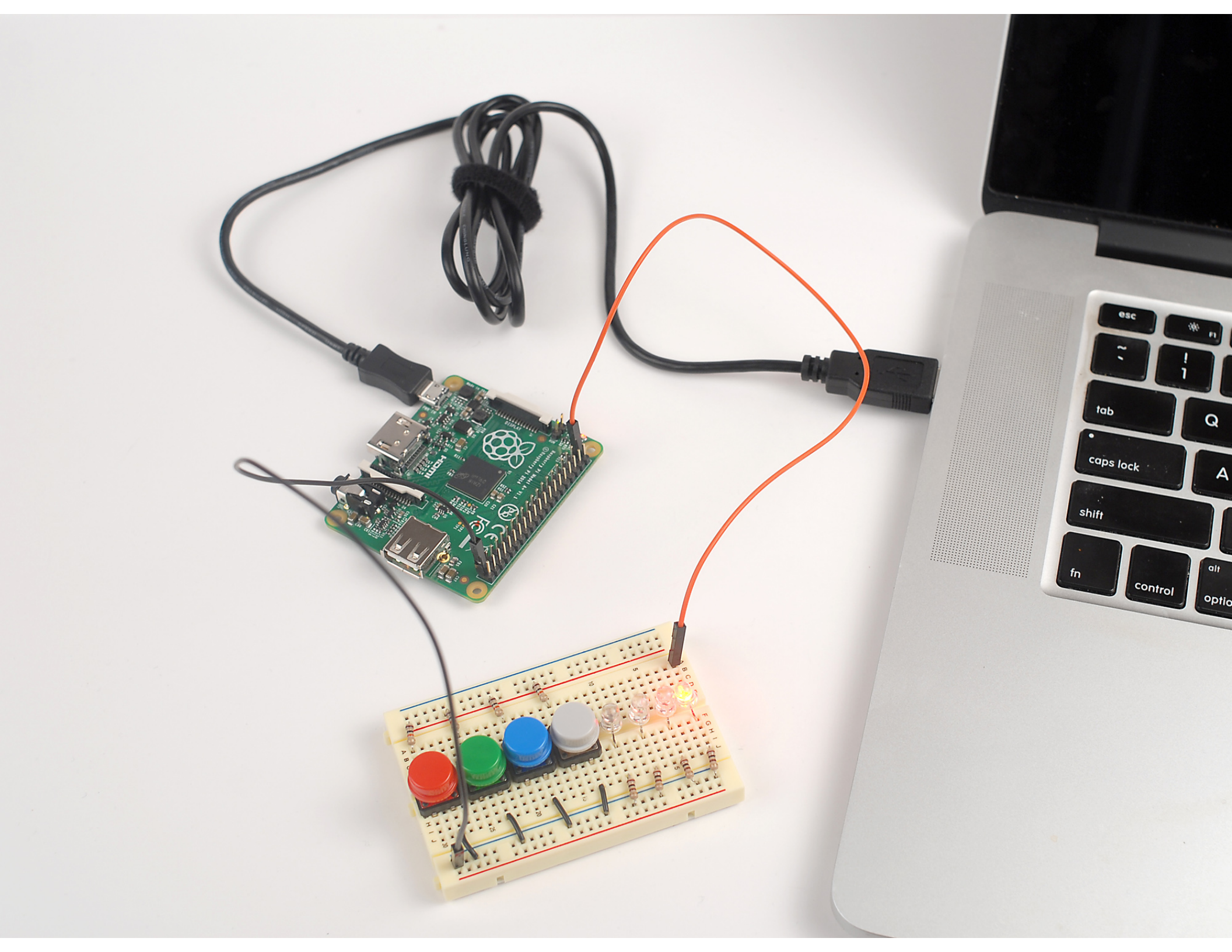
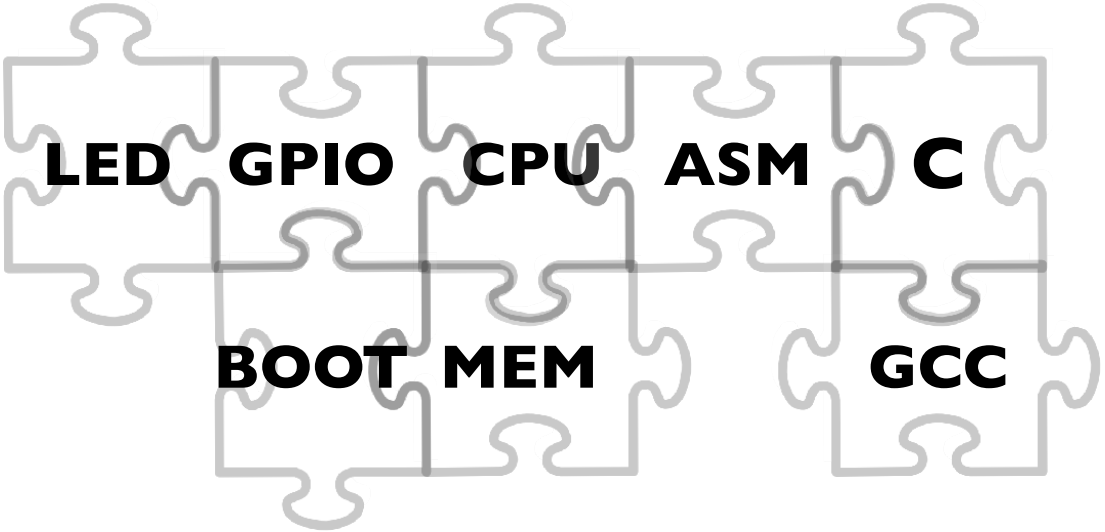
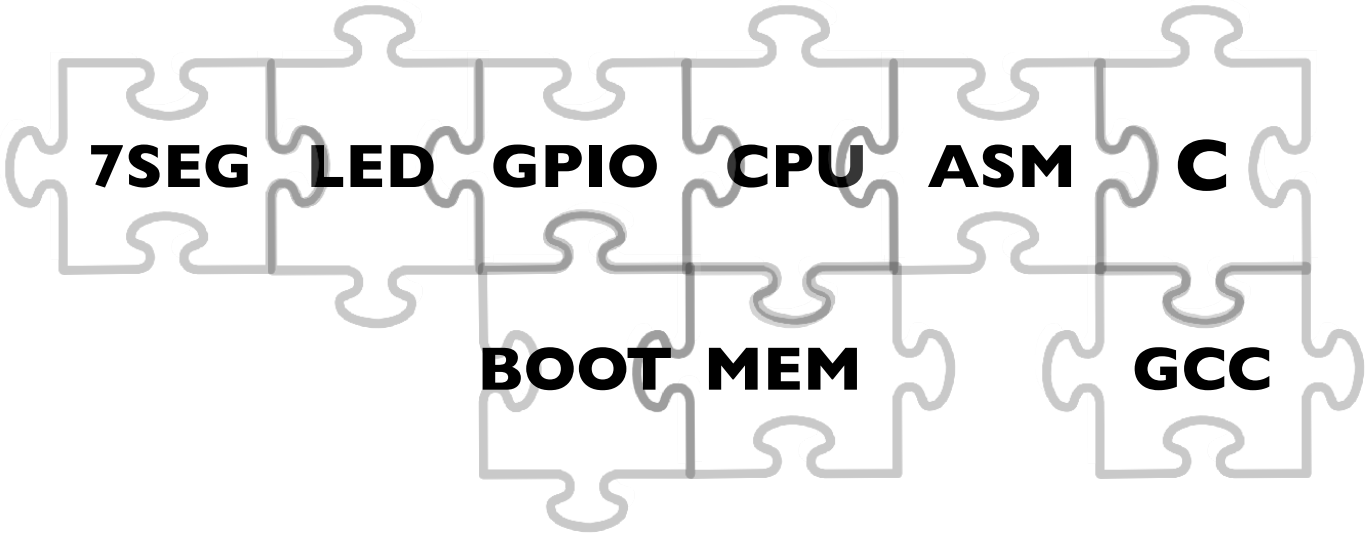
CPU
ASM
MEM


GPIO
CPU
ASM
BOOT
MEM


LED
GPIO
CPU
ASM
BOOT
MEM


esc
tab
caps lock
shift
fn
control


LED
GPIO
CPU
ASM
C
BOOT
MEM
GCC


7SEG
LED
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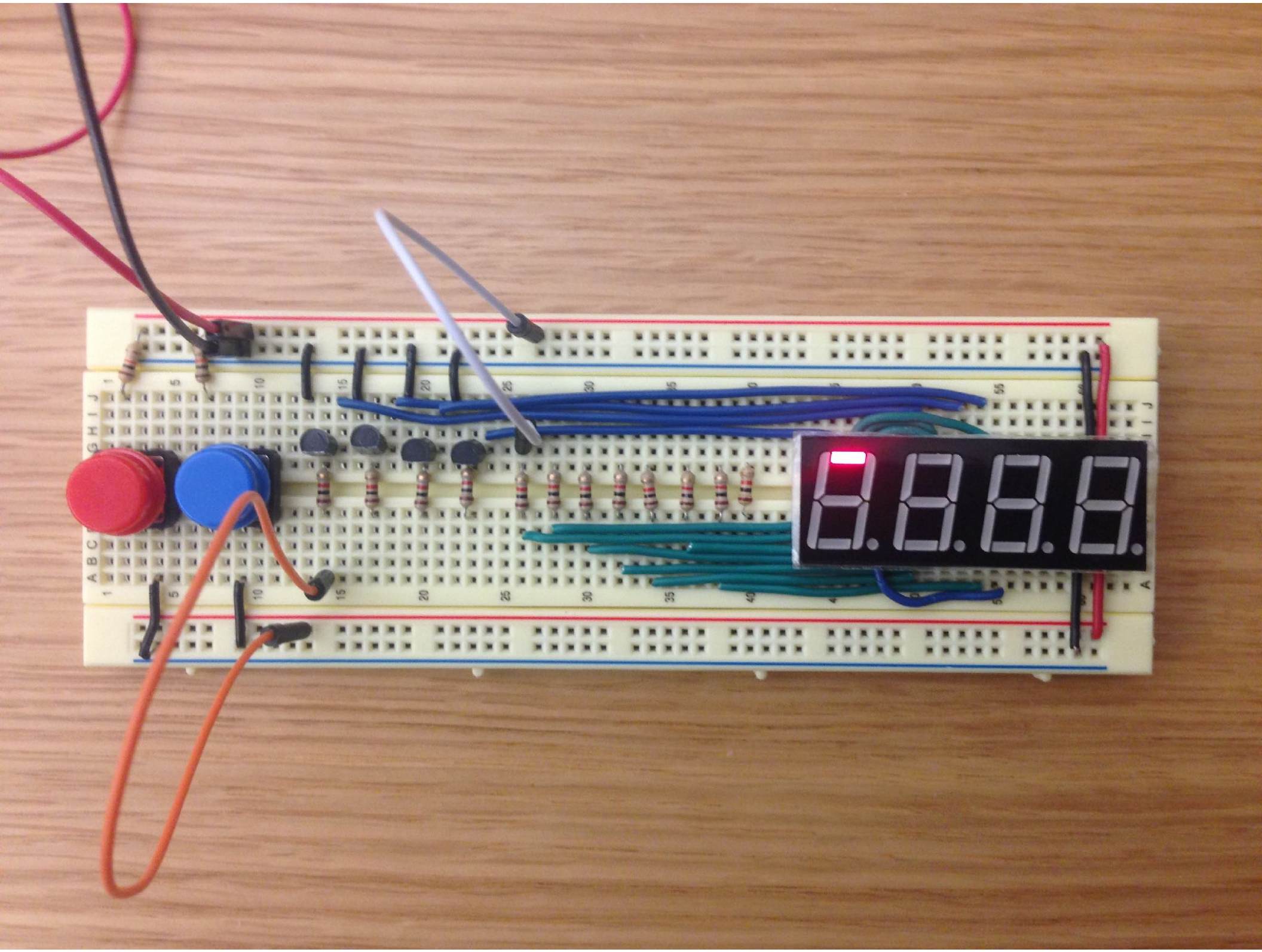
CPU
ASM
C
BOOT
MEM
GCC



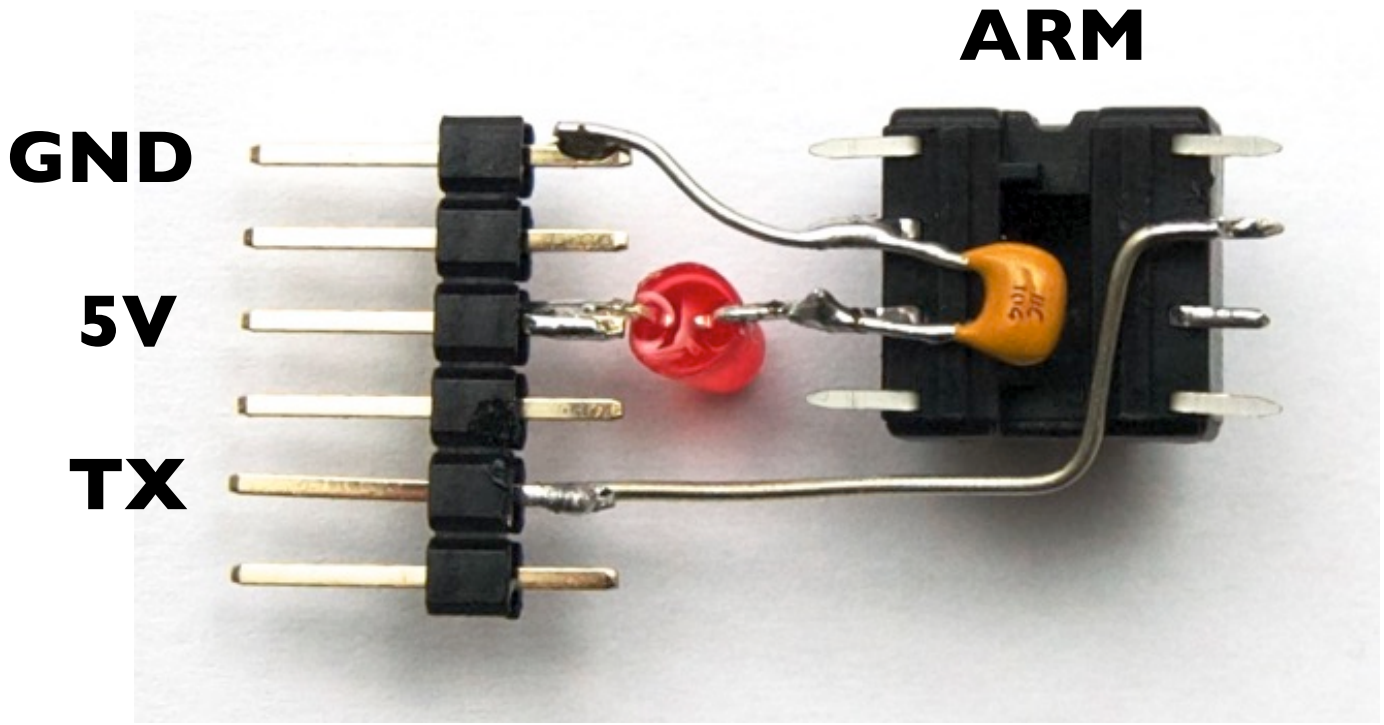
Simple and Clear

Functionality

is

Beautiful

Jean-Claude Wippler



www.jeelabs.org

```
/* match: search for regexp anywhere in text */
int match(char *regexp, char *text) {
   if (regexp[0] == '^')
     return matchhere(regexp+1, text);
   do {    /* must look even if string is empty */
      if (matchhere(regexp, text))
         return 1;
   } while (*text++ != '\0');
   return 0;
}
/* matchhere: search for regexp at beginning of text */
int matchhere(char *regexp, char *text) {
   if (regexp[0] == '\0')
      return 1;
   if (regexp[1] == '*')
      return matchstar(regexp[0], regexp+2, text);
   if (regexp[0] == '$' && regexp[1] == '\0')
      return *text == '\0';
   if (*text!='\0' && (regexp[0]=='.' || regexp[0]==*text))
      return matchhere(regexp+1, text+1);
   return 0;
}
/* matchstar: search for c*regexp at beginning of text*/
int matchstar(int c, char *regexp, char *text) {
   do { /* a * matches zero or more instances */
      if (matchhere(regexp, text))
         return 1;
   } while (*text != '\0' && (*text++ == c || c == '.'));
   return 0;
}
```

Ken Thompson

Regular Expression

ch

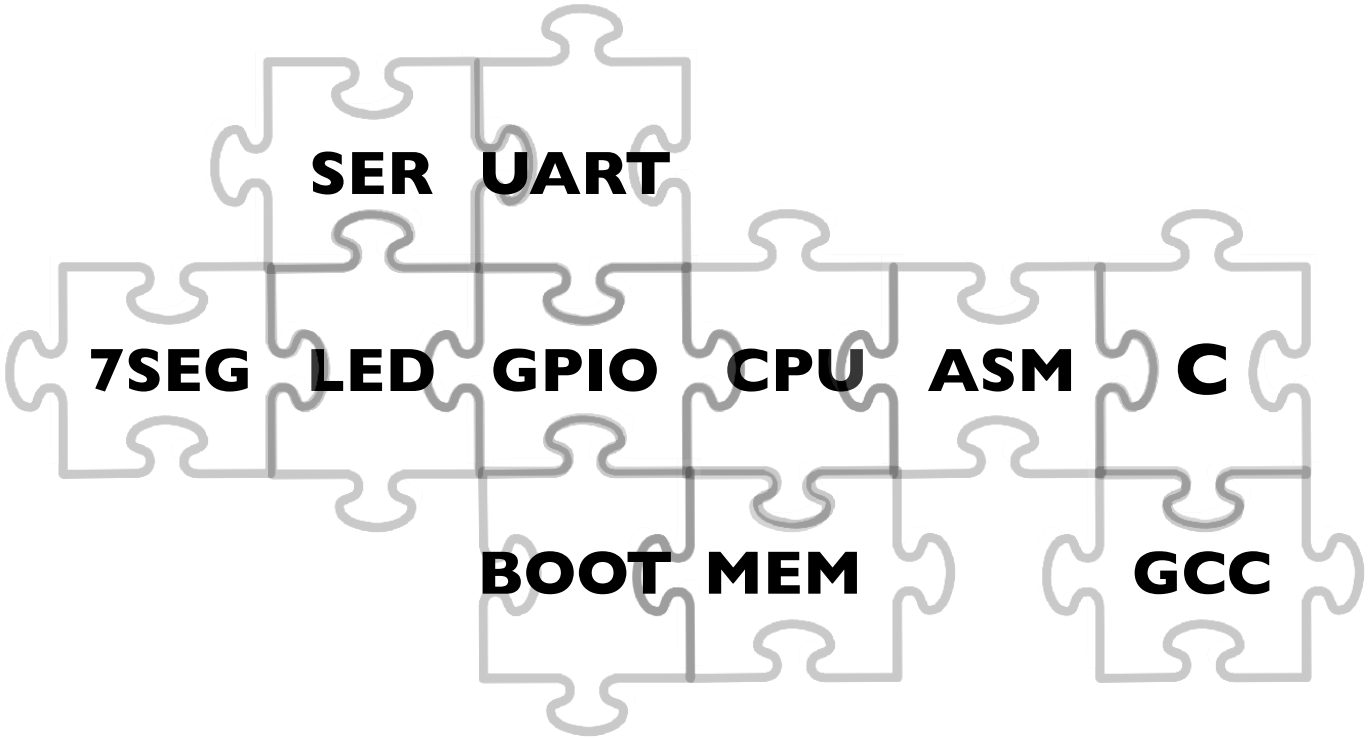
.

