AHCS November 12 2011

“RETROTRONICS”

What is ‘Retrotronics’?

“Augmentation of vintage computer systems using modern analogs to extend their usable lives”

Entropy

Wear

Interface

Capacity

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Capacity

- Magnetics
  - Bit preservation. Just sitting on a shelf, bits encoded in magnetic fields will evaporate
  - Need to access legacy media devices

What is 'Retrotronics'?

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Entropy | Wear | Interface | Capacity

- Electronic Components
  - Aluminum electrolytic capacitors will dry and leak
  - Thermal stress. Continuous heat/cool cycles will break down physical substrates
  - The Earth will eventually reclaim all it's magic smoke
  - Tin Whiskers (RoHS)

What is ‘Retrotronics’?

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Entropy | Wear | Interface | Capacity

- Physical Media
  - Head friction on floppy disks / Bit preservation
  - Disk head crashes / Bearing freeze / Stepper accuracy
- Human interfaces
  - Keyboards / Mice / Trackballs (eg. Brad)

What is 'Retrotronics'?

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Entropy | Wear | Interface | Capacity

- Human interfaces
  - ~~IBM Model M keyboards won't last forever~~
  - No current replacement for serial/bus mice / joysticks
- Displays
  - CRTs are dead / low-res proprietary CRTs are rare yet video signaling hasn't changed much in form since 1950
  - Composite video inputs will disappear on modern TVs

What is ‘Retrotronics’?

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Entropy | Wear | Interface | Capacity

- Networking
  - How do you connect AppleTalk / ArcNET / etc in 2011?
  - Connecting legacy serial protocols to modern systems
- Hundreds of other legacy interfaces without modern support – thus it must be built

What is ‘Retrotronics’?

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Entropy | Wear | Interface | Capacity

- Add capacity to older systems not available when new, or was simply unaffordable, or demanded unreasonable physical requirements
  - Enough storage space to hold every software title ever made!
  - Who hasn’t dreamed of 100% maximizing available memory of their favorite system? How much would that cost new?

What is 'Retrotronics'?

"Augmentation of vintage computer systems using modern analogs to extend their usable lives"

Lastly:

"Because we CAN!"

What is 'Retrotronics'?

"Augmentation of vintage computer systems using modern analogs to extend their usable lives"

Availability

- Replacement ASICs are no longer made
  - Jameco, eBay, Scavengers/Salvagers
- Have to go back to basics using modern techniques for ASIC design
- Rapid prototyping through the use of programmable logic fabrics
- Or use emulation by a more general purpose ASIC – Microprocessor, Microcontroller, DSP, etc

What is ‘Retrotronics’?

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Availability

Never throw away a board!
Even a broken one!

Programmable Logic

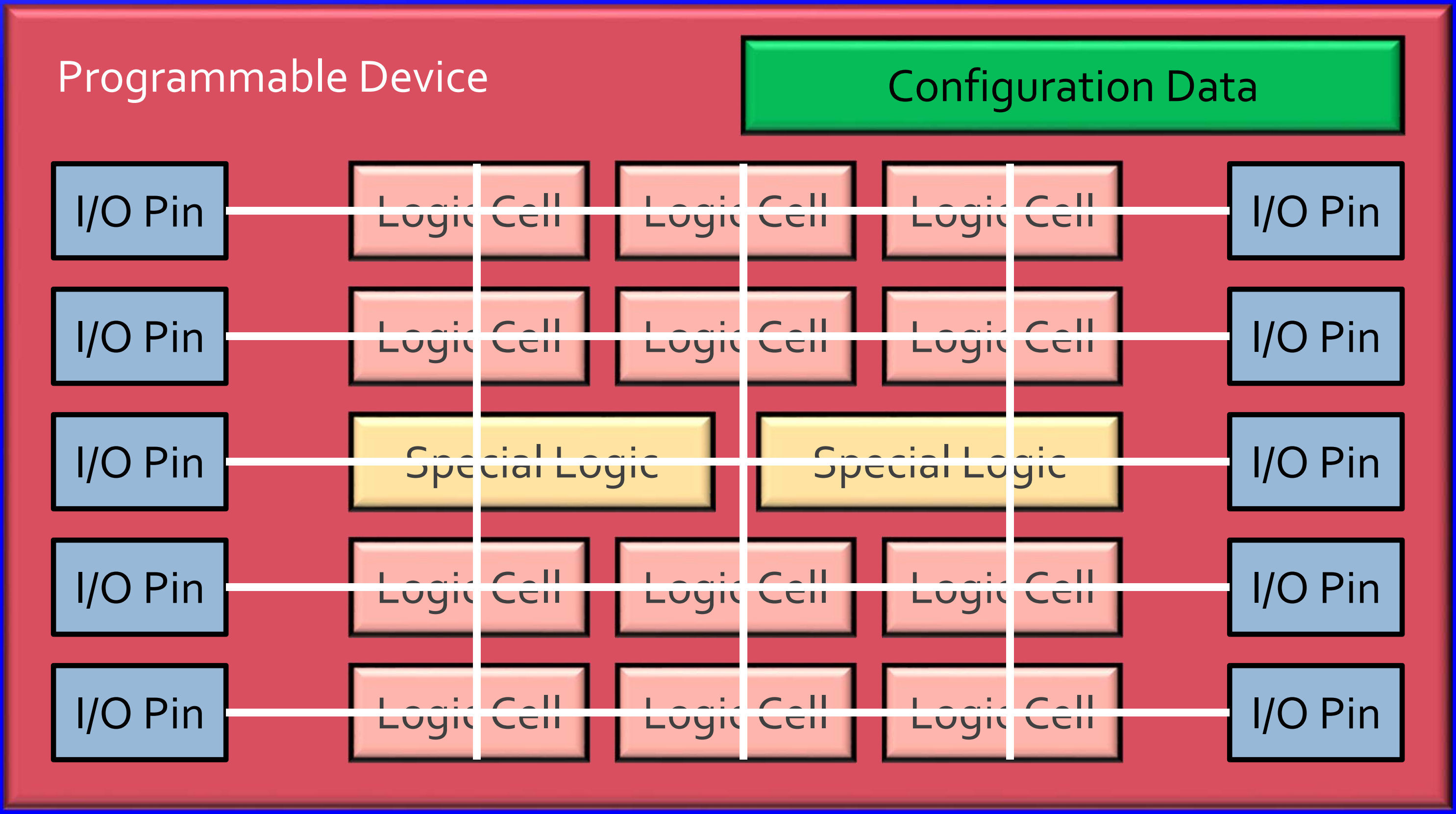
- PLD – Programmable Logic Device
- PLA – Programmable Logic Array
- PAL – Programmable Array Logic
- GAL – Generic Array Logic
- SPLD – Simple Programmable Logic Device
- CPLD – Complex Programmable Logic Device
- CPLD – Crossover PLD (Lattice Semiconductor)
- FPGA – Field Programmable Gate Array
- Many other legacy names
- Many variant names – eg PAL’Rs, PAL’Ls, PAL’Vs

Programmable Logic

- Major players:
  - Altera
  - Xilinx
- Growing in North America:
  - Lattice
- Significant Rest of World:
  - Actel
- Others
  - Cypress
  - Atmel
  - Others

