Introduction to Embedded System Design

Lecture - 1: Course Coverage. Preliminaries. Terminology.

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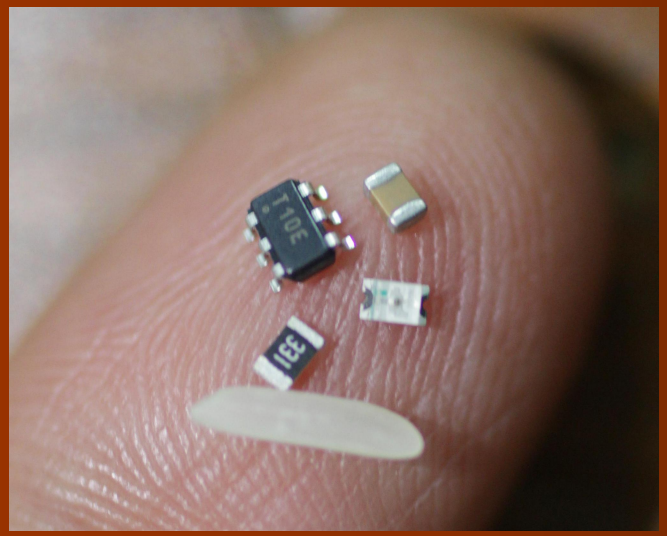
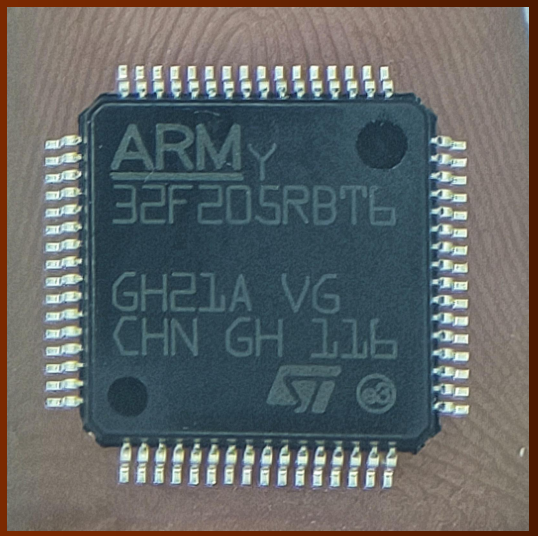
Course Objectives - 1

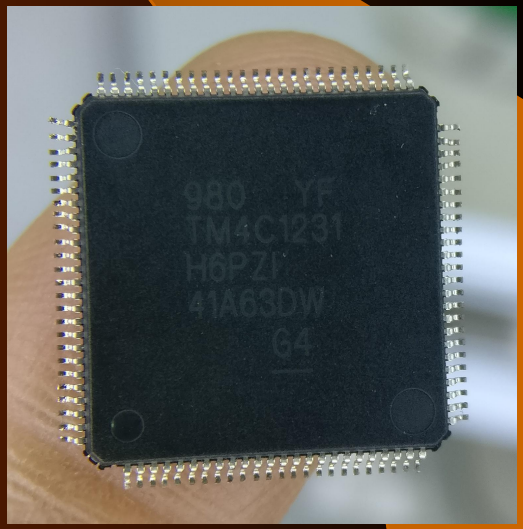
- Learn about the elements of embedded systems in general and their applications.
- Learn embedded system design using a building block approach. These blocks cover input devices and sensors, output devices and actuators, communication links, storage devices, power supply and of course the embedded computer.
- Learn various ways of implementing the embedded computer block, specially a Microcontroller. Microcontrollers are complete computers on a single chip.

Course Objectives - 2

- These microcontrollers have great diversity in terms of size and in terms of performance and we will give you some idea about that.







Course Objectives - 3

- Learn about TI's MSP430 - architecture, programming and interfacing. We will teach you Embedded C programming and how to write, debug and download the compiled program into the memory of the microcontroller.
- You will also learn about aspects of complete system design, including testing and debugging.
- At the end of this course, you can expect to be able to design simple embedded systems from scratch to finish.

Course Objectives - 4

- But larger motive is for us to make you fall in love with electronics.

- To enthuse you to build circuits and systems - From simple circuits to more complex ones and eventually, to be able to visualize and build complete systems.