*****

^

$

Read *Beautiful Code*


SER
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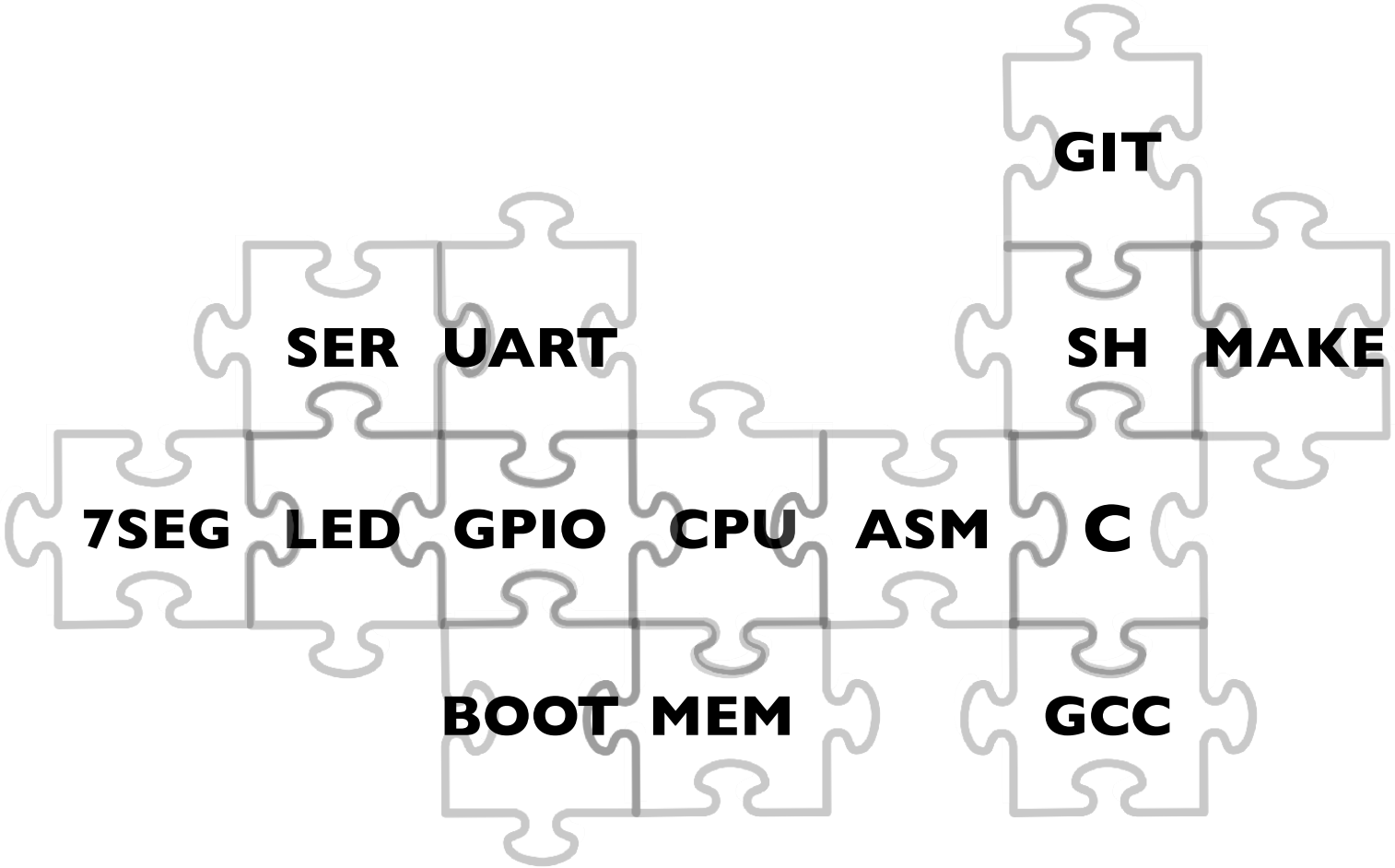
ASM
C
BOOT
MEM
GCC


GIT
SER
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7SEG
LED
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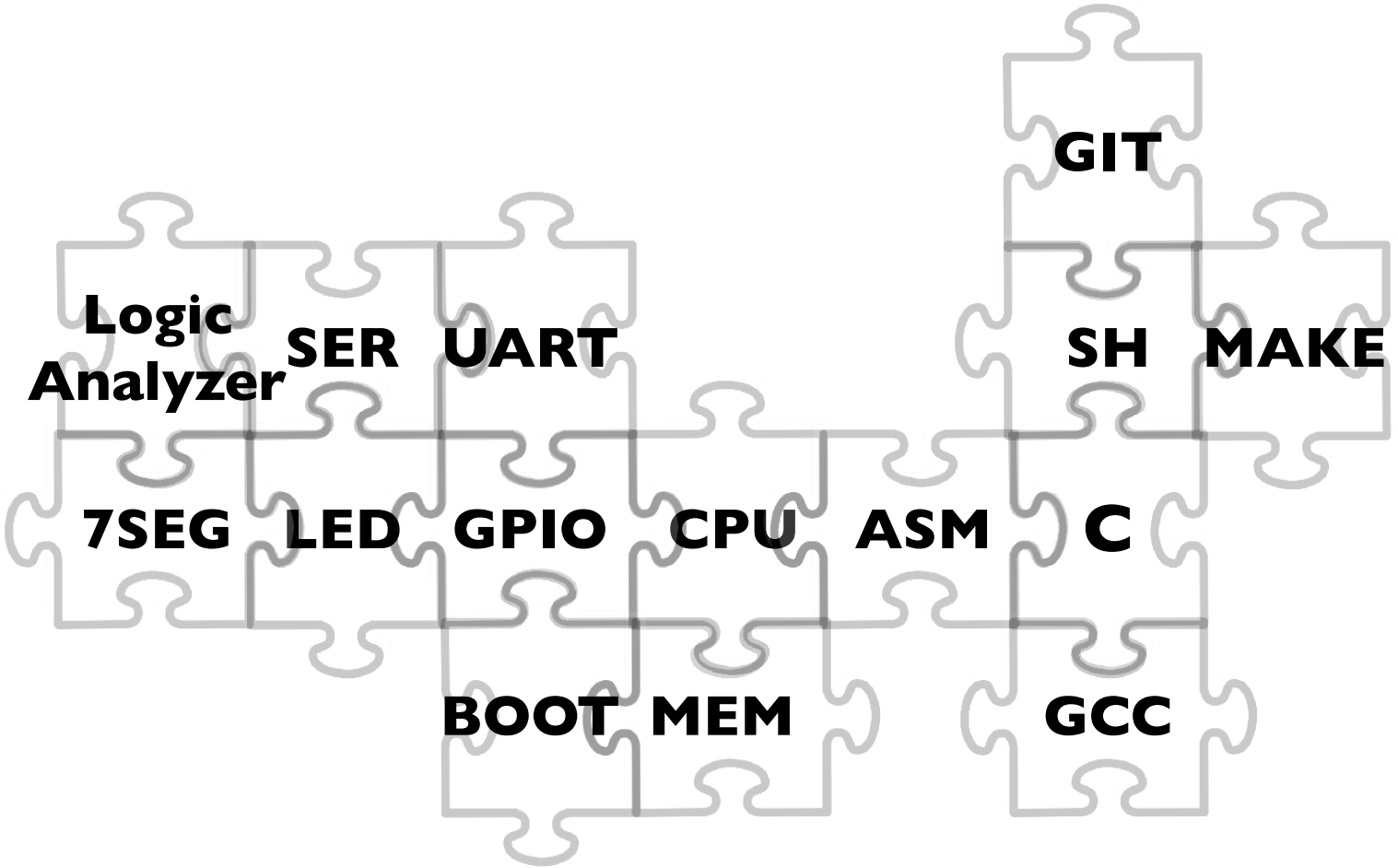
BOOT
MEM
GCC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Logic Analyzer
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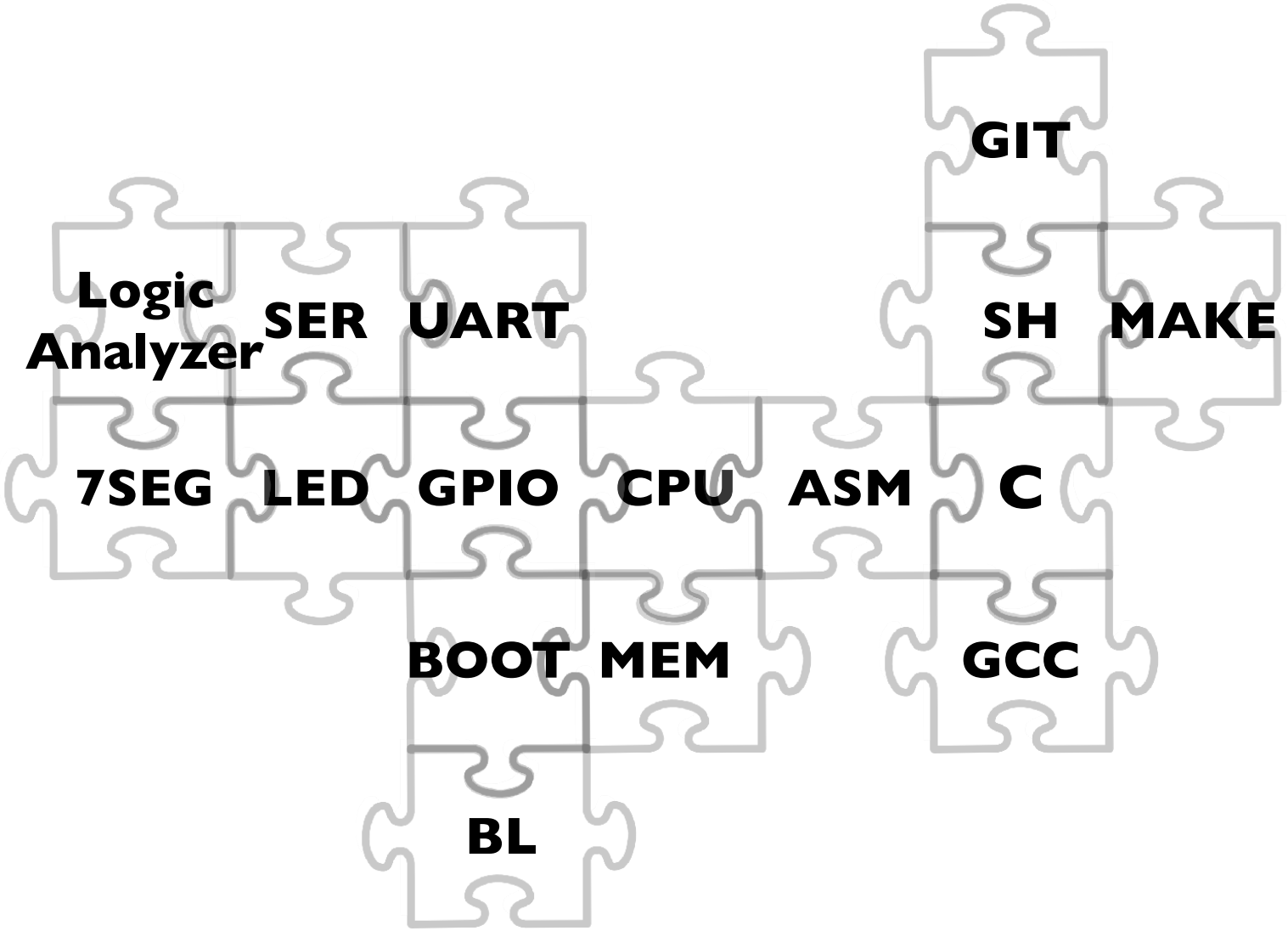
MEM
GCC