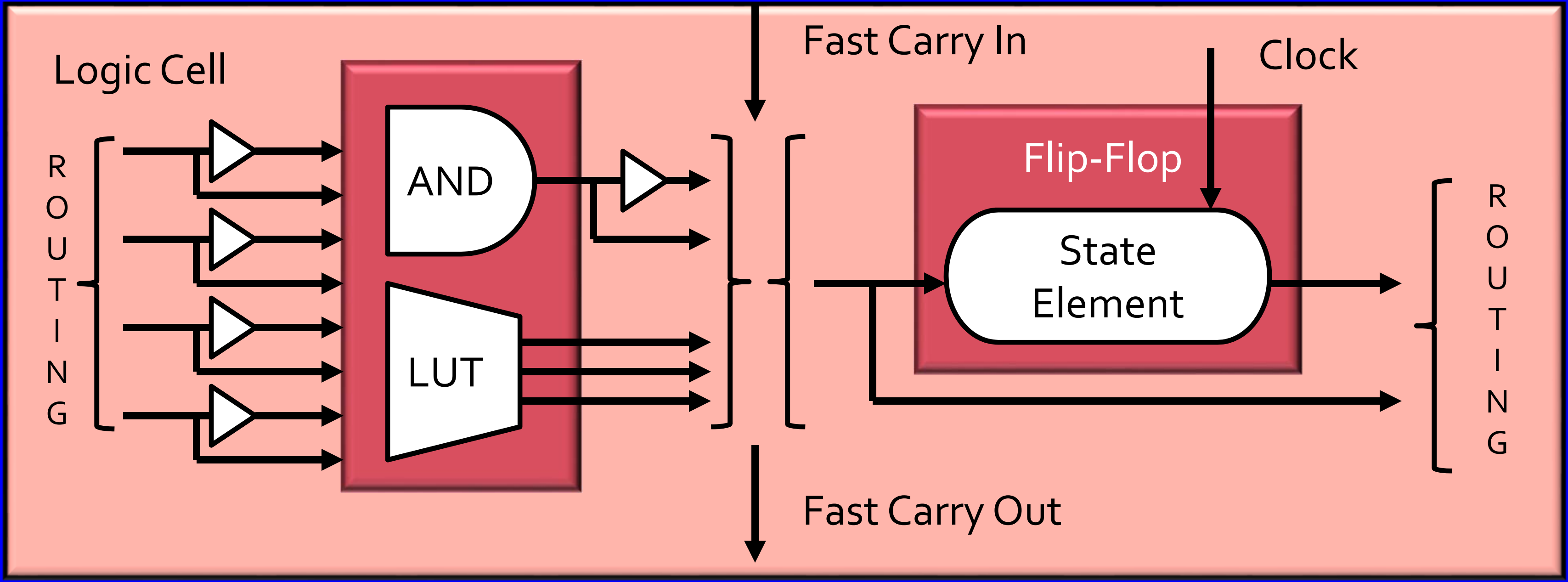
Programmable Logic

- They are all fundamentally similar:

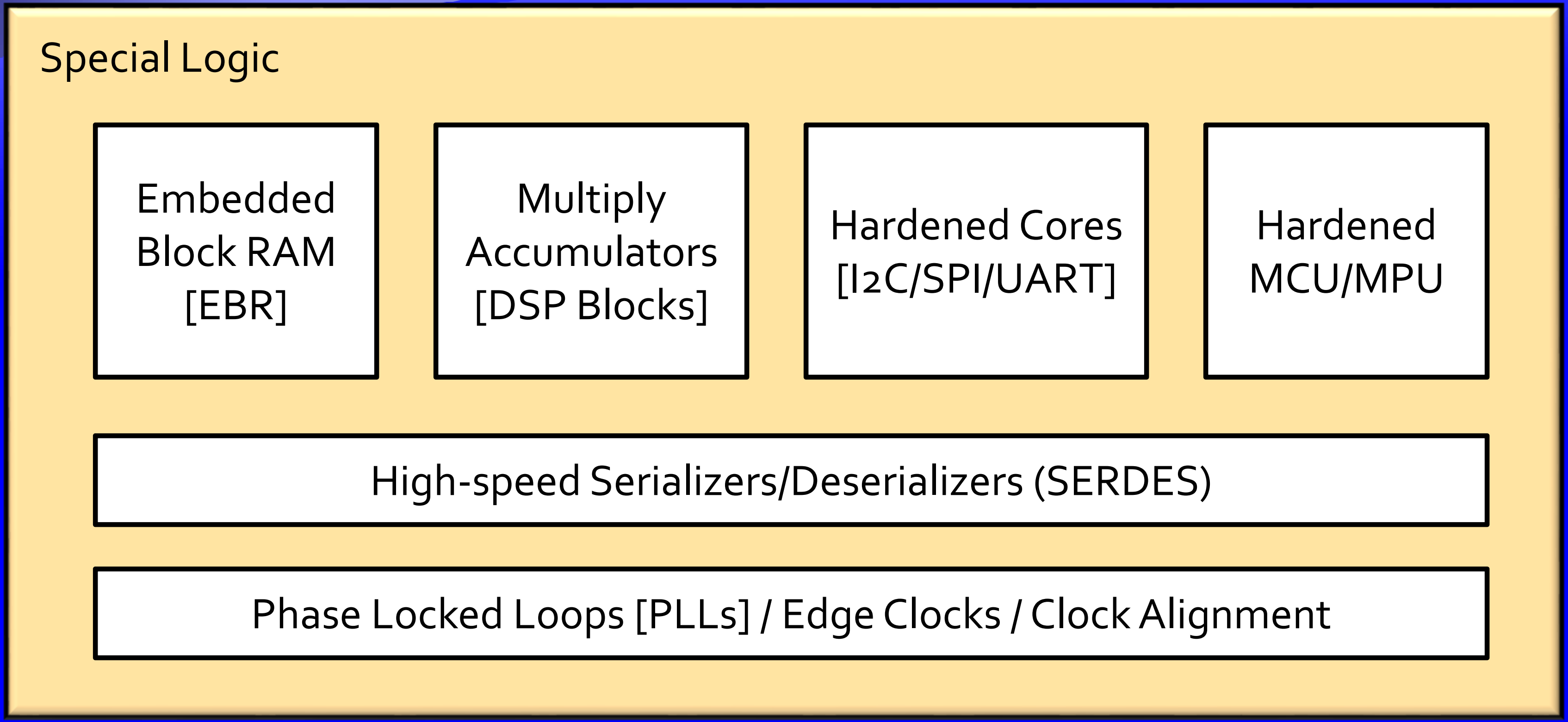


Programmable Logic - Cell

- Product Terms
  - Selectable inputs from regional or global routing matrix
  - Number of pre-operations dependent on vendor architecture
- Combinatorial Block
  - AND or OR with selectable/invertible inputs & output
  - Look-up Table [miniature ROM]
- Register Block / State Element / Flop-Flop
- Output routing



Programmable Logic



Special Logic

Embedded Block RAM [EBR]

Multiply Accumulators [DSP Blocks]

Hardened Cores [I2C/SPI/UART]