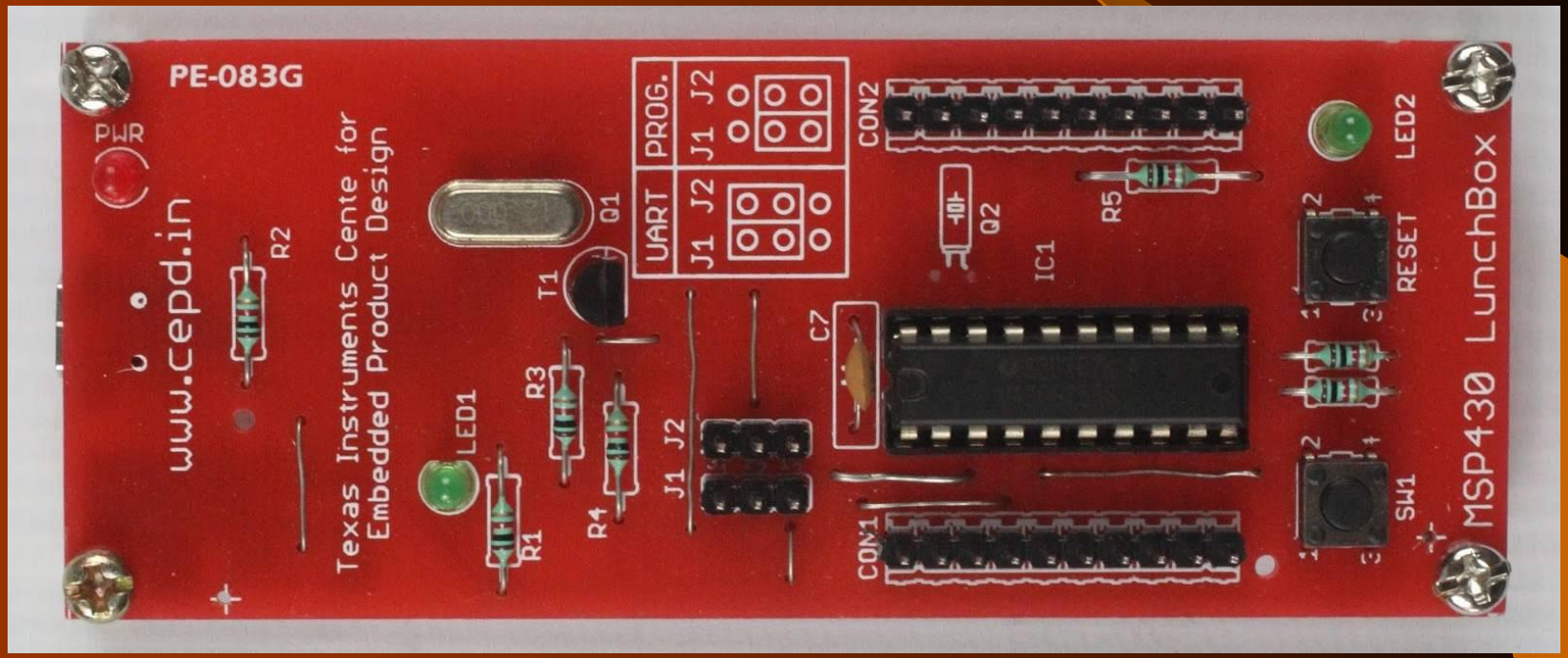
Prerequisites for the Course

We expect you to know

- How basic electronic components and circuits work
- Elements of digital circuits and systems, including an idea about Finite State Machines.
- Some experience in C programming
- Idea of computer architecture

Logistics - 1

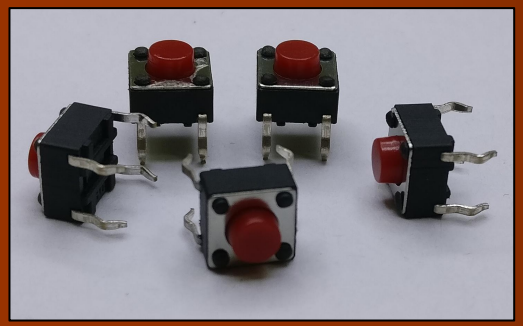
MSP430 LunchBox Microcontroller Evaluation Kit



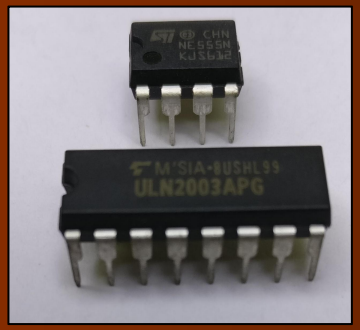
http://dvgadre.blogspot.com/2017/01/make-yourself-msp430-lunchbox-for-1.html?m=1