GIT
Logic Analyzer
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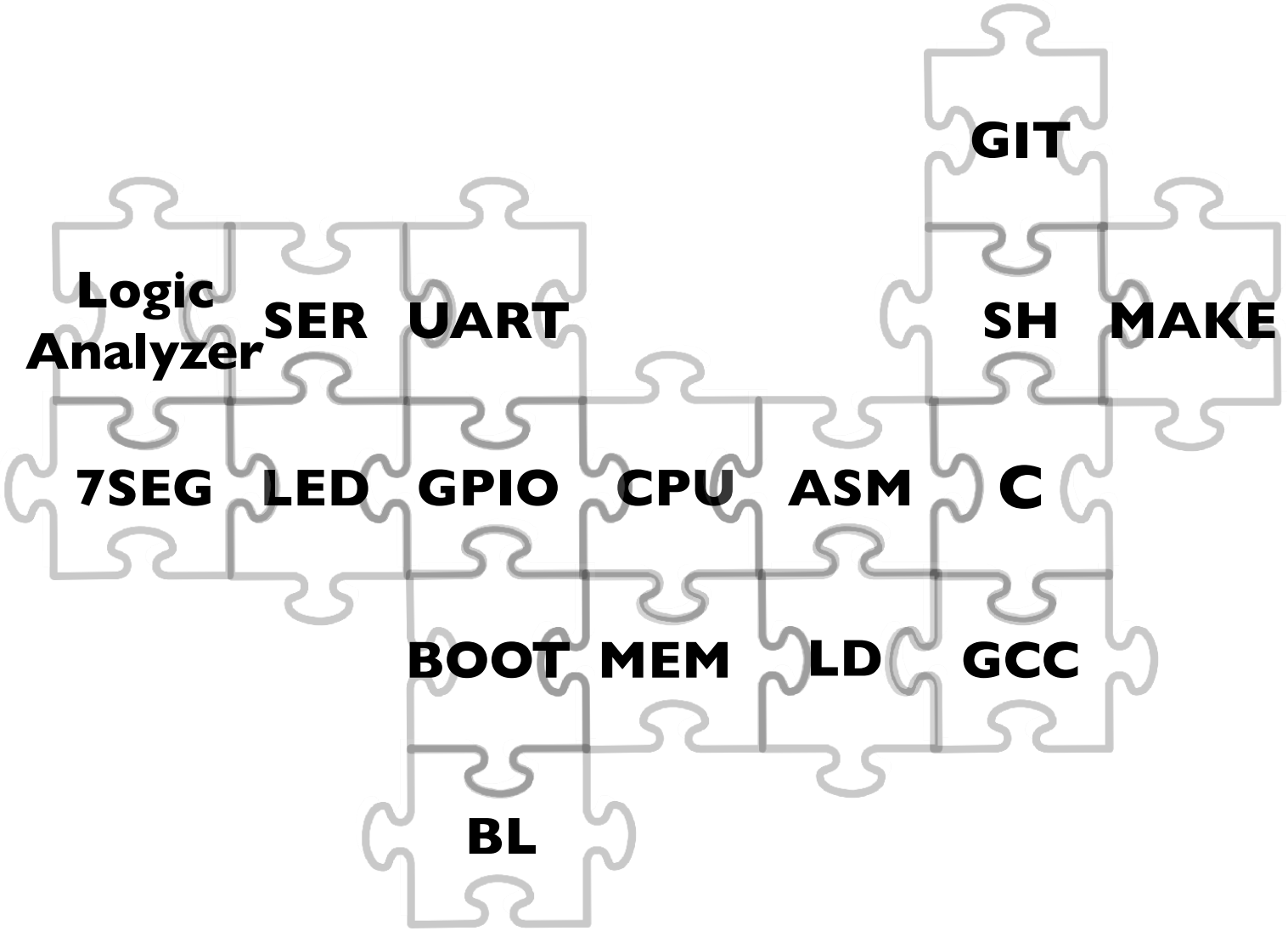
GIT
Logic Analyzer
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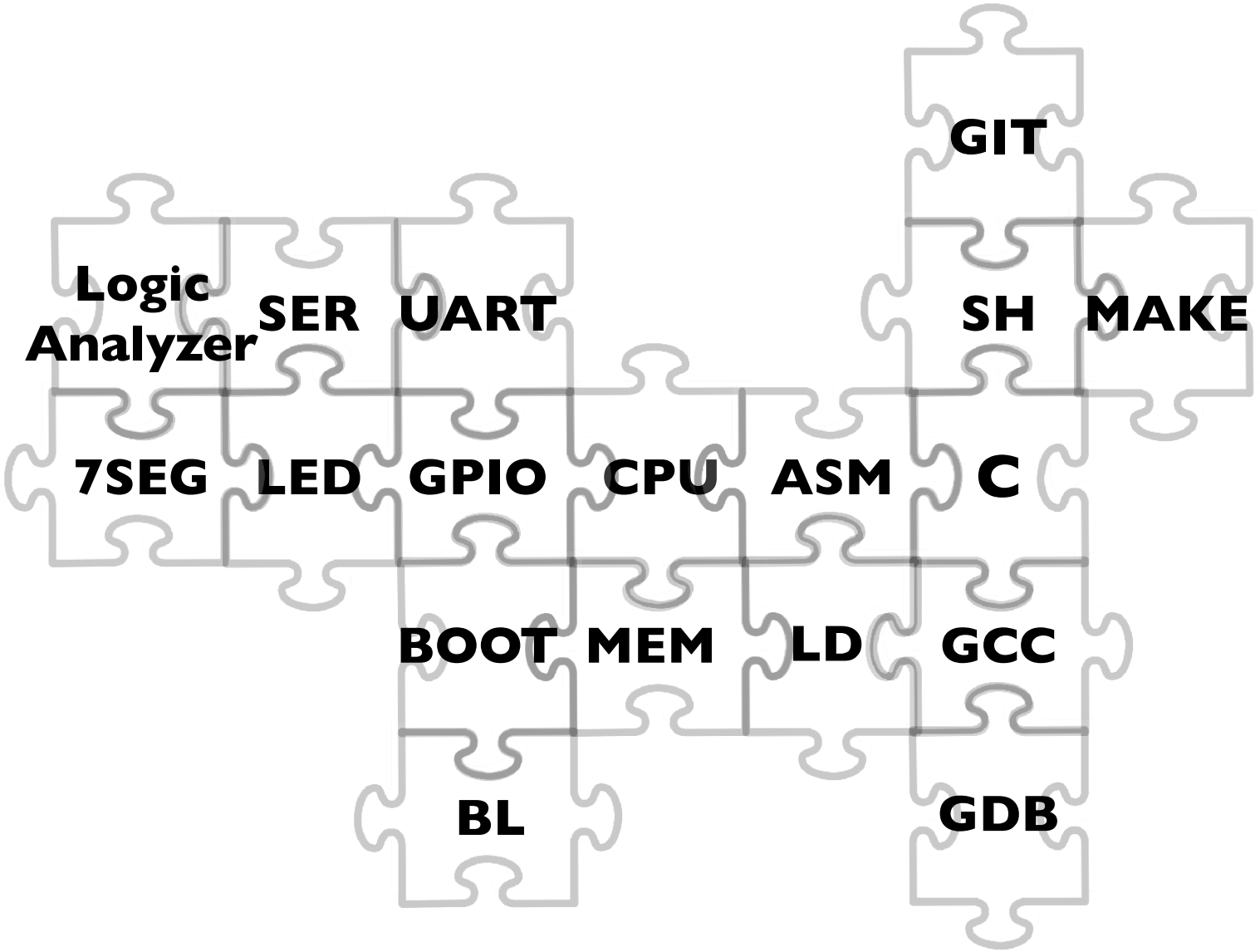
GIT
Logic Analyzer
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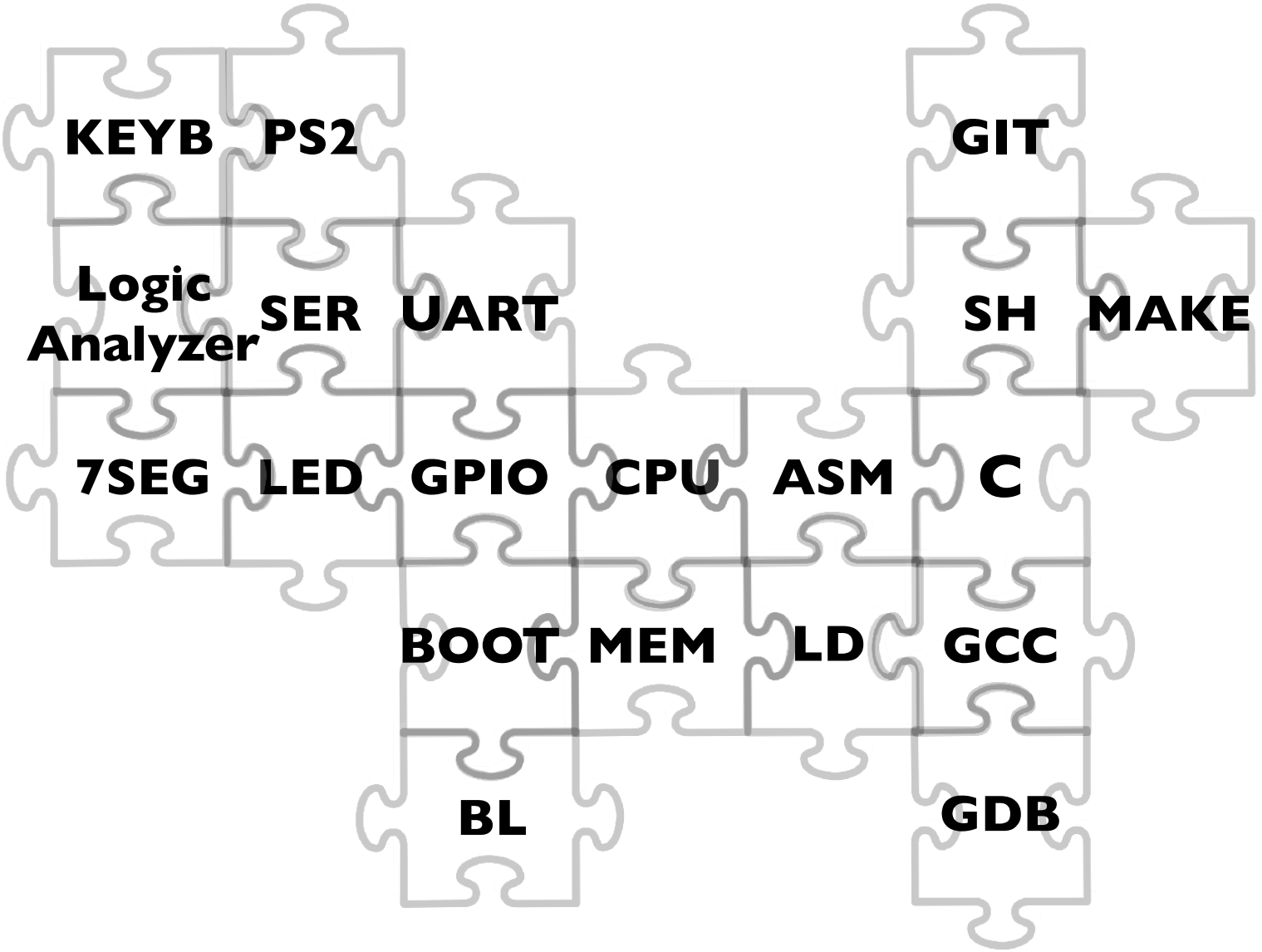
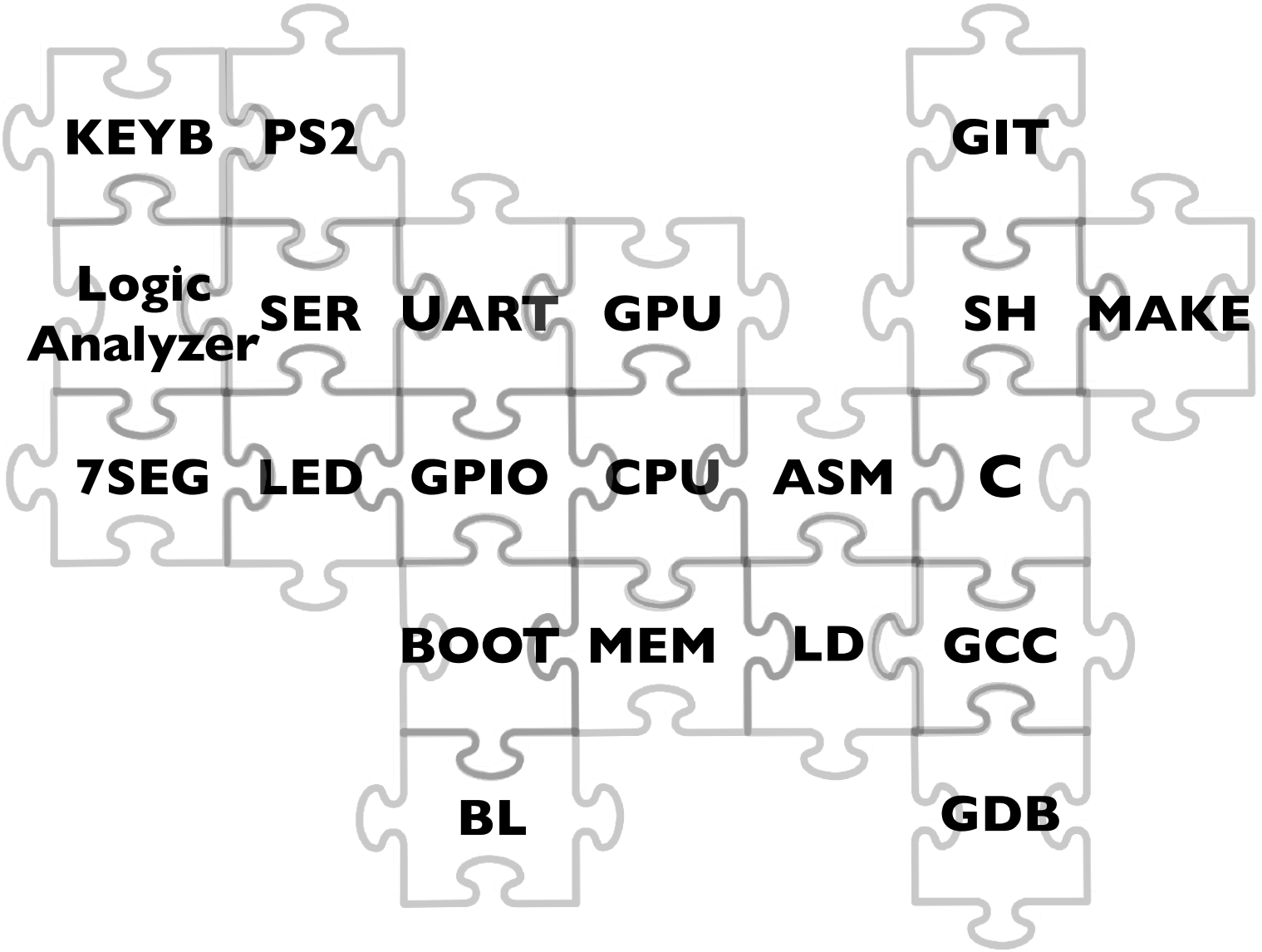
GDB


KEYB
PS2
GIT
Logic Analyzer
SER
UART
SH
MAKE
7SEG
LED
GPIO
CPU
ASM
C
BOOT
MEM
LD
GCC
BL
GDB


KEYB
PS2
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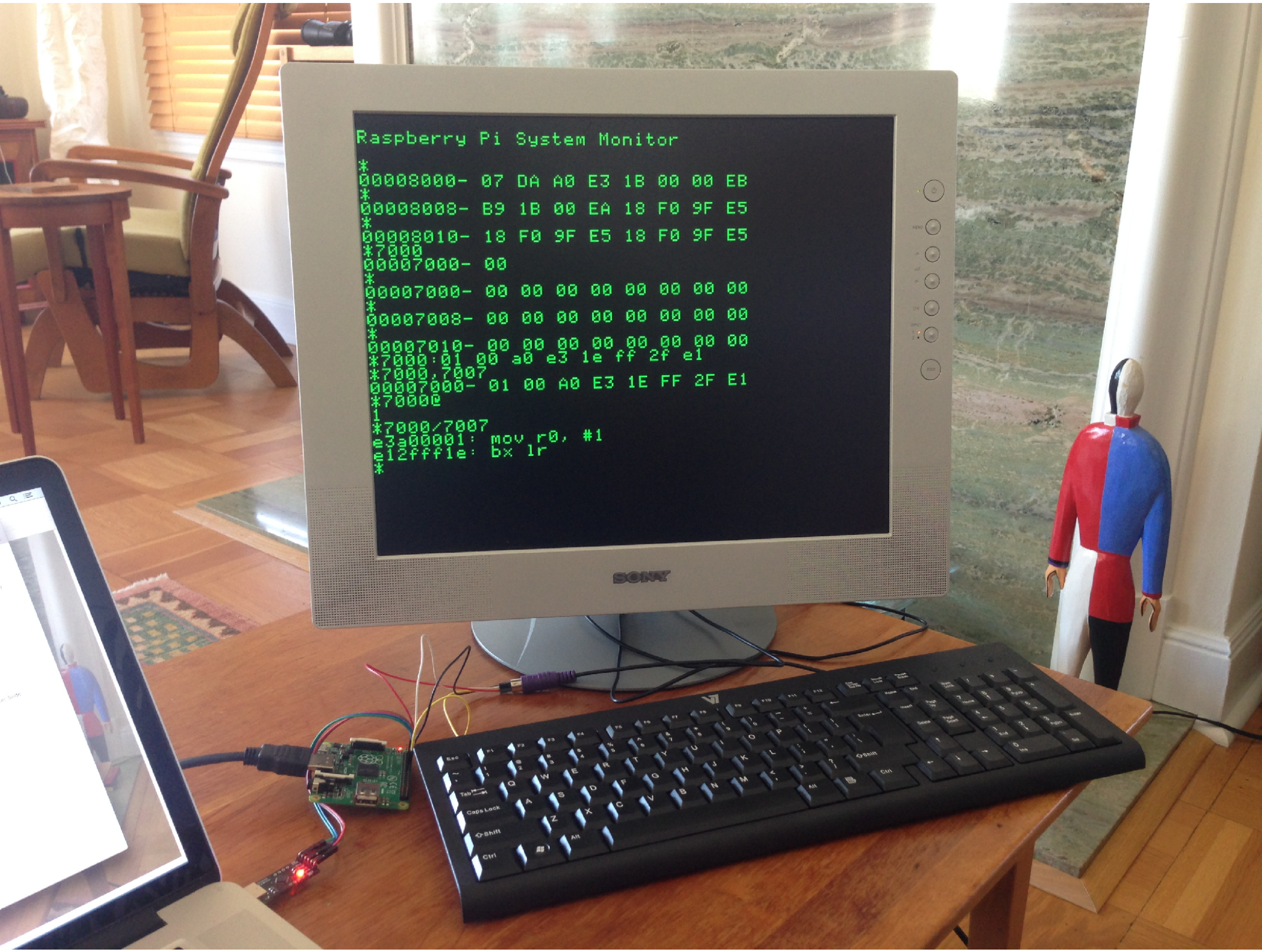
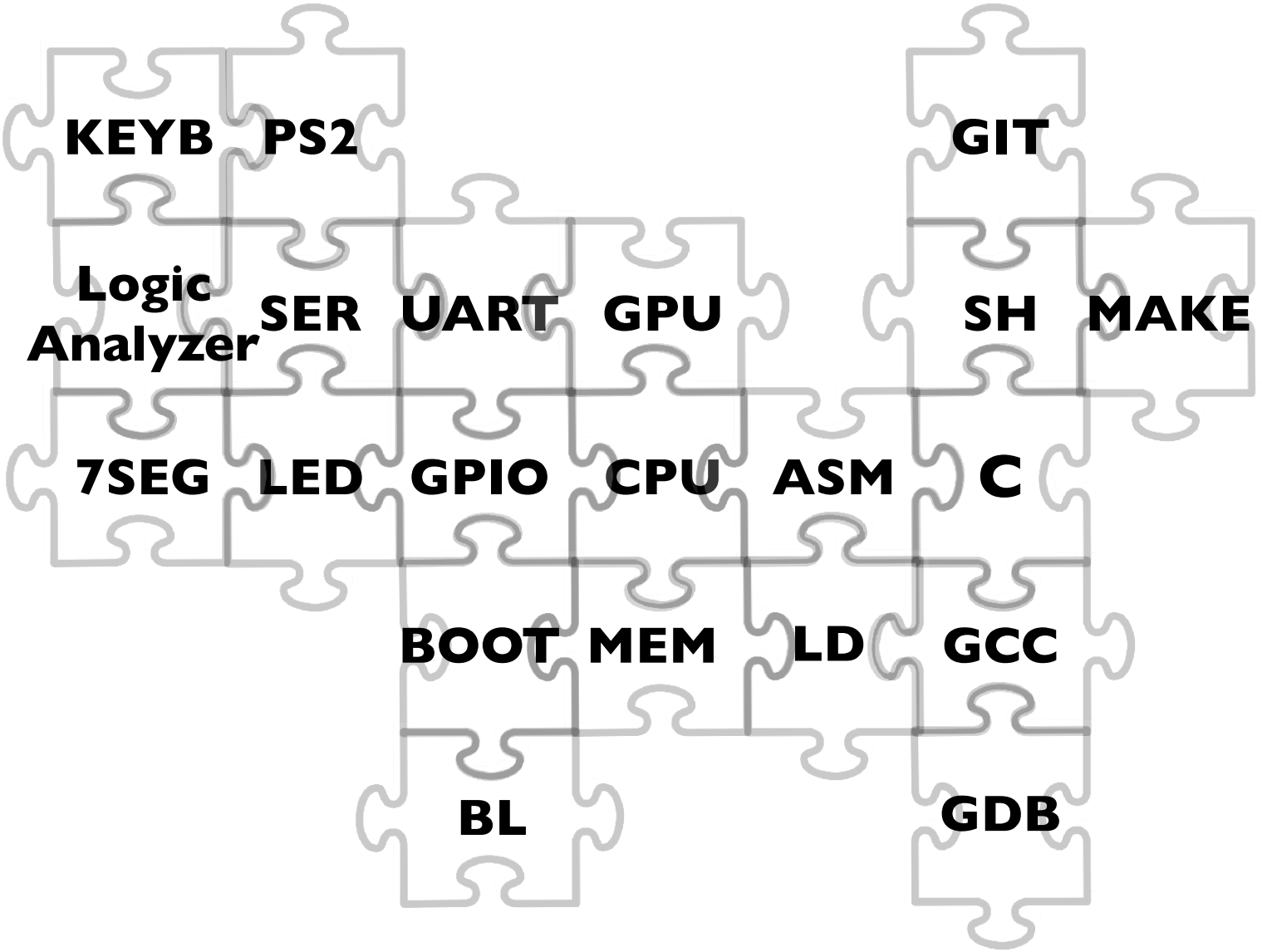
GCC
BL
GDB