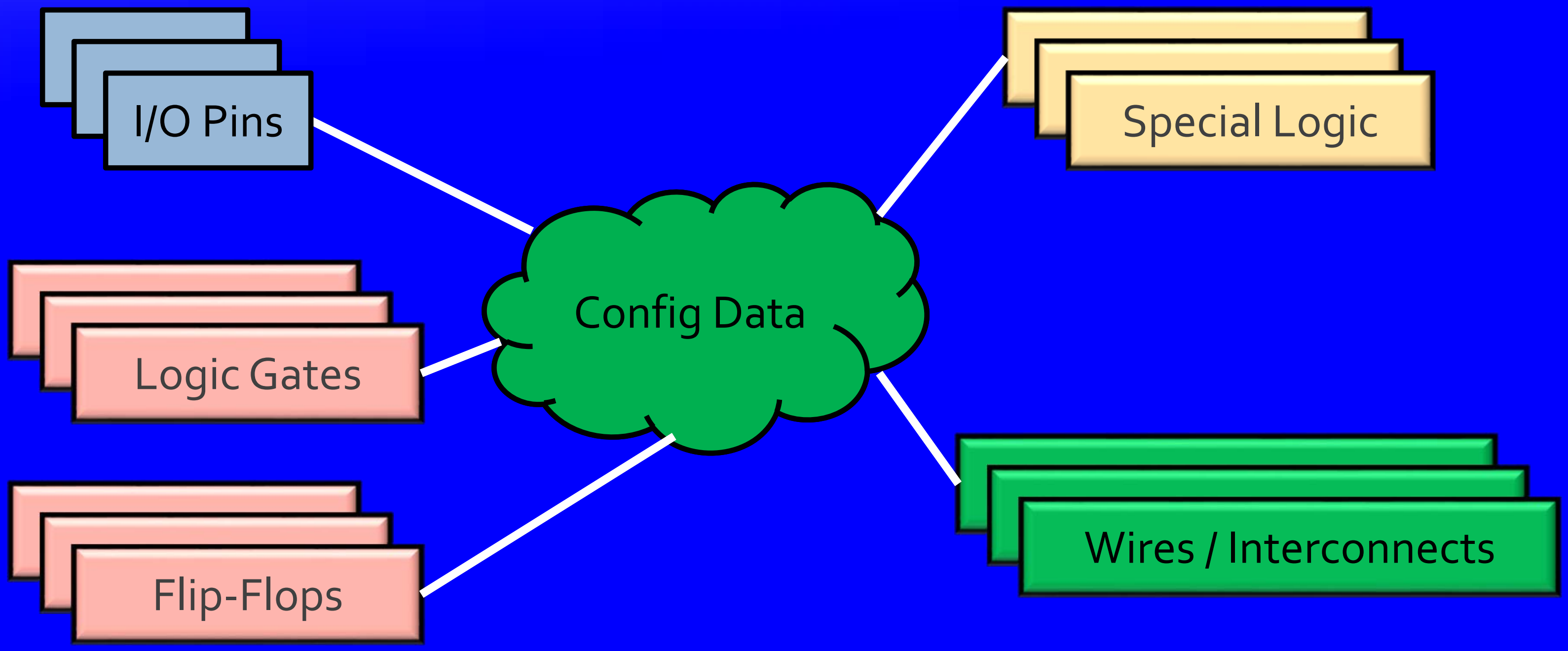
Hardened MCU/MPU

High-speed Serializers/Deserializers (SERDES)

Phase Locked Loops [PLLs] / Edge Clocks / Clock Alignment

Programmable Logic

- Infinitely reconfigurable digital circuit



Programmable Logic

- Read Only Memory (ROM) = Earliest PLD
  - Large combinatorial only Look Up Table
  - Address lines = input, Data lines = output

Programmable Logic

- PLD Sizes:

GAL16V8	XC9572	MachXO2	Spartan 3E	Cyclone III	Stratix 9	Virtex 5
SPLD	Small CPLD	CPLD	Small-Mid FPGA	Small FPGA	Large FPGA	Mid-Large FPGA
8	72	256-7000	2K-33K	300-12K	72K-800K	20K-330K

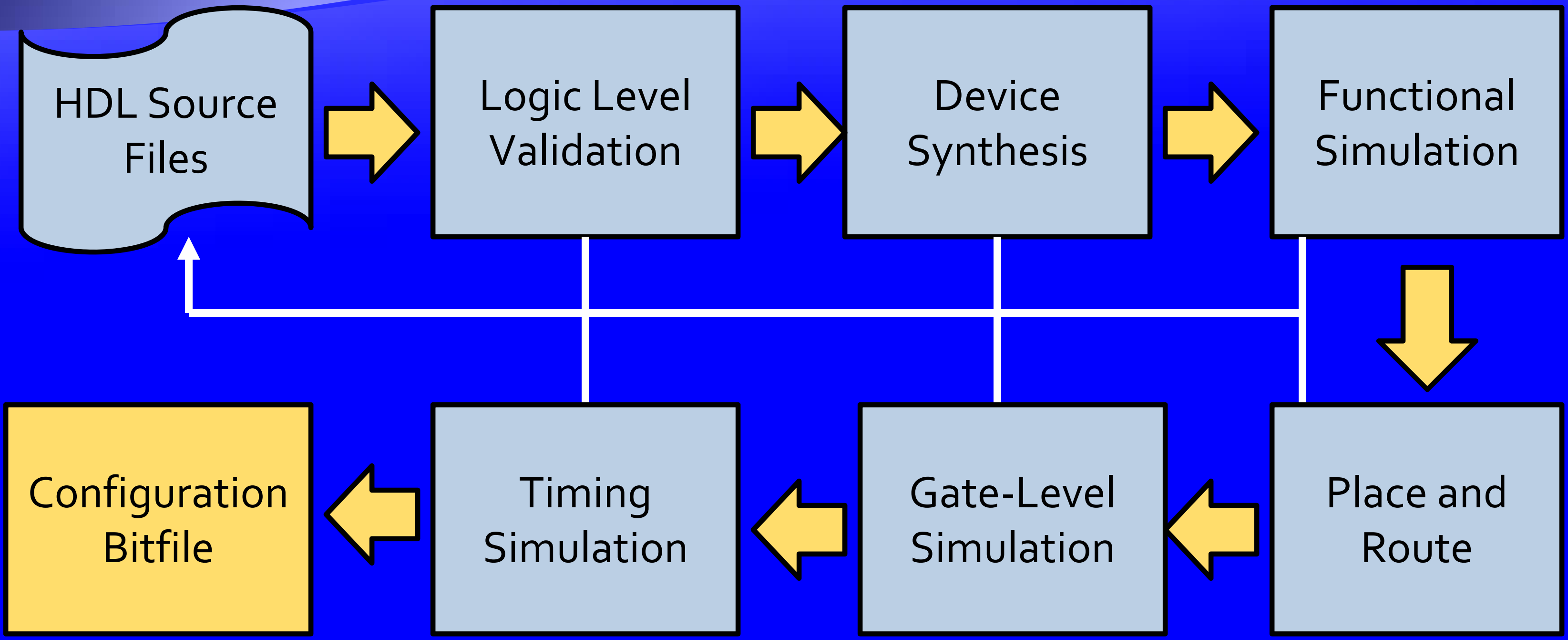
- IP/Core Sizes (rough):

I2C	UART	SPI	Bridge	DRAM-Ctrl	MCU	MPU
280-500	200-600	20-150	25-1000	120-2000	600-2000	2K-10K

High Level Description Language

- Logical expression syntax designed for easy fit into combinatorial logic blocks
  - Takes advantage of Boolean expression equivalency
- State expression syntax designed for easy match to flip-flop logic
  - Take advantage of FF equivalency circuits using combinatorial logic
- Verilog, VHDL, ABEL, PALasm, CUPL, many more