Logistics - 2

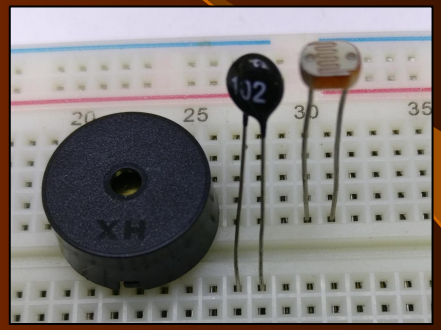
Components Kit



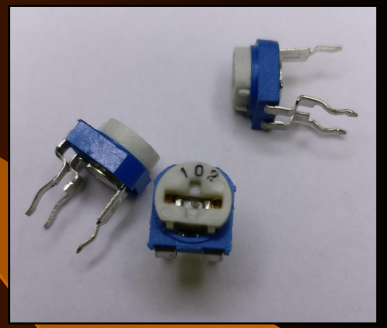
Switches



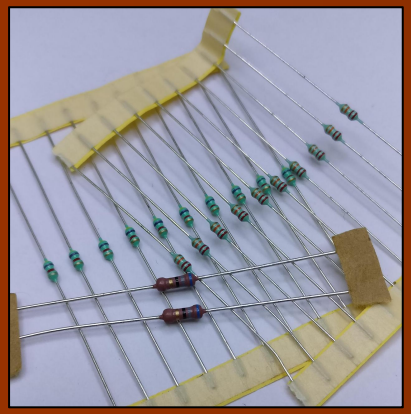
ICs: ULN2003 and 555



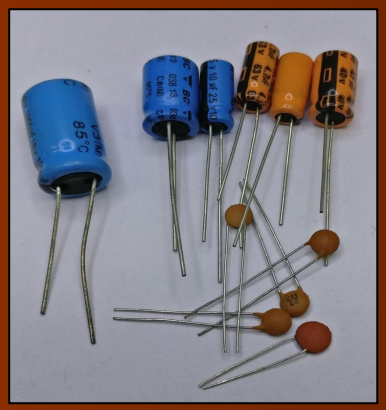
Buzzer, NTC and LDR



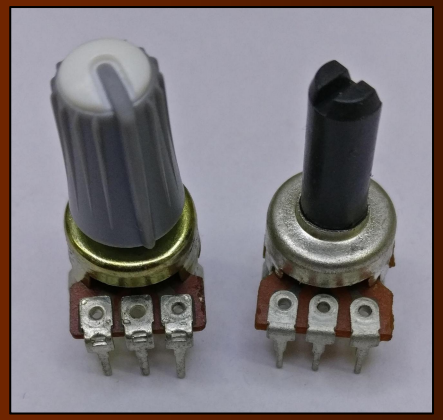
Preset



Resistors



Capacitors

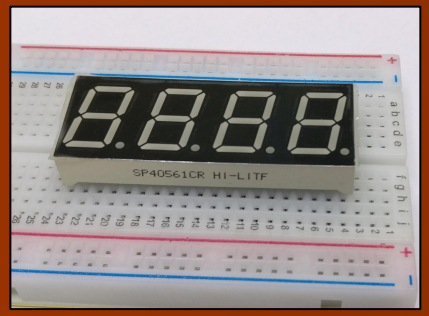


Potentiometer

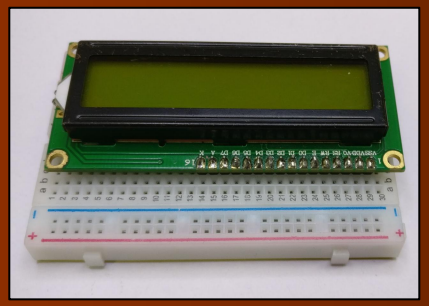
LEDs

Logistics - 2

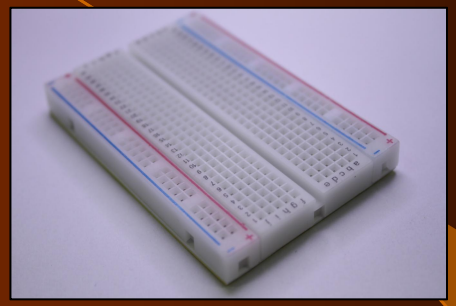
Components Kit



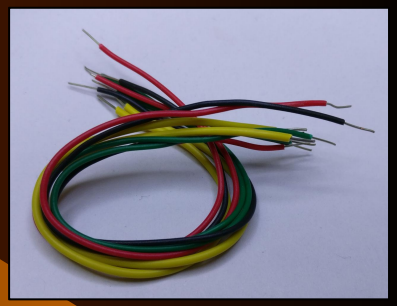
Seven Segment Display



16 x 2 LCD

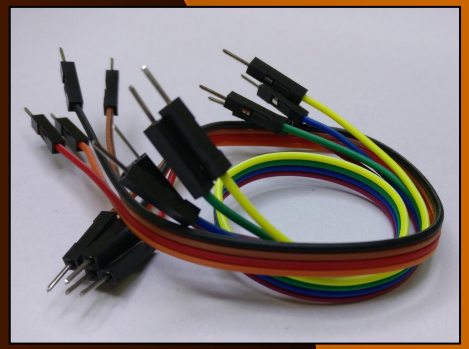


Breadboard



Hookup wires

- You should also be familiar with Fritzing and be able to use it: https://fritzing.org/home/
- You should also be familiar with Eagle CAD: https://www.autodesk.in/products/eagle/overview



Jumper Wires

Definitions and characteristics of an Embedded System

- *A combination of computer hardware and software, and perhaps additional mechanical or other parts, designed to perform a dedicated function.*
- *Any computer system whose end objective is not primarily computational.*

Definitions and characteristics of an Embedded System

- *Any computer system other than the traditional desktop or laptop system. Lately, the smartphone also falls in the category of general purpose computing device!*