Raspberry Pi System Monitor
*
00008000- 07 DA A0 E3 1B 00 00 EB
*
00008008- B9 1B 00 EA 18 F0 9F E5
*
00008010- 18 F0 9F E5 18 F0 9F E5
*7000
00007000- 00
*
00007000- 00 00 00 00 00 00 00 00
*
00007008- 00 00 00 00 00 00 00 00
*
00007010- 00 00 00 00 00 00 00 00
*7000:01 00 a0 e3 1e ff 2f e1
*7000,7007
00007000- 01 00 A0 E3 1E FF 2F E1
*7000@
1
*7000/7007
e3a00001: mov r0, #1
e12fff1e: bx lr
*
SONY

```
****************************
*                          *
*        APPLE II          *
*     SYSTEM MONITOR       *
*                          *
*    COPYRIGHT 1977 BY     *
*   APPLE COMPUTER, INC.   *
*                          *
*   ALL RIGHTS RESERVED    *
*                          *
*       S. WOZNIAK         *
*        A. BAUM           *
*                          *
****************************
        TITLE             "APPLE II SYSTEM MONITOR"
LOC0     EPZ   $00
LOC1     EPZ   $01
WNDLFT   EPZ   $20
WNDWDTH  EPZ   $21
WNDTOP   EPZ   $22
WNDBTM   EPZ   $23
CH       EPZ   $24
CV       EPZ   $25
GBASL    EPZ   $26
GBASH    EPZ   $27
BASL     EPZ   $28
BASH     EPZ   $29
BAS2L    EPZ   $2A
BAS2H    EPZ   $2B
H2       EPZ   $2C
LMNEM    EPZ   $2C
RTNL     EPZ   $2C
V2       EPZ   $2D
RMNEM    EPZ   $2D
RTNH     EPZ   $2D
MASK     EPZ   $2E
```


KEYB
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Logic Analyzer
SER
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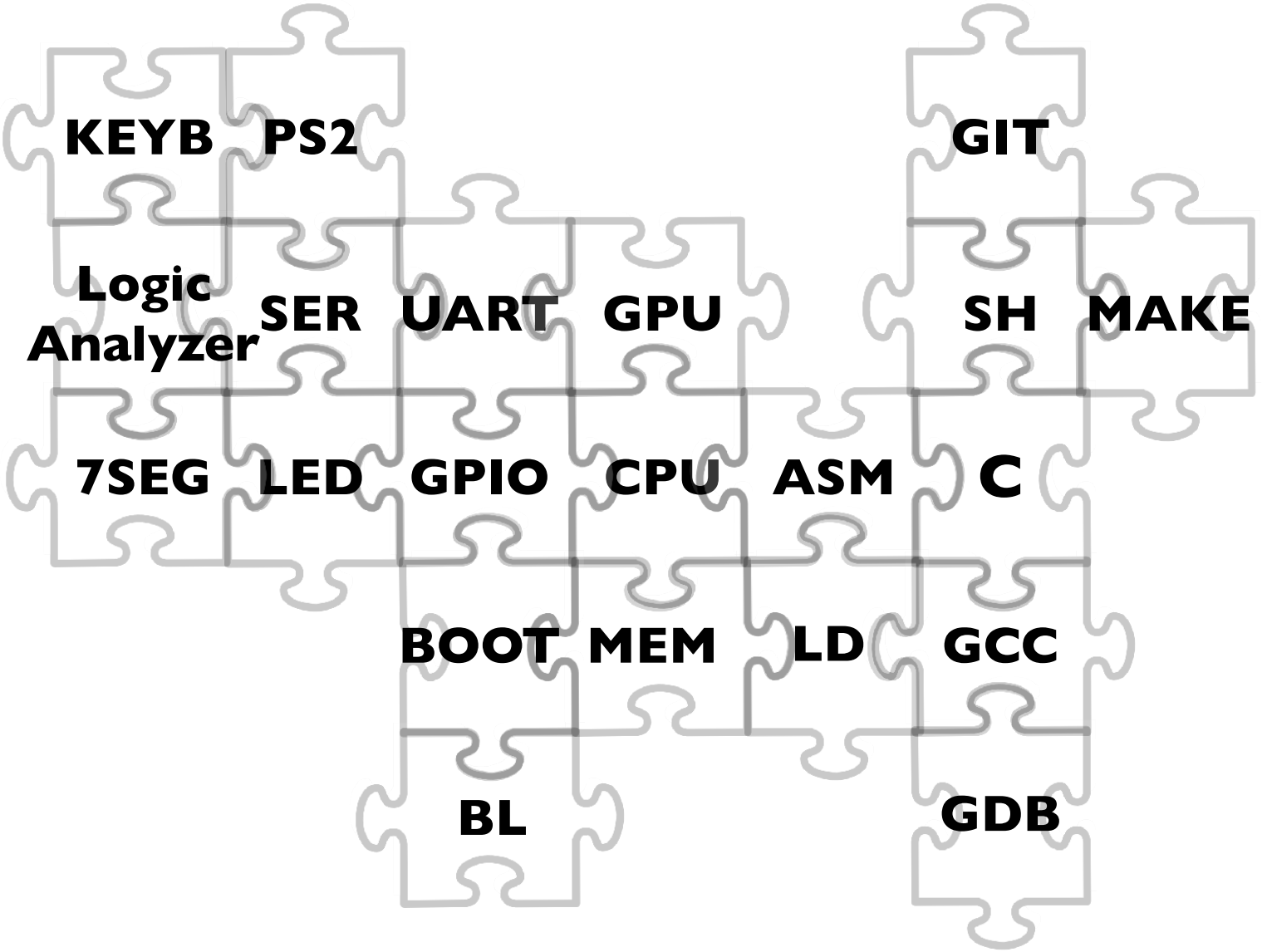
SH
MAKE
7SEG
LED
GPIO
CPU
ASM
C
BOOT
MEM
LD
GCC
BL
GDB

But It Keeps Growing!


KEYB
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Logic Analyzer
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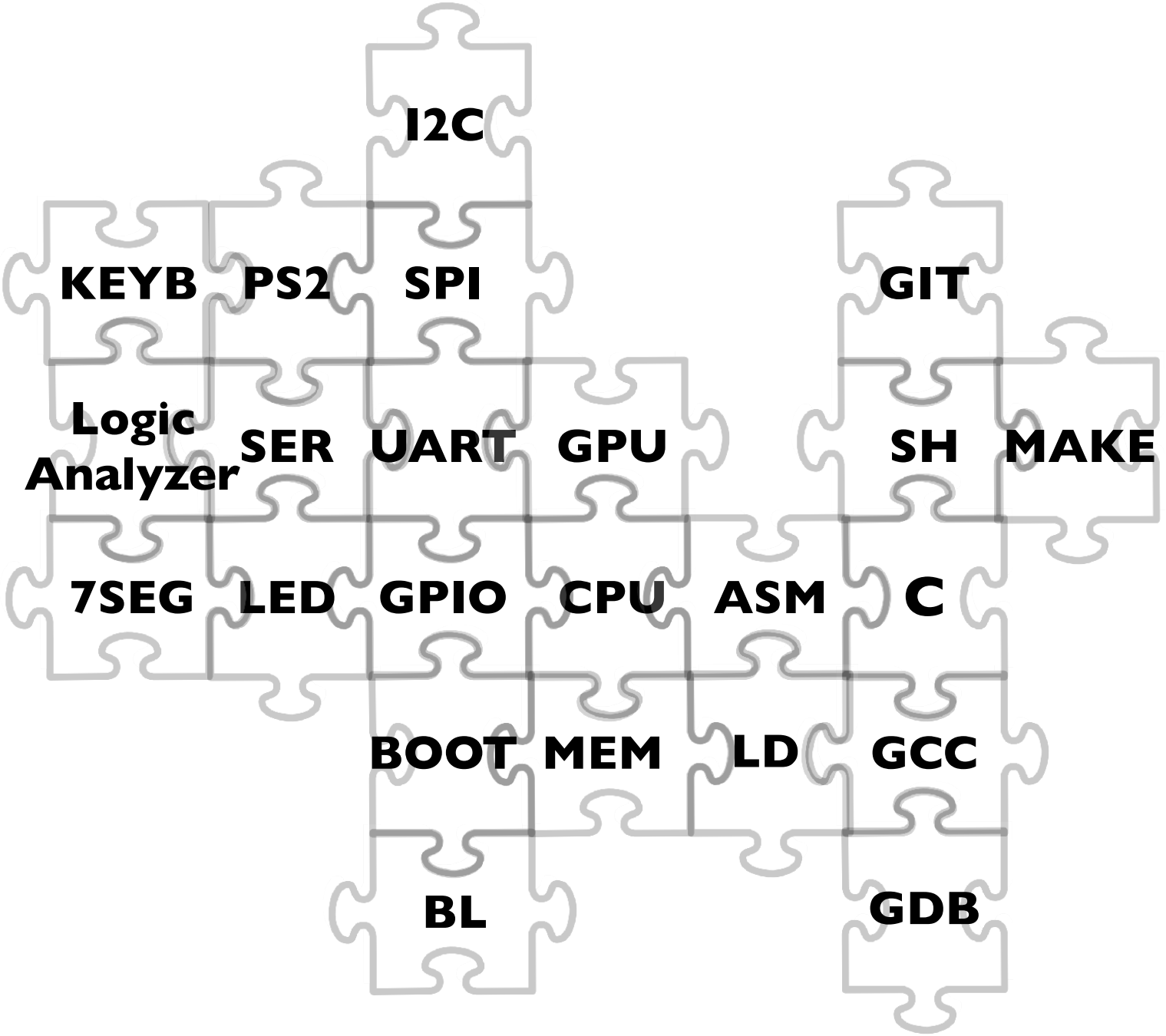
GDB