High Level Description Language



HDL Source Files

Logic Level Validation

Device Synthesis

Functional Simulation

Place and Route

Gate-Level Simulation

Timing Simulation

Configuration Bitfile

HDL - Verilog

```
module dff_sync_reset (
        data   , // Data Input
        clk    , // Clock Input
        reset  , // Reset input
        q        // Q output
);
//-----------Input Ports---------------
input data, clk, reset;

//-----------Output Ports---------------
output q;

//------------Internal Variables--------
reg q;

//-------------Code Starts Here---------
always @ ( posedge clk)
if (~reset) begin
        q <= 1'b0;
end  else begin
        q <= data;
End

endmodule
```

HDL - CUPL

```
Pin  1 = !SIZE1;
Pin  2 = !PAGE1_A18;
Pin  3 = !PAGE1_A17;
Pin  4 = !PAGE1_A16;
Pin  5 = !PAGE1_A15;

Pin  7 = !SIZE2;
Pin  8 = !PAGE2_A18;
Pin  9 = !PAGE2_A17;
Pin 10 = !PAGE2_A16;
Pin 11 = !PAGE2_A15;
```

```
Pin 15 = !CS2;
Pin 18 = !CS3;
Pin 13 = !CS4;
Pin 19 = !CS5;
Pin 14 = !CS6;
Pin 20 = !CS7;

Pin 17 = A18;
Pin 21 = A17;
Pin 23 = A16;
Pin 22 = A15;

Pin 16 = !ROM_CS;

Pin  6 = !ENABLE;
```

```
A18 = !CS6 & !CS7 & (((CS5 # CS3) & PAGE1_A18) # ((CS4 # CS2) & PAGE2_A18));
A17 = !CS6 & !CS7 & (((CS5 # CS3) & PAGE1_A17) # ((CS4 # CS2) & PAGE2_A17));
A16 = !CS6 & !CS7 & (((CS5 # CS3) & PAGE1_A16) # ((CS4 # CS2) & PAGE2_A16));
A15 = !CS6 & (CS7 #  ((CS5 # CS3) & PAGE1_A15) # ((CS4 # CS2) & PAGE2_A15) # (CS2 & SIZE2) # (CS3 & SIZE1));

ROM_CS = ENABLE & (CS5 # (CS3 & !SIZE1) # CS4 # (CS2 & !SIZE2) # CS6 # CS7);
```

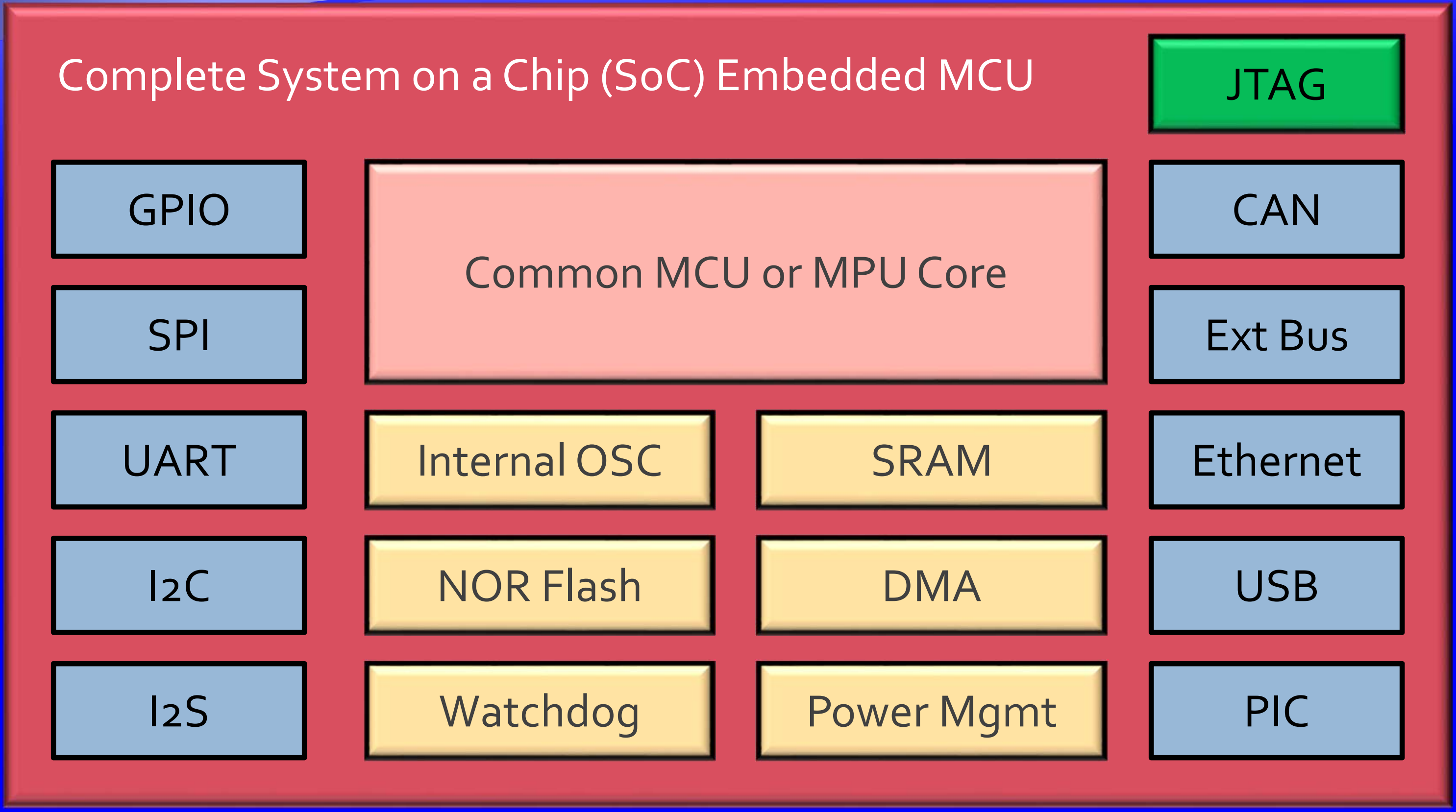
Programmable Logic vs MCUs

- Programmable Logic
  - Allows for linear (and potentially massive) parallel scaling
  - Much lower and predictable latency
  - Completely reconfigurable hardware
  - Increased cost vs dedicated logic
- Microcontroller
  - Much easier to program and maintain
  - Only constrained by ROM space not silicon area
  - Often has plenty of useful I/O cores built-in / Swiss Army knife approach
  - Bit-banging is often fast enough for custom interfacing – especially for legacy/vintage applications

Microcontrollers (MCUs)

- To many to investigate in detail:
  - ARM Cortex M3/M4
  - ARM Cortex M0
  - Atmel AVR8 & AVR32 (UC3)
  - Microchip PIC 12/16/18/24/24dsp/32MX
  - Freescale iMX
  - Intel MCS 51 (8051 and derivatives)
  - Parallax Propeller
  - Rabbit 2000/3000/4000
  - FTDI Vinculum II
  - Motorola/Freescale HC05/08 and derivatives
  - Many…. Many…. More

System On a Chip (SoC)