I2C
KEYB
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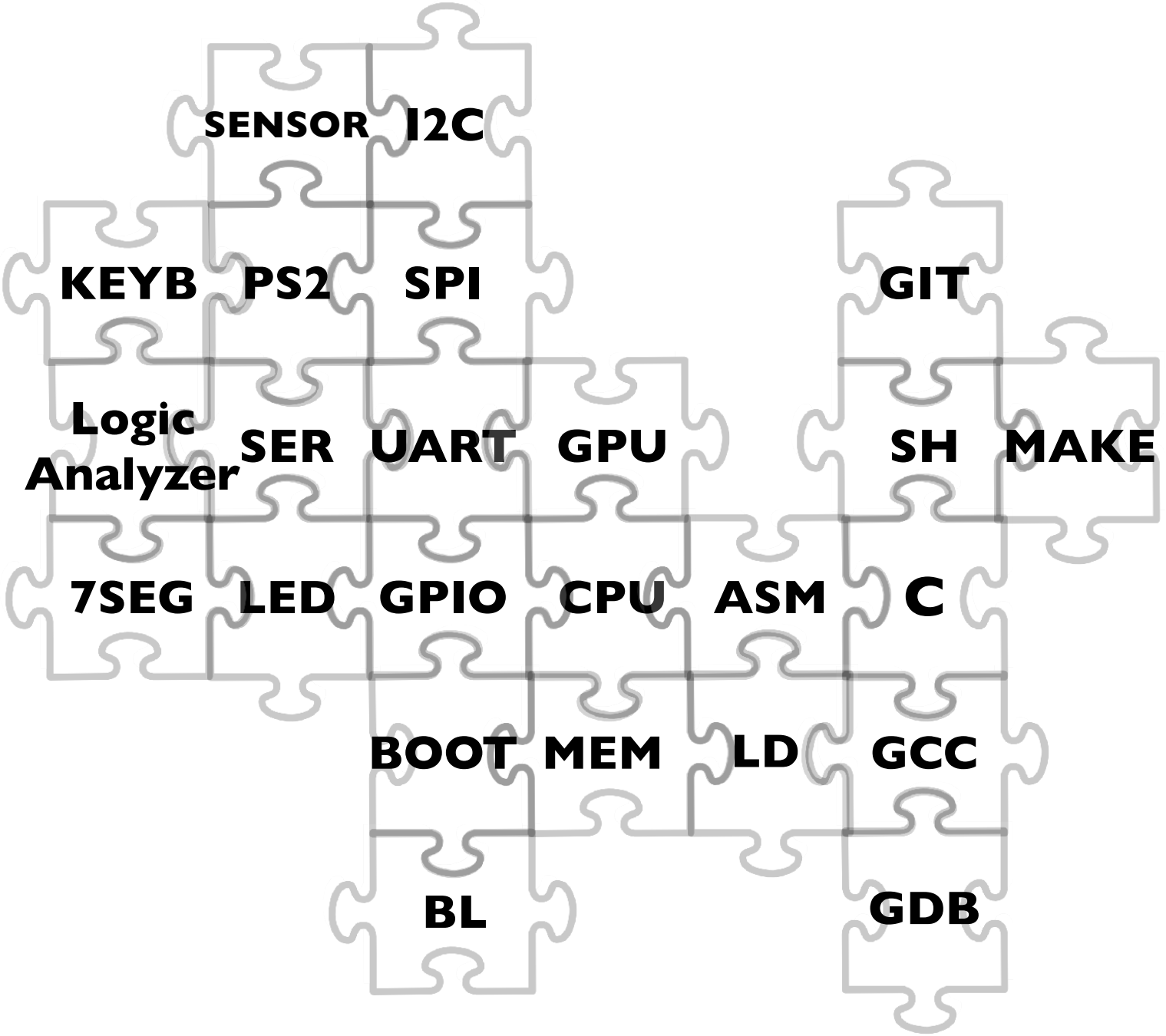
SENSOR
I2C
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Logic Analyzer
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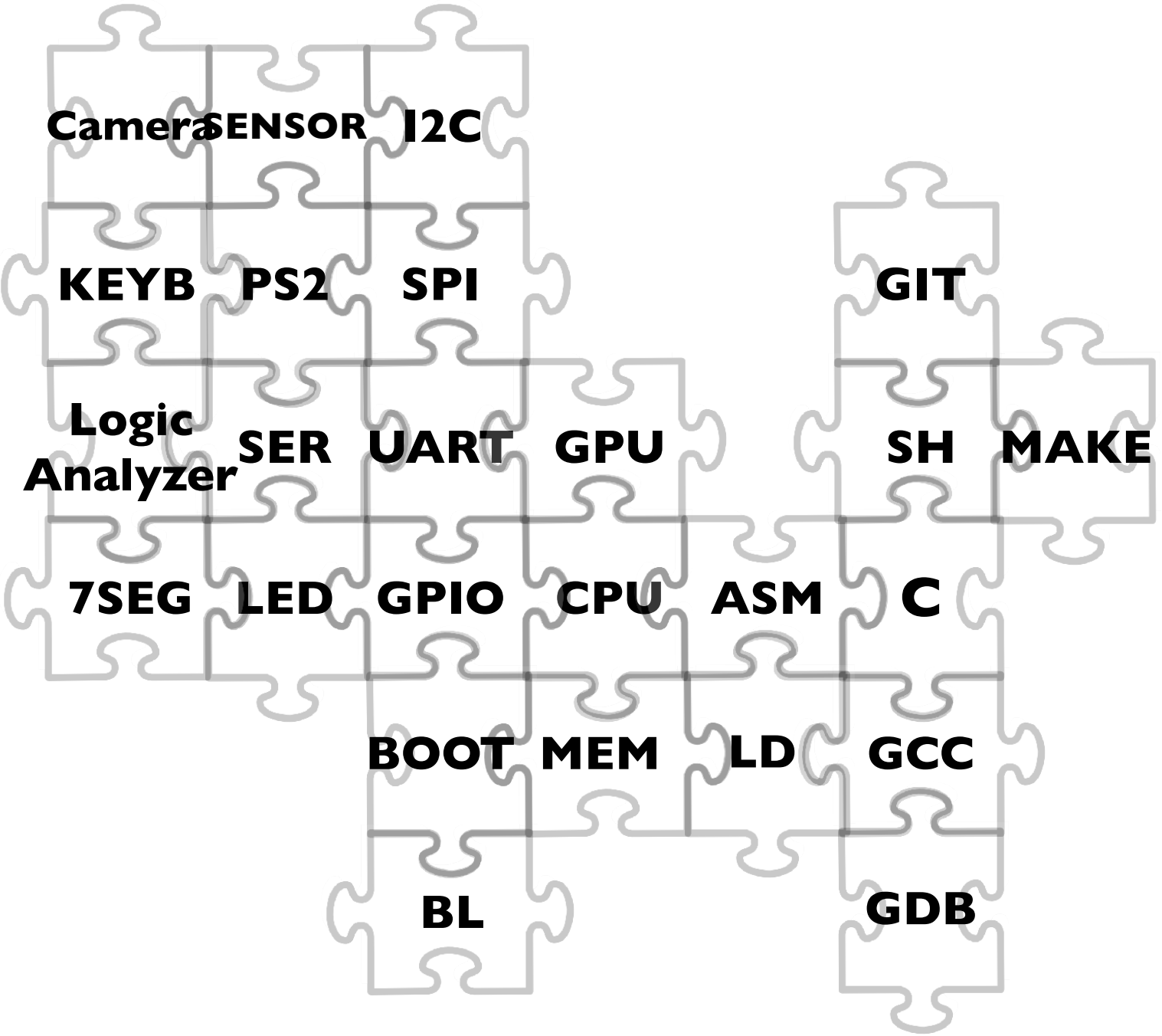
Camera
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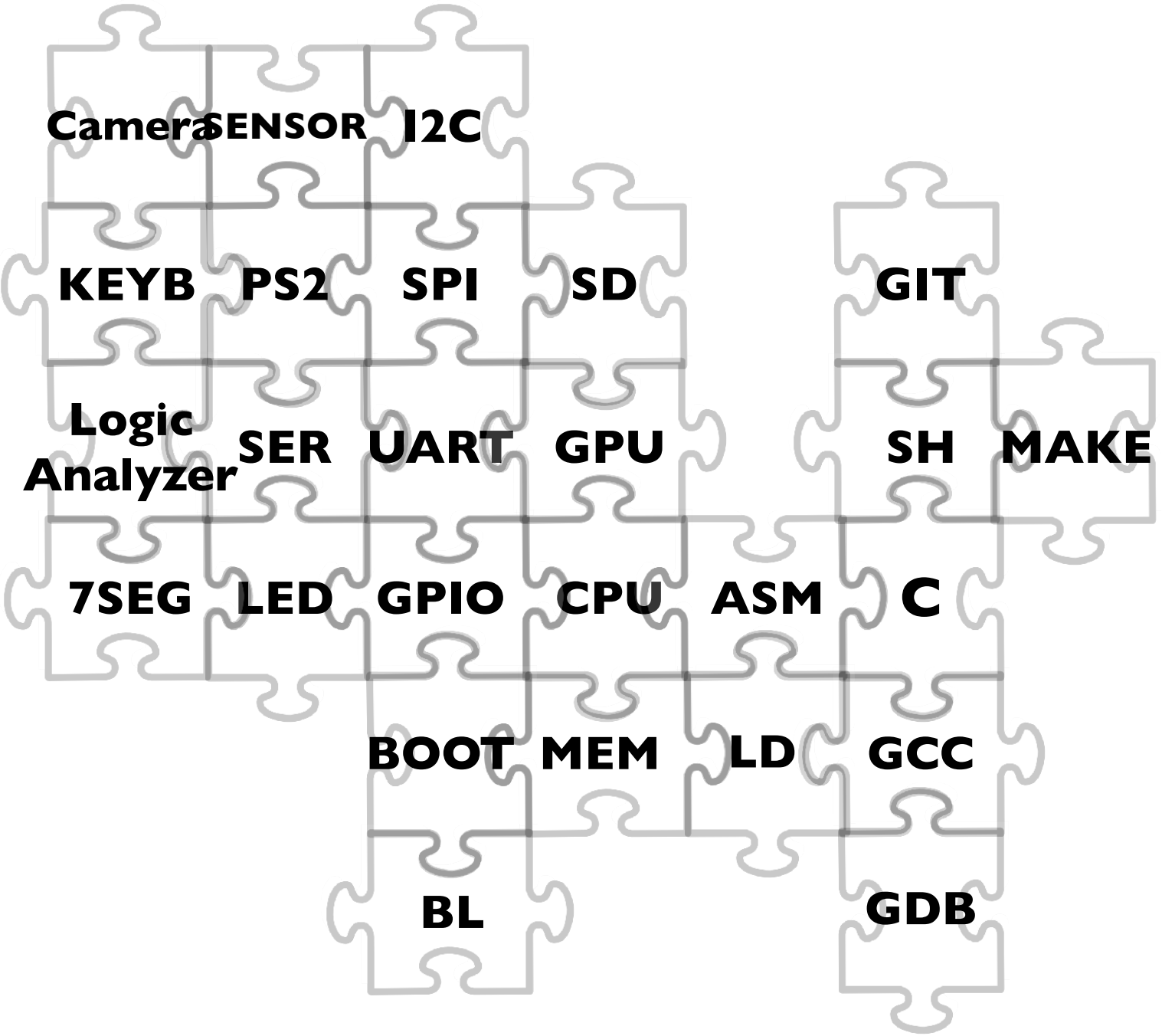
Camera
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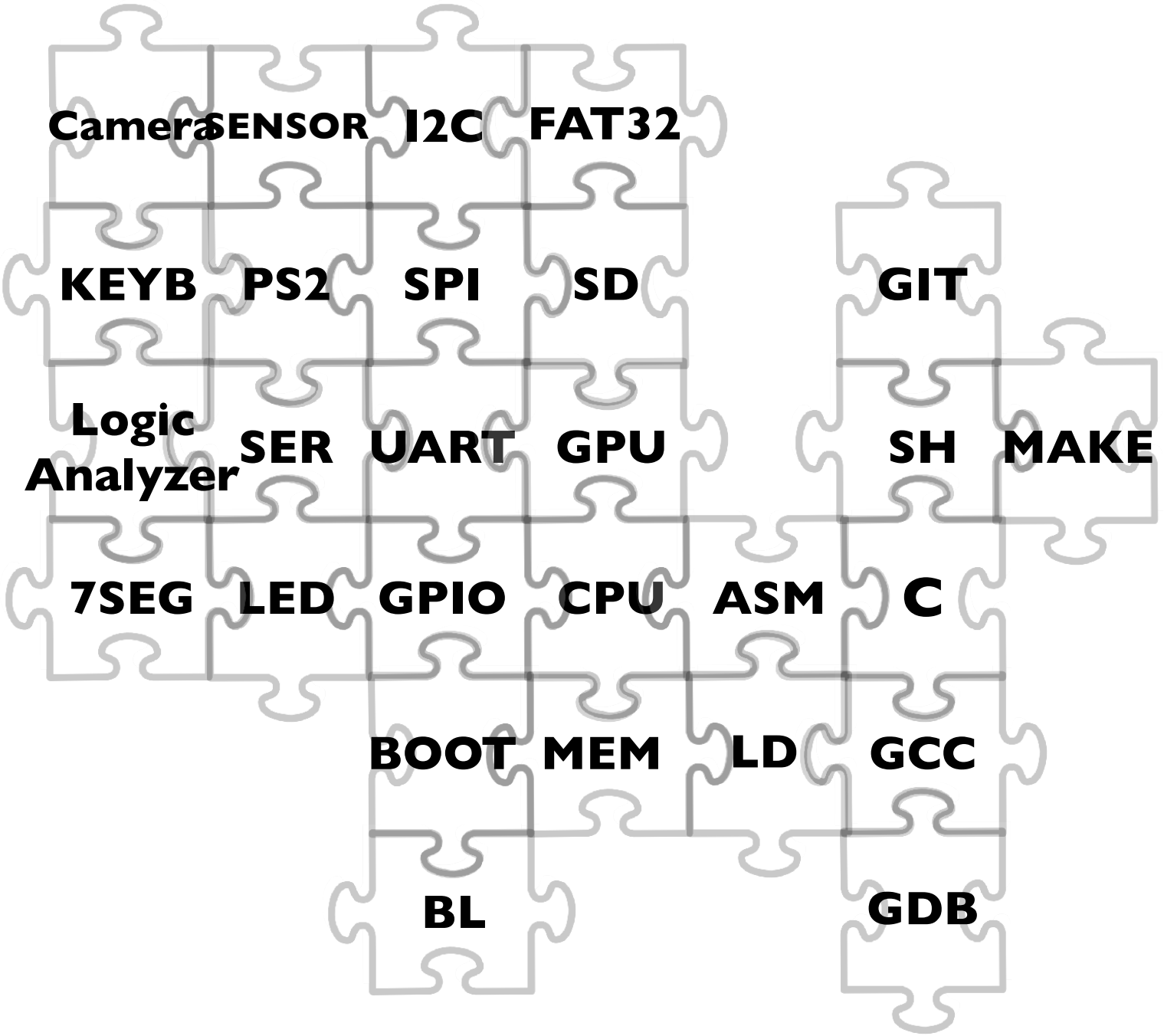
Camera
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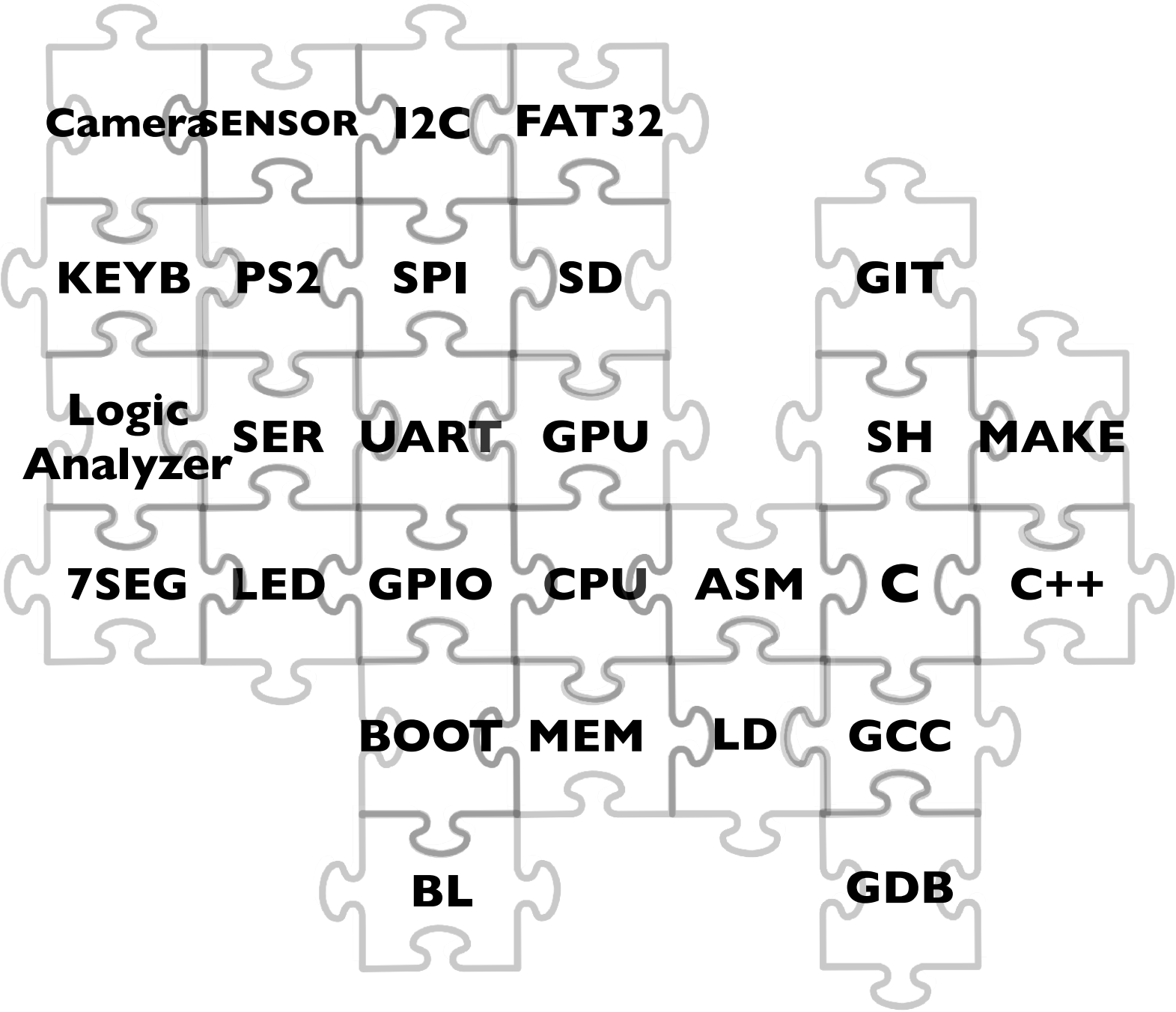
Camera
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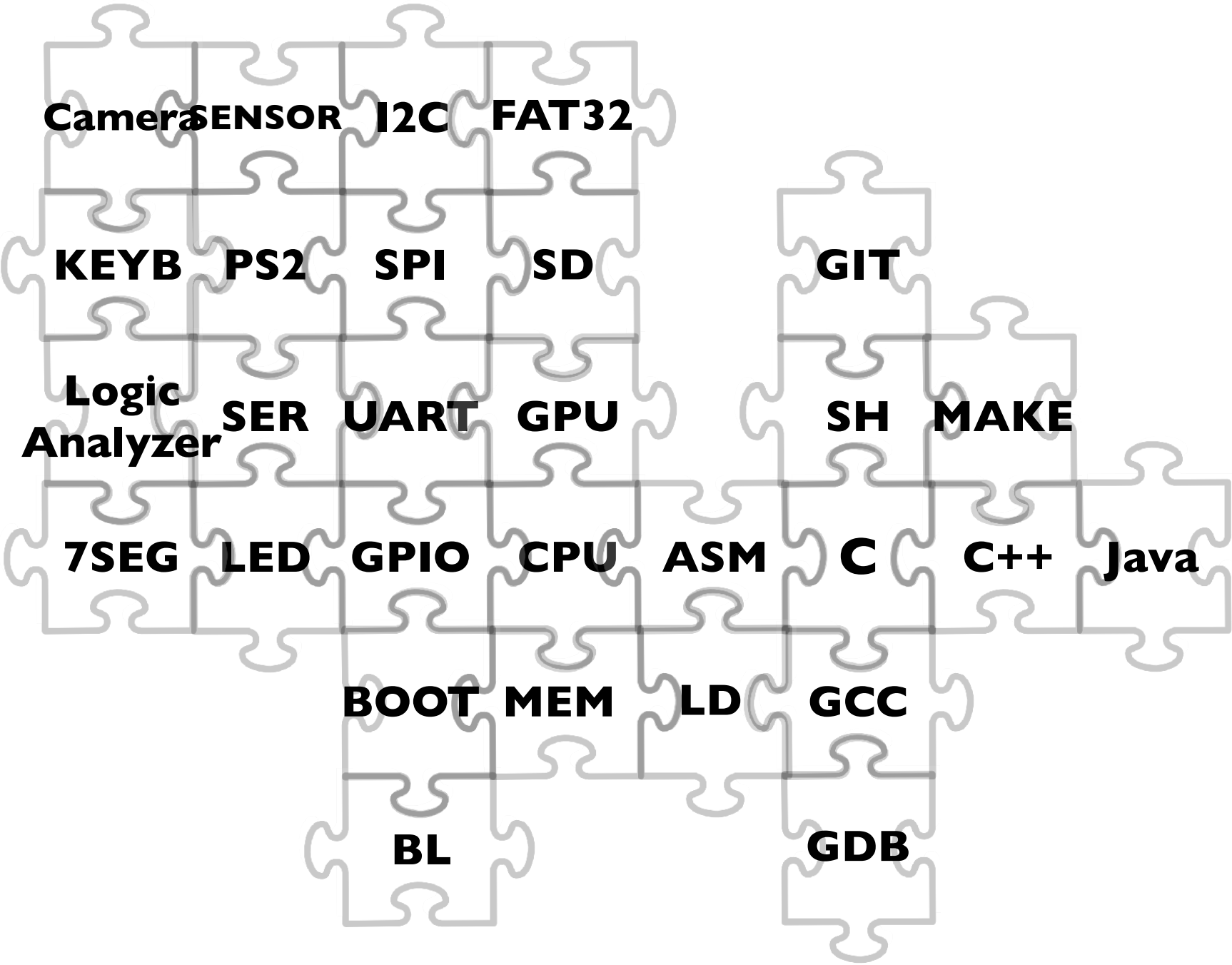
GPIO
CPU
ASM
C
C++
BOOT
MEM
LD
GCC
BL
GDB


Camera
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C++
Java
BOOT
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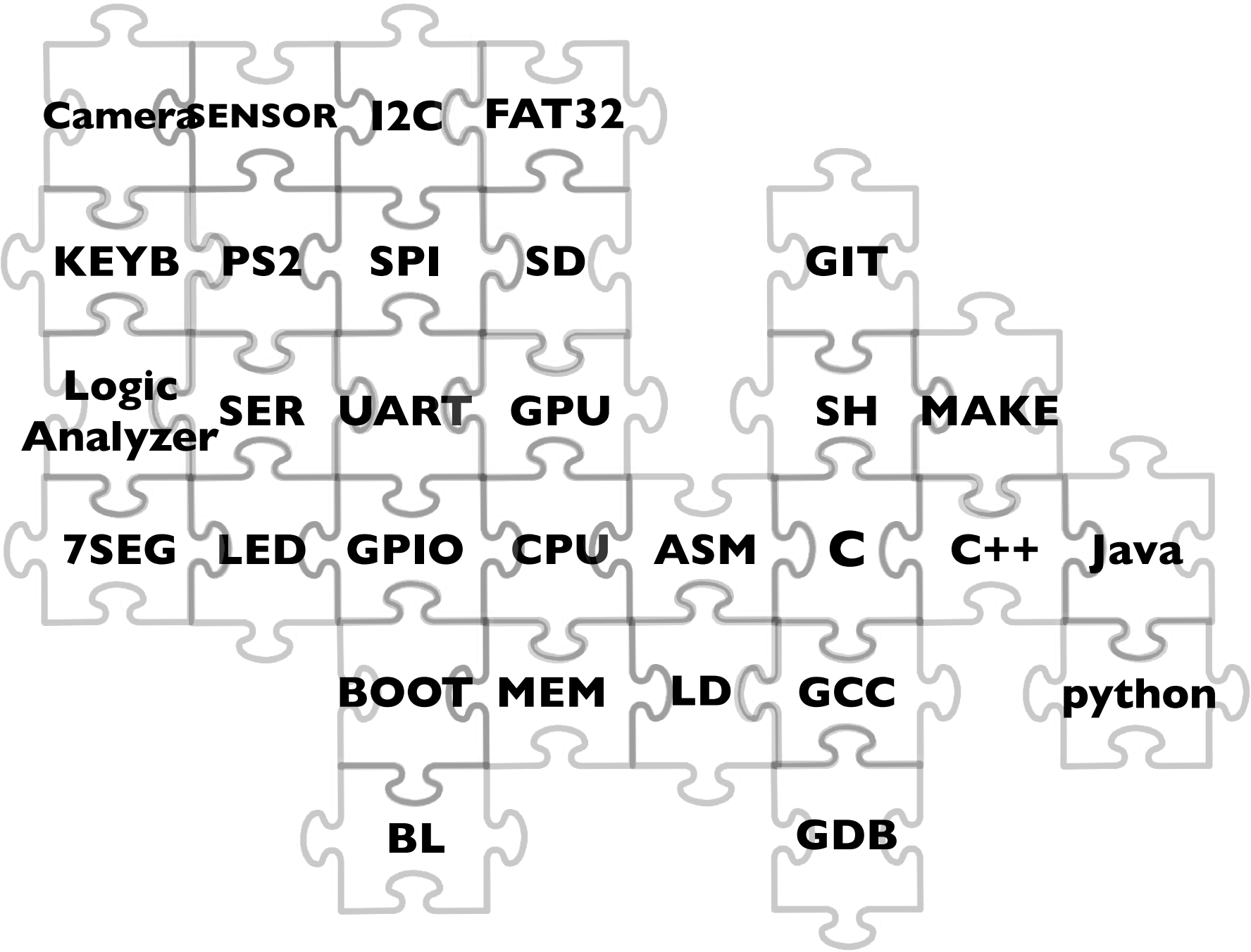
GCC
BL
GDB


Camera
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C++
Java
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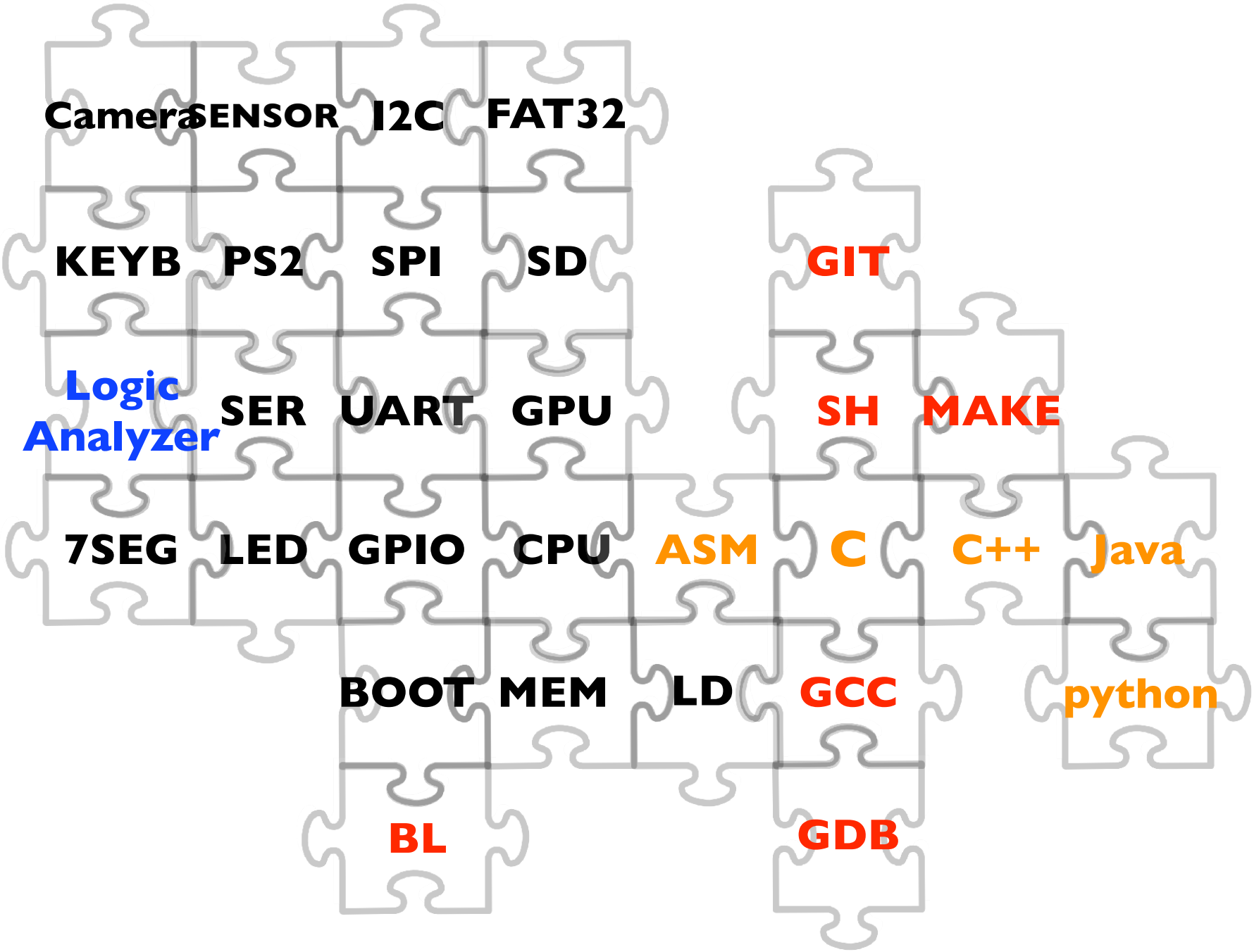
LD
GCC
python
BL
GDB

Goal 2

Master Your Tools


Camera
SENSOR
I2C
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SPI
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Logic Analyzer
SER
UART
GPU
SH
MAKE
7SEG
LED
GPIO
CPU
ASM
C
C++
Java
BOOT
MEM
LD
GCC
python
BL
GDB


The Essential Set of Skills
Debugging, Testing, and Troubleshooting

Engineering Habits

Test, test, test, and test some more; Test as you go

Always start from a working state, take small steps

Visibility is key (printf, logic analyzer, gdb)

Methodical, not random. Search for cause of problem, not solution. Don't throw darts!

Fast prototyping, embrace automation, 1-click build

Don’t be frustrated by bugs, relish the challenge, take frequent breaks.

Organized Development Environment

http://amhistory.si.edu/juliachild/


To invent, you need a good imagination and a pile of junk
Thomas Edison

Be a Maker and a Doer

Become an Engineer

https://sites.google.com/stanford.edu/ee125-interactive-light-sculpt/home

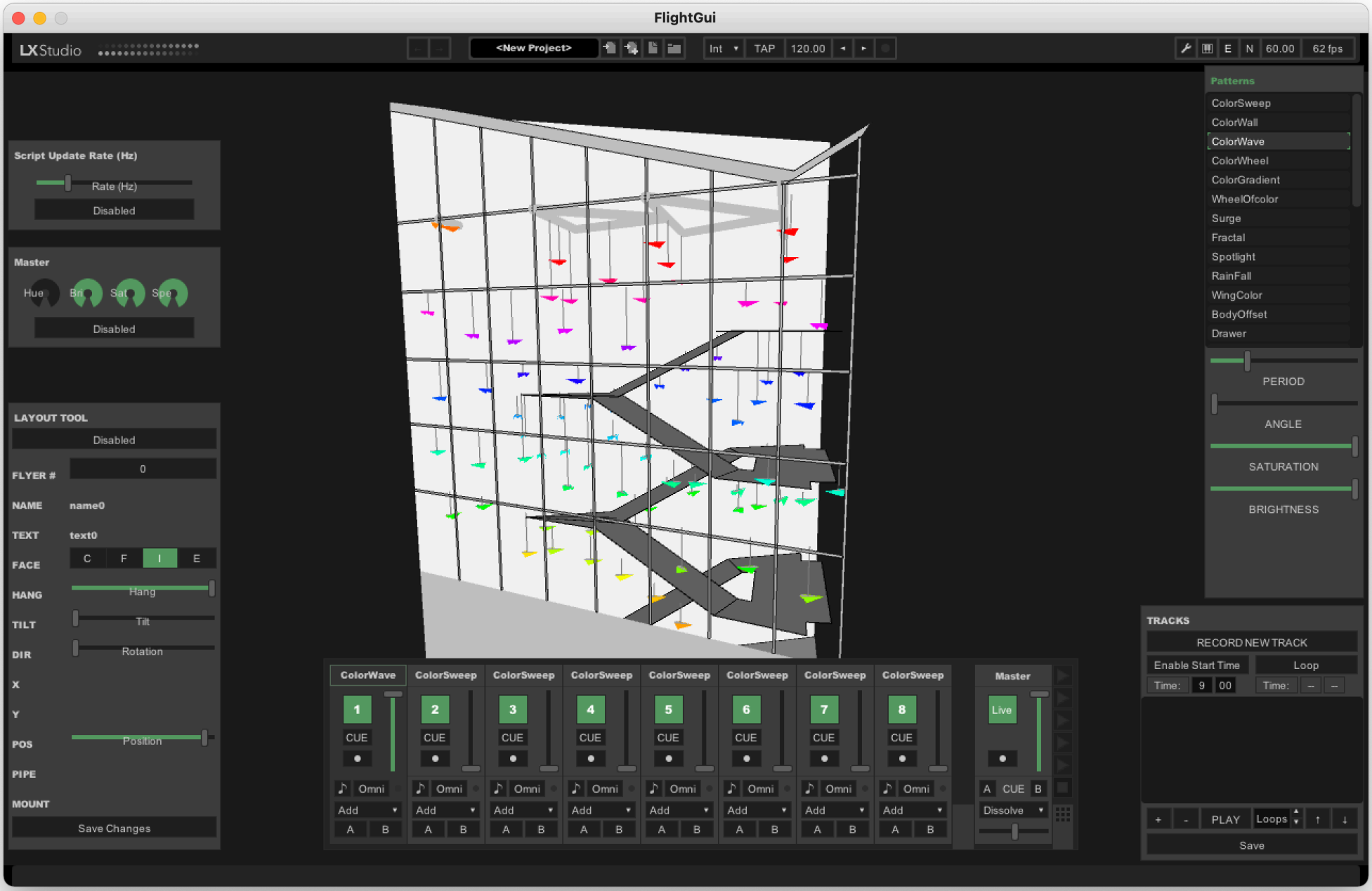
Most Visited | Axess | sensorium | CS107e Slack | CalTrain | Line P | Tock | Kindle | powerclocks | Power Clocks Evalu... | maholli/SAM32 | EE185 git | EE185 Slack | EE125 | cs-teaching-online