Complete System on a Chip (SoC) Embedded MCU

JTAG

GPIO

SPI

UART

I2C

I2S

Common MCU or MPU Core

Internal OSC

SRAM

NOR Flash

DMA

Watchdog

Power Mgmt

CAN

Ext Bus

Ethernet

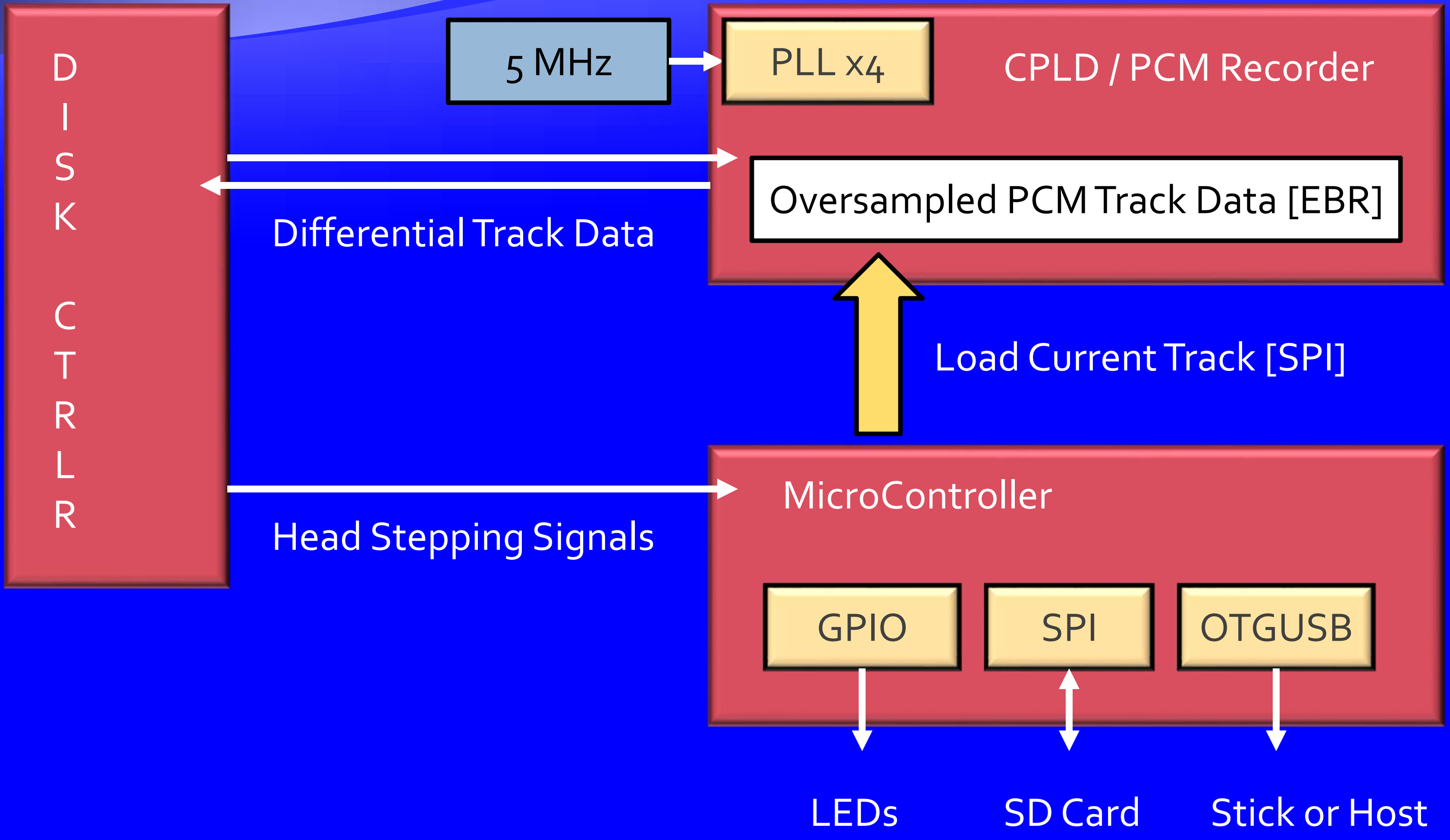
USB

PIC

Hybrid Solutions

- Most flexibility is often a board with a MCU and some programmable logic (SPLD, CPLD, or FPGA)
- Programmable logic handles fast unattended data I/O serviced by FIFOs in RAM
- MCU handles human interface, host interface, data marshalling

Flux Level Drive Emulator



D I S K C T R L R

5 MHz

PLL x4

CPLD / PCM Recorder

Oversampled PCM Track Data [EBR]

Differential Track Data

Load Current Track [SPI]

MicroController

Head Stepping Signals

GPIO

SPI

OTGUSB

LEDs

SD Card

Stick or Host

Hybrid Solutions

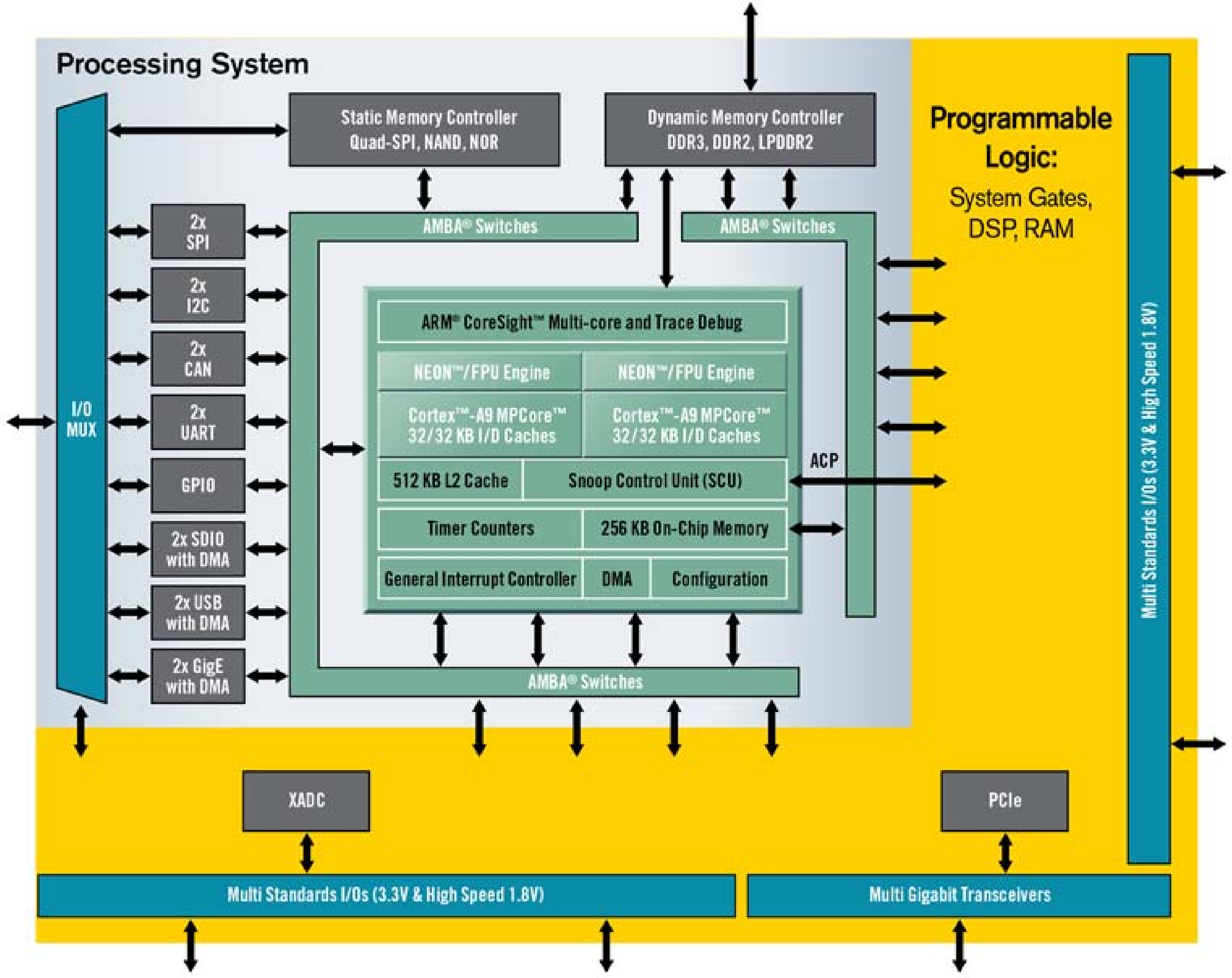
- ‘Soft’ MCU/MPU IP:
  - LEON2/LEON3 (Sparc 8)
  - OpenRISC
  - Xilinx MicroBlaze & OpenFire
  - Lattice Mico32
  - Altera NIOS
  - CPU86/Zet
  - HC05/HC08/Z80/AVR/etc
- Change and reconfigure as needs change