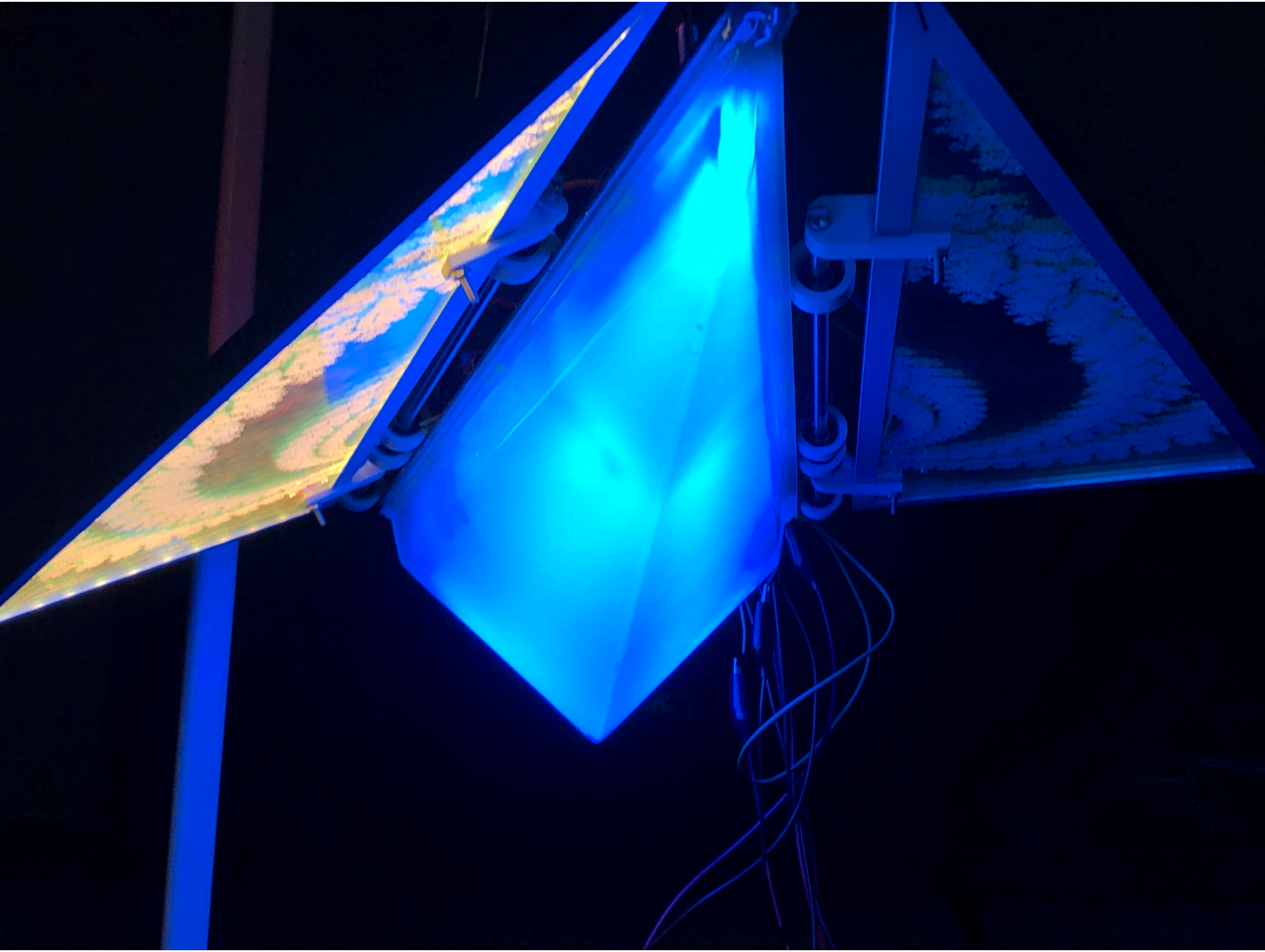
EE125 Interactive Light Sculpture

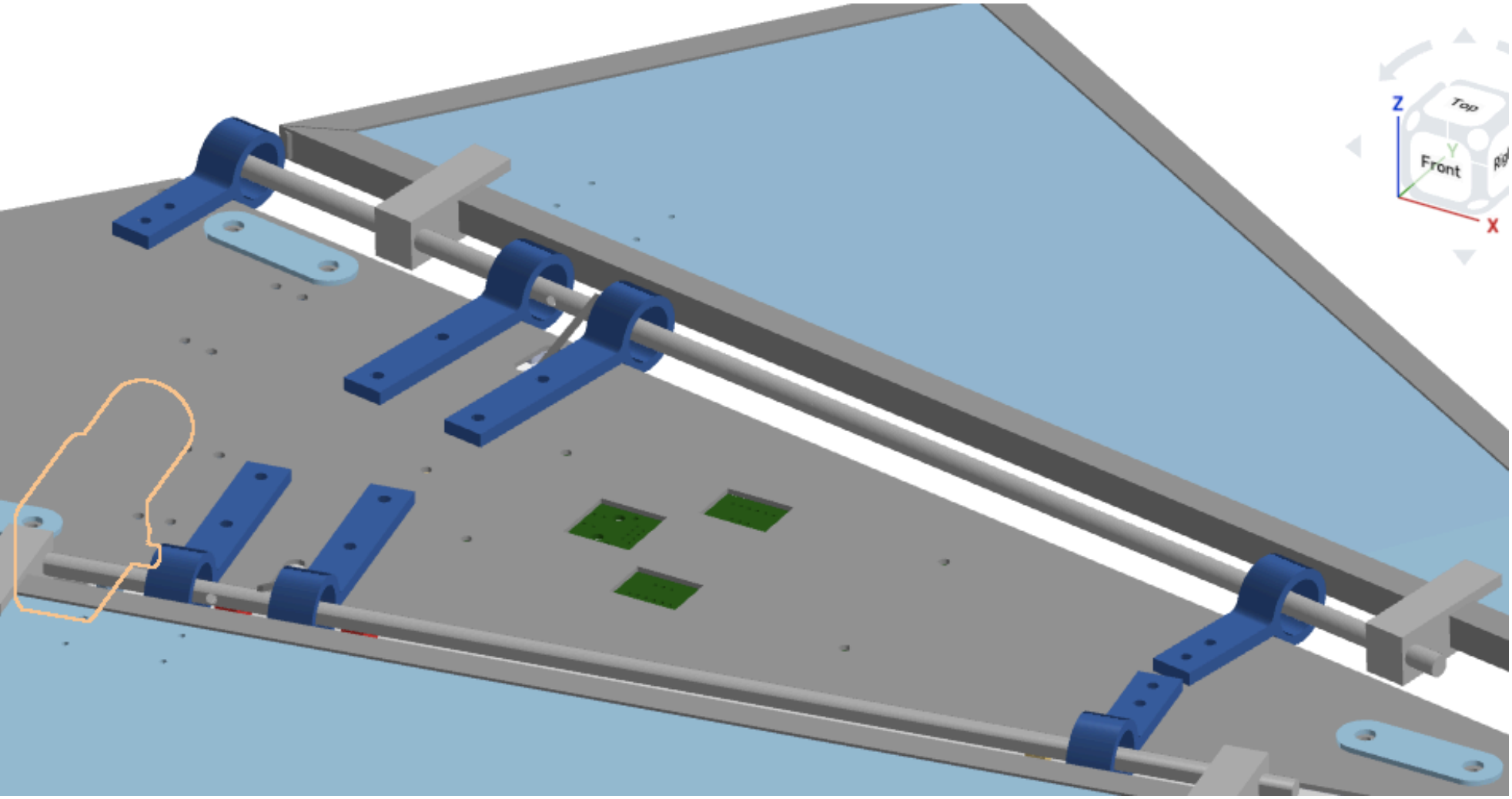
Make Something Beautiful

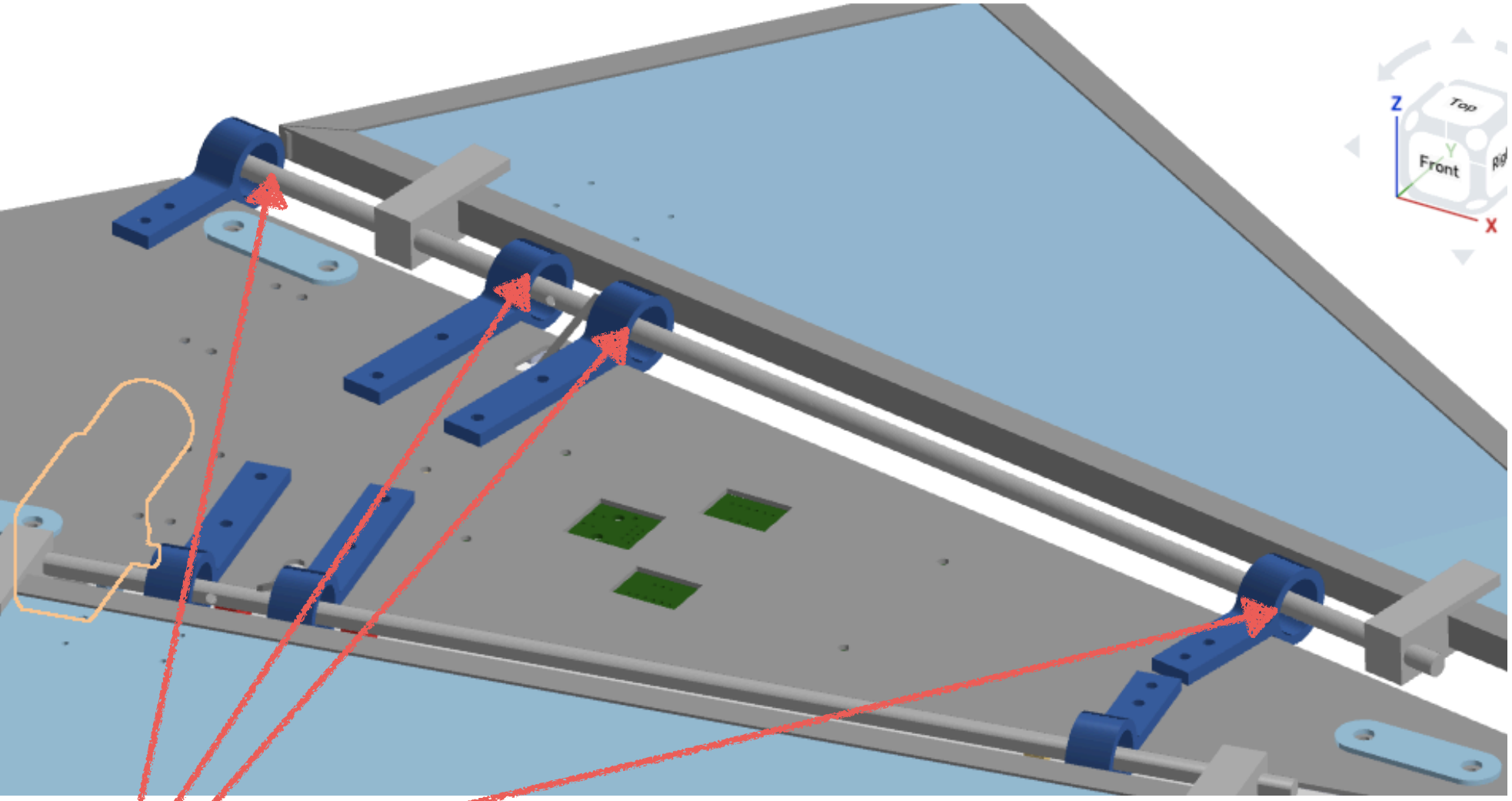
Help Us Celebrate Our 125th Anniversary!

This year the EE Department celebrates its 125th anniversary. As part of the celebration we are building a beautiful interactive light sculpture to be installed in the David Packard Electrical Engineering Building staircase.


FlightGui
LXStudio
<New Project>
Int
TAP
120.00
E
N
60.00
62 fps
Script Update Rate (Hz)
Rate (Hz)
Disabled
Master
Hue
Sat
Disabled
LAYOUT TOOL
Disabled
FLYER #
0
NAME
name0
TEXT
text0
FACE
C
F
I
E
HANG
Hang
TILT
Tilt
DIR
Rotation
X
Y
POS
Position
PIPE
MOUNT
Save Changes
Patterns
ColorSweep
ColorWall
ColorWave
ColorWheel
ColorGradient
WheelOfcolor
Surge
Fractal
Spotlight
RainFall
WingColor
BodyOffset
Drawer
PERIOD
ANGLE
SATURATION
BRIGHTNESS
ColorWave
ColorSweep
Master
1
2
3
4
5
6
7
8
CUE
Live
Omni
Add
A
B
Dissolve
TRACKS
RECORD NEW TRACK
Enable Start Time
Loop
Time:
9
00
PLAY
Loops
Save




Z
Top
Y
Front
X



Each

ADD TO ORDER

In stock
$5.98 Each
60355K503

$50 for just the bearings!

Dry-Running Sleeve Bearings

High-Load Dry-Running Sleeve Bearings

A metal shell adds strength.

Light Duty Dry-Running Sleeve Bearings

Use where high loads and speeds are not required.

High-Temperature Dry-Running Sleeve Bearings

Graphite provides a layer of dry lubrication that can operate in high-temperature environments.

Ultra-Low-Friction Dry-Running Sleeve Bearings

Use these bearings in applications with frequent starts and stops because they operate with very little friction.

Food Industry Dry-Running Sleeve Bearings

Made of FDA listed materials for use in food applications, these bearings also withstand caustic and washdown environments.

Chemical-Resistant Dry-Running Sleeve Bearings

These bearings stand up to a wider range of chemicals than other dry-running sleeve bearings.

Multipurpose Dry-Running Sleeve Bearings

Reinforced with polyester fabric, these plastic bearings have load and speed capabilities comparable to metal bearings.

Water-Resistant Dry-Running Sleeve Bearings

Good for underwater applications, these bearings won't swell or warp when wet.

Harsh Environment

Ball Bearings

Ball Bearings

These steel ball bearings handle higher loads than stainless steel and plastic bearings.

High-Load Ball Bearings

Wider than our standard ball bearings, these rugged bearings are good for handling heavy loads at low speeds.

Permanently Lubricated Ball Bearings

A solid polymer lubricant surrounds the balls, eliminating the need for additional lubrication. Because it's solid, the lubricant blocks out water and dust, extending the life of the bearing.

Light Duty Ball Bearings

Use these bearings where high speed and precision are not required.

Precision Ball Bearings

For greater accuracy and higher speeds, these bearings are made to tighter tolerances than standard ball bearings.

Self-Aligning Ball Bearings

With a spherical raceway and two rows of balls, these bearings compensate for shaft misalignment.

Hex-Bore Ball Bearings

Mount these bearings onto a hex shaft.

Electrically Insulated Ball Bearings

Good for use in electric motors and power generators, these bearings have ceramic balls that insulate against stray current to prevent damage to the bearing.

One-Way Locking Ball Bearing Clutches

Internal locking

Stainless Steel Ball Bearings

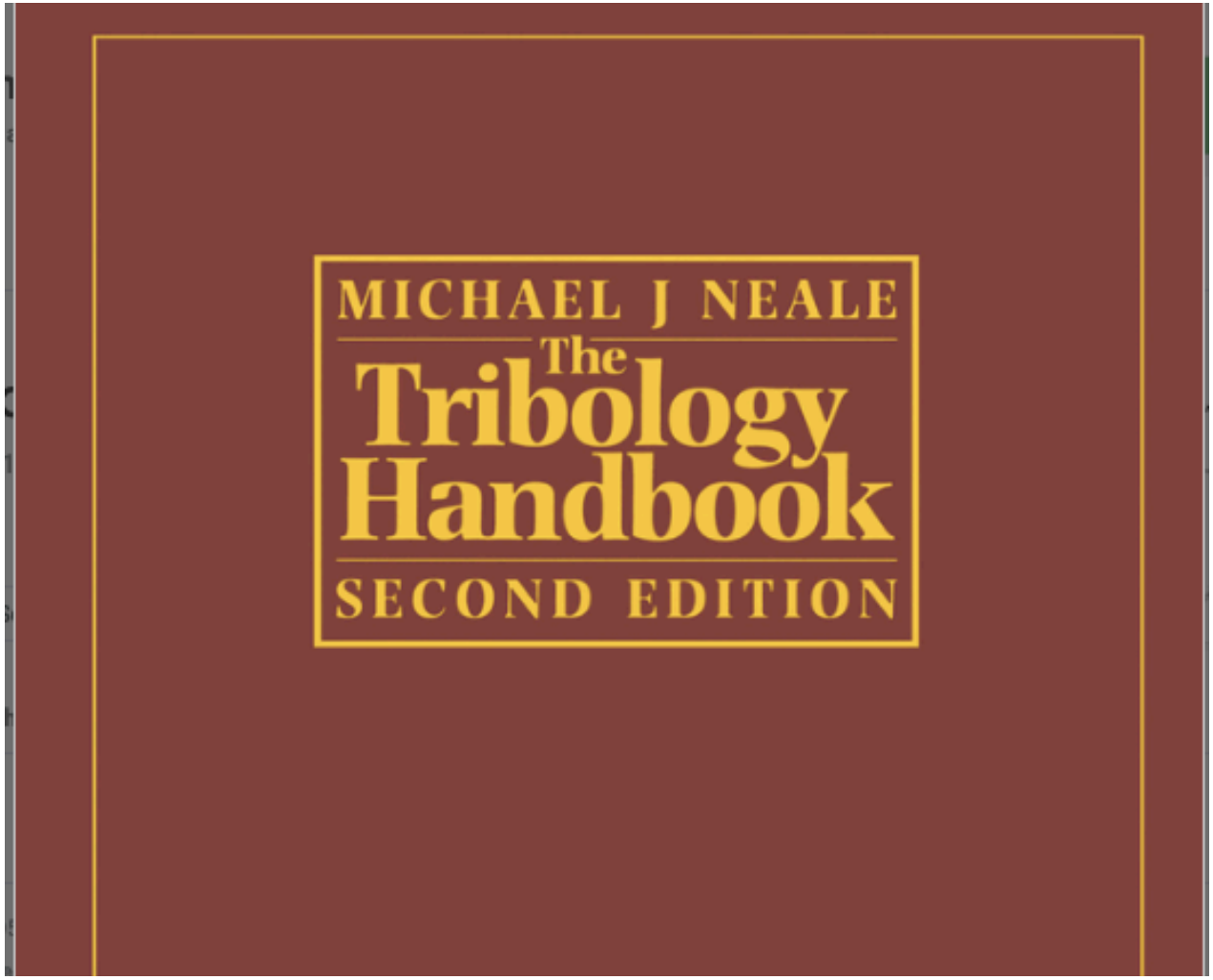
Bearings are 440C stainless steel for good

Permanently Lubricated Stainless Steel Ball Bearings

A solid polymer

Ultra-Corrosion-Resistant Stainless Steel Ball Bearings

These 316 stainless

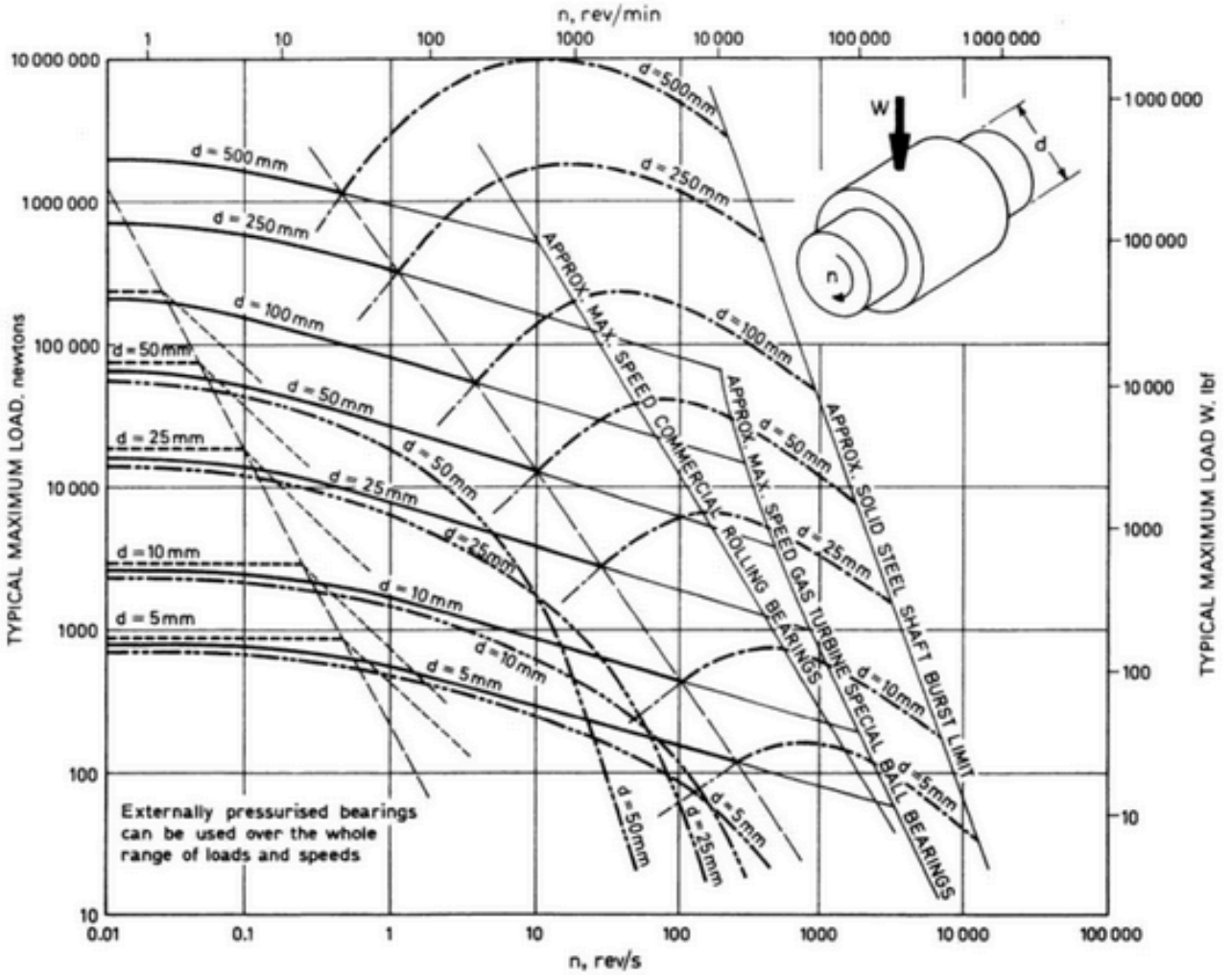


Tribology

From Wikipedia, the free encyclopedia

It has been suggested that *Draft:Green tribology* be merged into this article. (Discuss) *Proposed since May 2020.*

Tribology is the science and engineering of interacting surfaces in relative motion. It includes the study and application of the principles of friction, lubrication, and wear. Tribology is highly interdisciplinary. It draws on many academic fields, including physics, chemistry, materials science, mathematics, biology, and engineering. People who work in the field of tribology are referred to as *tribologists*.[1]

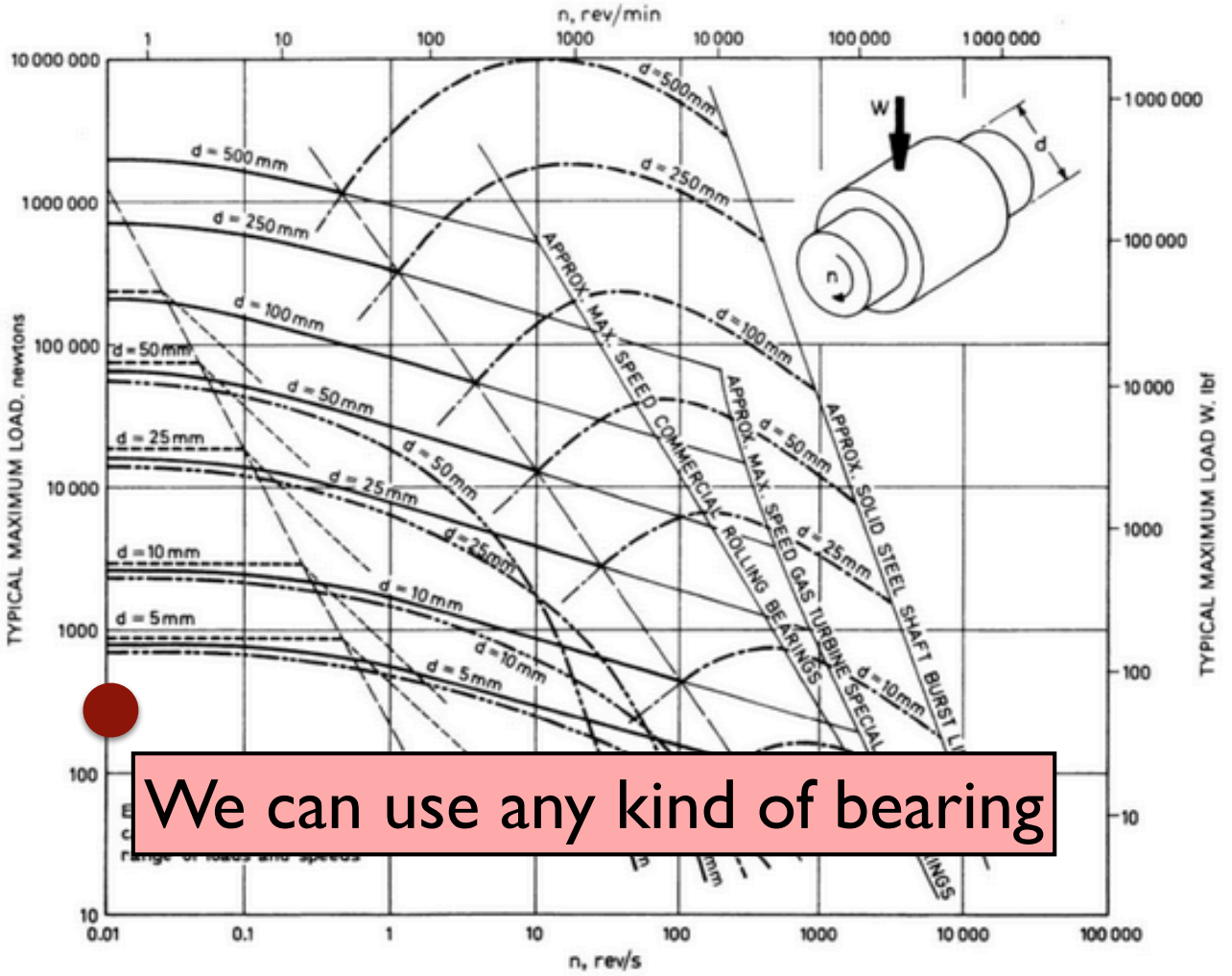


Rubbing plain bearings in which the surfaces rub together. The bearing is usually non-metallic.

Plain bearings of porous metal impregnated with a lubricant.

Rolling bearings. The materials are hard, and rolling elements separate the two moving components.

Fluid film plain bearings. A hydrodynamic pressure is generated by the relative movement dragging a viscous fluid into a taper film.



We can use any kind of bearing

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Rolling bearings. The materials are hard, and rolling elements separate the two moving components.

Fluid film plain bearings. A hydrodynamic pressure is generated by the relative movement dragging a viscous fluid into a taper film.

https://www.hackster.io/

https://www.electronicshub.org/iot-project-ideas/

https://electronicsforu.com/iot-projects-ideas

https://makezine.com/category/technology/wearables/

http://blondihacks.com/

Linux and Beyond

Operating Systems

Multiple processes (scheduling)

Memory management (virtual memory)

Share peripherals (devices)

File systems and storage

Networking

Protect/secure processes from each other

Modes

Privileged modes

Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1	R1	R1	R1	R1
R2	R2	R2	R2	R2	R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	R9_fiq
R10	R10	R10	R10	R10	R10	R10_fiq
R11	R11	R11	R11	R11	R11	R11_fiq
R12	R12	R12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

Modes

Privileged modes

Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1			R1	R1
R2	R2	R2			R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	R9_fiq
R10	R10	R10	R10	R10	R10	R10_fiq
R11	R11	R11	R11	R11	R11	R11_fiq
R12	R12	R12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

Bare metal code

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

Modes

Privileged modes

Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1			R1	R1
R2	R2	R2			R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	
R10	R10	R10	R10	R10	R10	
R11	R11	R11	R11	R11	R11	R11_fiq
R12	R12	R12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

Bare metal code

Interrupt code

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

Modes

Privileged modes

Exception modes

User	System	Supervisor	Abort	Undefined	Interrupt	Fast interrupt
R0	R0	R0	R0	R0	R0	R0
R1	R1	R1			R1	R1
R2	R2	R2			R2	R2
R3	R3	R3	R3	R3	R3	R3
R4	R4	R4	R4	R4	R4	R4
R5	R5	R5	R5	R5	R5	R5
R6	R6	R6	R6	R6	R6	R6
R7	R7	R7	R7	R7	R7	R7
R8	R8	R8	R8	R8	R8	R8_fiq
R9	R9	R9	R9	R9	R9	
R10	R10	R10	R10	R10	R10	
R11	R11	R11	R11	R11	R11	R11_fiq
R12		12	R12	R12	R12	R12_fiq
R13	R13	R13_svc	R13_abt	R13_und	R13_irq	R13_fiq
R14	R14	R14_svc	R14_abt	R14_und	R14_irq	R14_fiq
PC	PC	PC	PC	PC	PC	PC
CPSR	CPSR	CPSR	CPSR	CPSR	CPSR	CPSR
		SPSR_svc	SPSR_abt	SPSR_und	SPSR_irq	SPSR_fiq

Bare metal code

User code

Interrupt code

indicates that the normal register used by User or System mode has been replaced by an alternative register specific to the exception mode

User vs Supervisor Mode

User mode can't do a lot of things ...

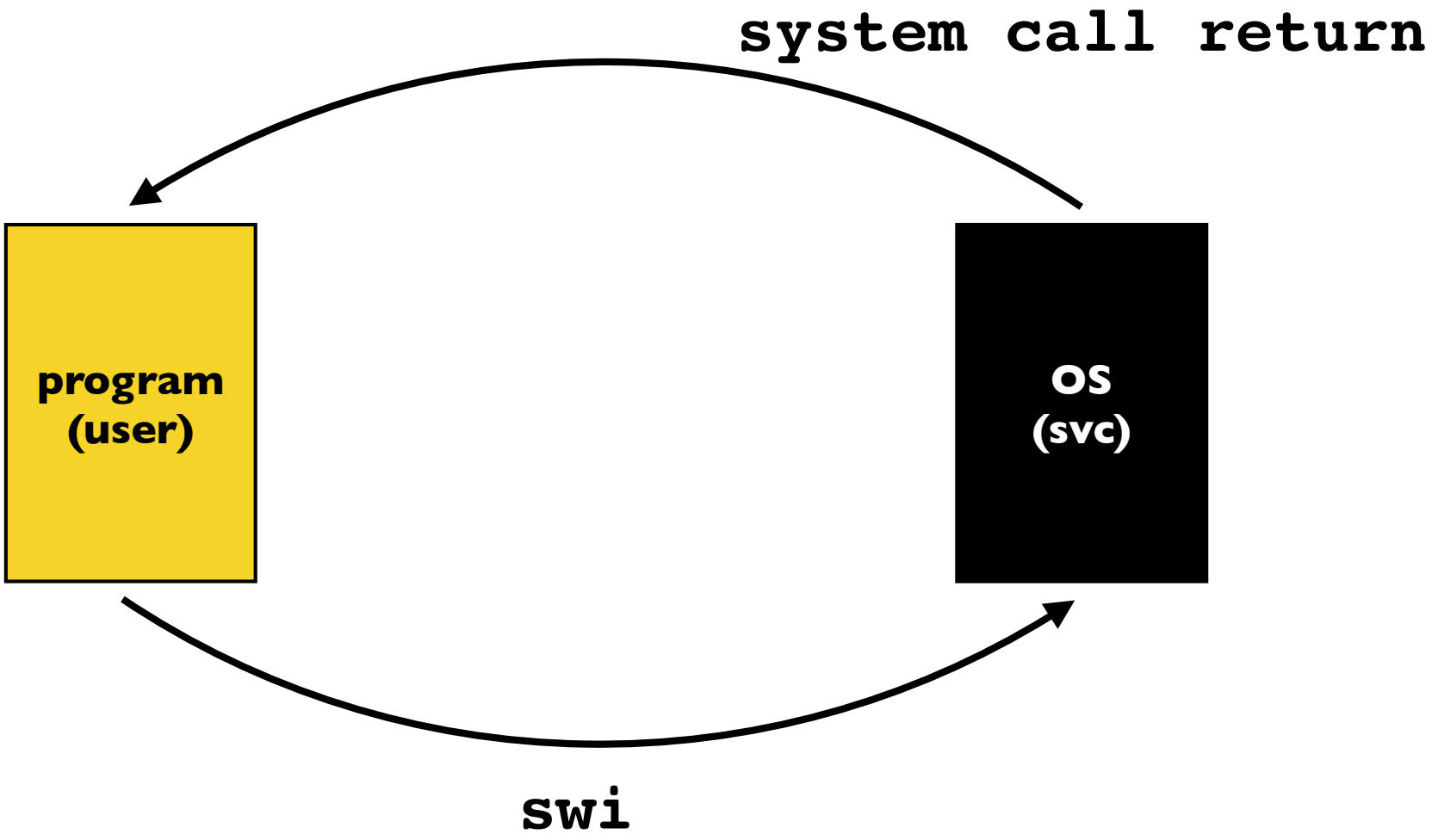
1. Modify CPSR (change modes)
2. Access configuration registers
3. Access IO registers/memory

Hardware throws an exception if user mode program does any of these things

Enables operating system to keep processes from interfering with each other

Essential for security

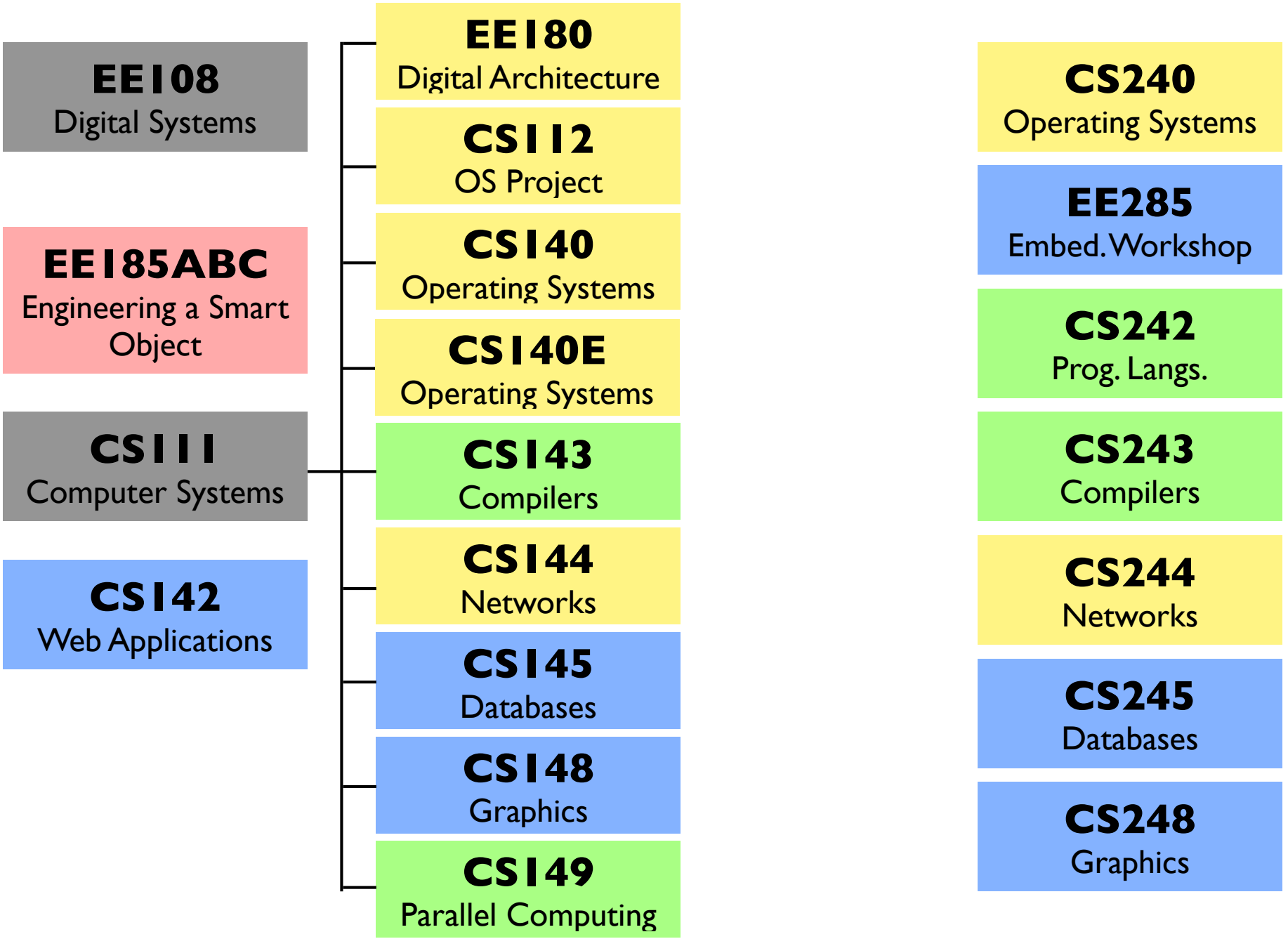
Operating System



Linux Boot

https://github.com/torvalds/linux/blob/master/arch/arm/boot/compressed/head.S

Next Steps


EE108
Digital Systems
EE185ABC
Engineering a Smart Object
CS111
Computer Systems
CS142
Web Applications
EE180
Digital Architecture
CS112
OS Project
CS140
Operating Systems
CS140E
Operating Systems
CS143
Compilers
CS144
Networks
CS145
Databases
CS148
Graphics
CS149
Parallel Computing
CS240
Operating Systems
EE285
Embed. Workshop
CS242
Prog. Langs.
CS243
Compilers
CS244
Networks
CS245
Databases
CS248
Graphics

Demos on Thursday!

- Milestones!
- To submit receipts
  - http://tinyurl.com/edaffairs
  - Please do it this week! You may have to pay taxes if you wait

Demonstrations

- Thursday Dec 9, 12:15-3:15 pm, Packard Atrium

Submission

- Due Friday night
- Final github commit of code
- Include README.md describing your project (pictures!!, attributions)

Logistics

- Submit reimbursements (see previous slide)

CS107e — what have you accomplished?

https://www.youtube.com/watch?v=th5A6ZQ28pE