Hybrid Solutions

- Combine a hardeded microprocessor core + many traditional SoC cores + a programmable logic fabric on the same die.
- Increased flexibility for SoC customization

- Xilinx Virtex 4/5 FX (Power PC)
- Altera Excalibur (ARM9)
- Altera/Intel Partnership (Atom 5xx+ w/ Stratix 9)
- Atmel fpSLIC (AVR8)
- Xilinx Zynq-7000T EPP (Virtex/Kinetix 5 w/ dual Cortex A9MP @ 800 + SoC cores)

Hybrid Solutions



Microprocessors

- ARM Cortex A8/A9 & ARM 15
- PowerPC e500/600+
- Intel i960
- Freescale’s true 68Ks (Coldfire) & PPC (PowerQUICK II)
- Renesas/NEC/Hitachi SH4 derivitaves
- STMicro SPEAR & ARM based SoCs
- Zilog Z8/eZ80
- MIPS 4K/24K/74K embedded cores
- Marvell PXA/Shiva/Kirkwood
- Even ‘new’ Intersil and Intel 80188/80186/386/486
- Many more

Retro-projects by others

CatWeasel

RetroClinic DataCentre
for BBC Model B

Retro-projects by others

BlueFlash – Apple II
Bluetooth/Disk Controller

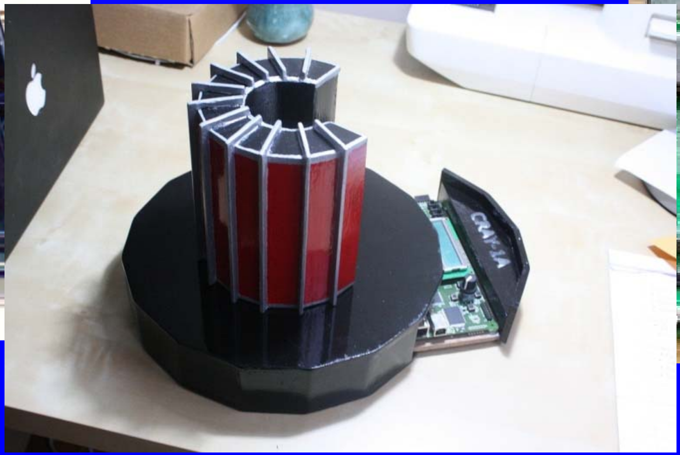
FPGApple – Modular Apple II interface system

- 1541 Emulators [RAJ]
- LISA disk emulator [David]
- V-SID – Emulated SID + Post processing on Altium

Retro-systems by others

1chipMSX

Cray-1A



MiniMig

SAM440/460ex

C-ONE commercial multi-machine emulator

N8VEM project

Possibilities

- Can add USB support to any vintage peripheral
- Can add infinite RAM and disk storage to any vintage system
- Can add USB peripherals to vintage systems
- Can add modern network and display interfaces to vintage system
- Emulate entire vintage systems
- Recreate specific components/IC

Possibilities

- USB Host Controllers:
  - Atmel AVR32UC3
  - Microchip PIC32MX (MIPS R4K)
  - FTDI Vinculo II (VNC2)
  - Cypress EZ-OTG/EZ-Host (CY16)
  - STM32F4 (Cortex M3/4)
- FPGA w/ UTMI/ULPI PHY or HCI

Legacy->Modern Challenges

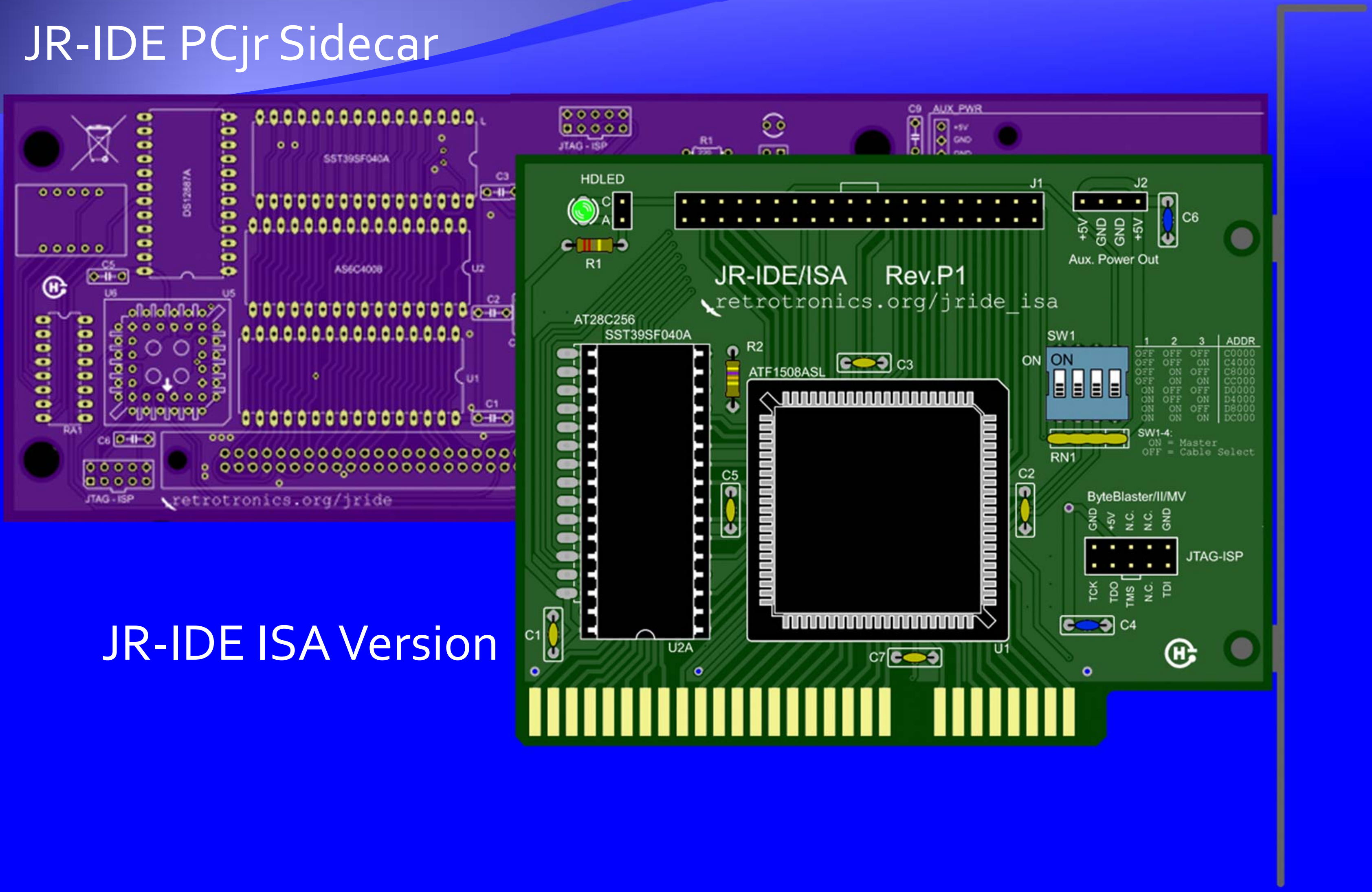
- SMT vs Through Hole
  - New soldering techniques
  - Breakout modules
- Nothing is +5V TTL
  - Buffers / Bus Tranceivers
  - LDO Regulators and Switching Supplies
  - Transient Voltage Suppression
  - High speed transients

Fabrication

- Don’t be afraid of SMT/SMD
- EDA is easy to learn but takes experience to perfect
- Dorkbot PDX by the square inch quick turn
- Soldering techniques
  - Fine tip iron and good eyes
  - Hot Air / Paste Stencils
  - Drag Soldering
  - Reflow Oven / X-Ray / Microscope

Retrotronics.org Pipeline

JR-IDE PCjr Sidecar



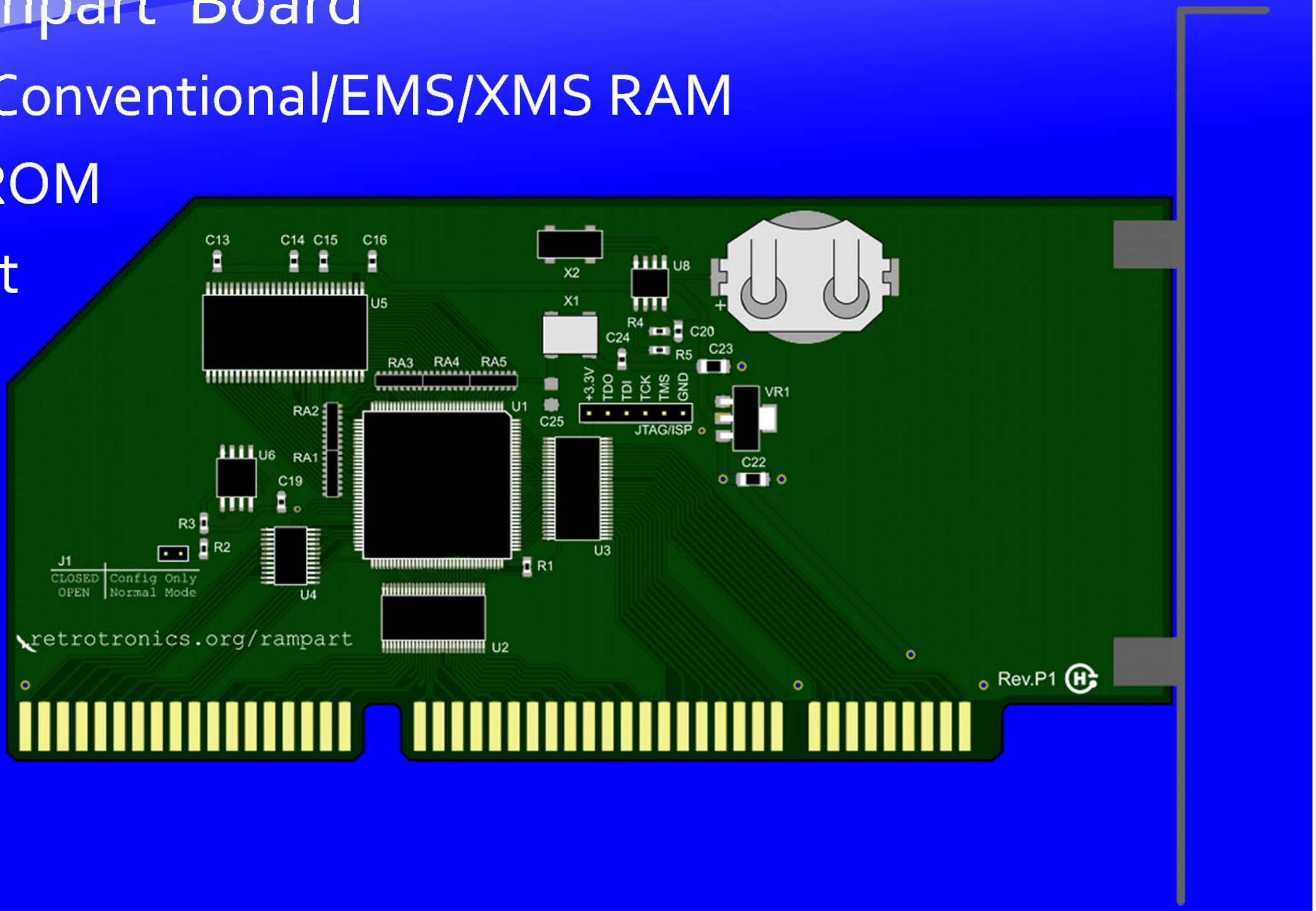
1	2	3	ADDR
OFF	OFF	OFF	C0000
OFF	OFF	ON	C4000
OFF	ON	OFF	C8000
OFF	ON	ON	CC000
ON	OFF	OFF	D0000
ON	OFF	ON	D4000
ON	ON	OFF	D8000
ON	ON	ON	DC000

SW1-4:
ON = Master
OFF = Cable Select

JR-IDE ISA Version

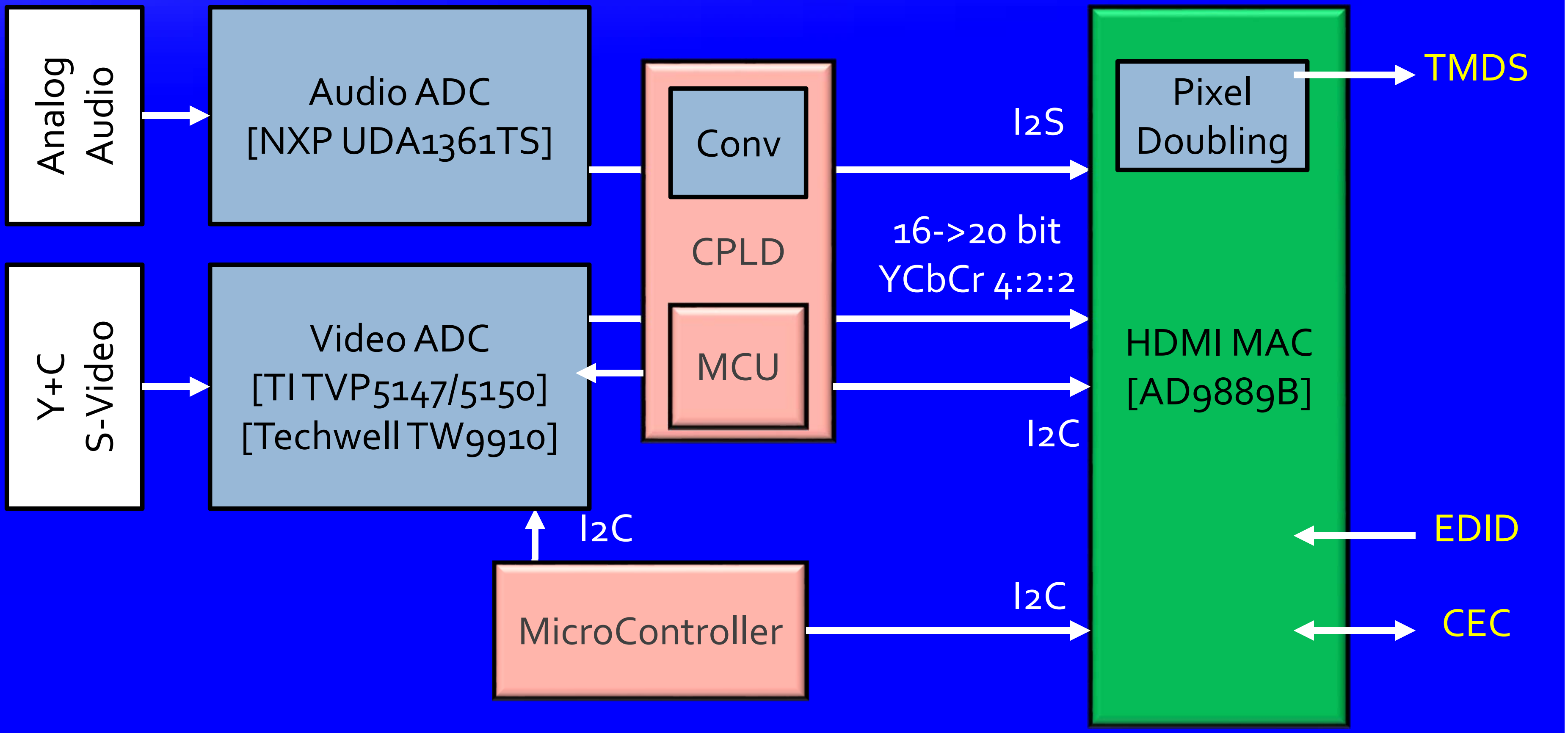
Retrotronics.org Pipeline

- ISA 'Rampart' Board
  - 32MB Conventional/EMS/XMS RAM
  - 4 MB ROM
  - 8/16 Bit
  - PnP



Retrotronics.org Pipeline

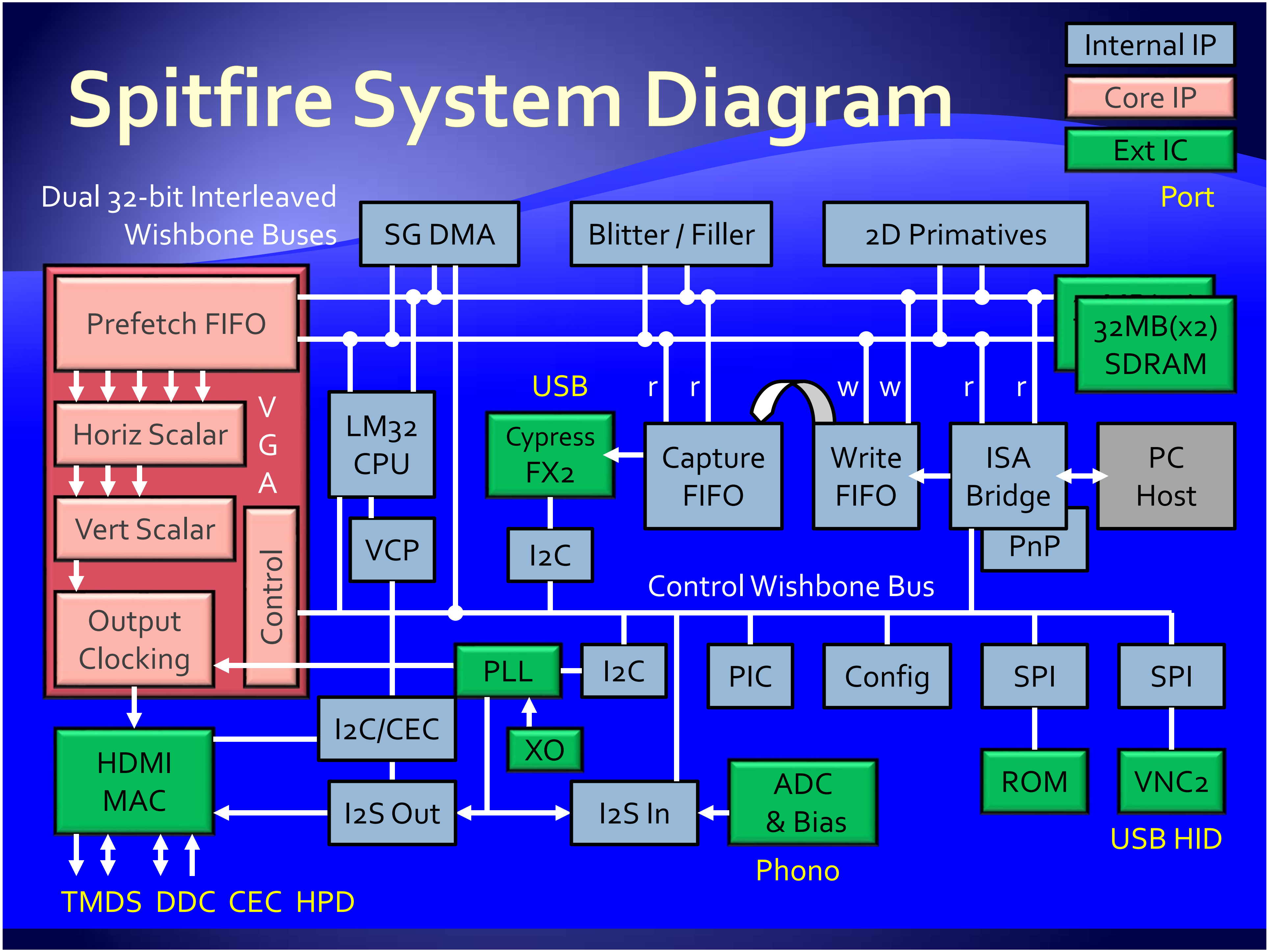
- C=64 Native HDMI
  - Replace RF Modulator w/ S-Video -> HDMI



Retrotronics.org Pipeline

- ISA Bus Analyzer
- Spitfire ISA Upscaling VGA/HDTV Card
- 8088 In-Line Emulator
- Modular Motherboard & Chipset

Spitfire System Diagram



Demonstrations

- PCjr Sidecar
- FPGA Eval Board
- EDA Software – Eagle
- Soldering Techniques

I hope I didn’t suck

- But I probably did!

Thank You!!!