- *In some cases, embedded systems are part of a larger system or product, as is the case of an airbag deployment system or anti-lock braking system in a car.*

Ubiquity of Embedded Systems

- Work place: Printers, scanners, network switches
- Banks: ATM, Passbook printer.
- Hospitals: Medical Equipment
- Industry: Industrial equipment, automation.
- Agriculture: Drip irrigation, soil quality instrument.
- Supermarkets: POS, scanner.
- Defence and Space: Missiles, rockets, satellites, space probes.
- Transport: locomotives, cars.
- Telecom: Mobile broadband equipment, switches, Telephone exchanges.
- Entertainment: Projection systems in Cinema halls, 4D seats

Embedded System Application Areas

- Small and single microcontroller applications: small toys, home gadgets etc.
- Control and automotive systems: ABS, Cruise control etc.
- Distributed Embedded Control: Networked Industrial control applications, automotive.
- Networking: Network switches, routers.
- Critical systems: Nuclear, medical and aviation devices.
- Robotics: Warehouse robots, assembly line robots.
- Computer peripheral applications: Portable HDD, Printers, scanners.
- Signal processing: Radar, Security cameras.

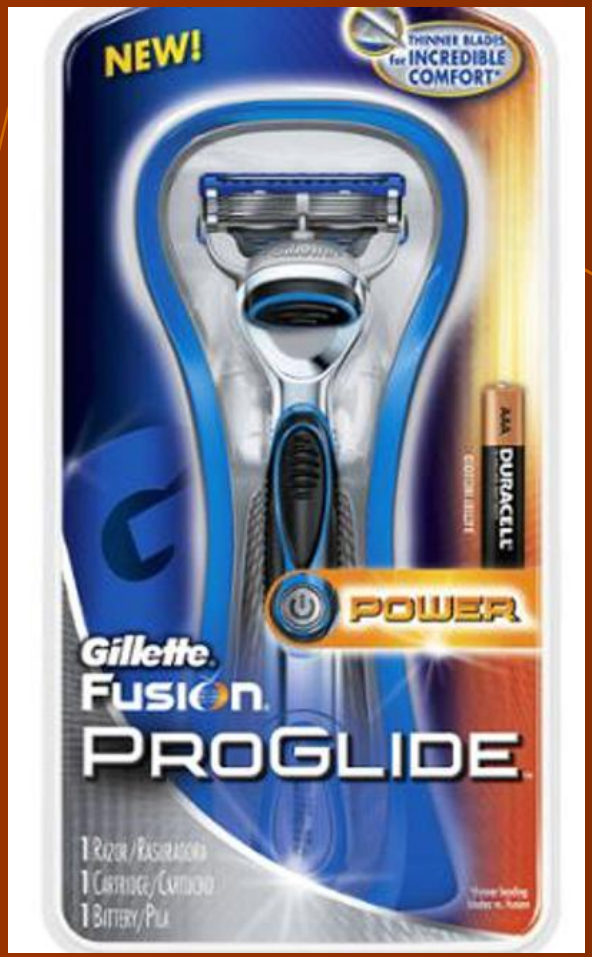
Examples of Embedded Systems at Home

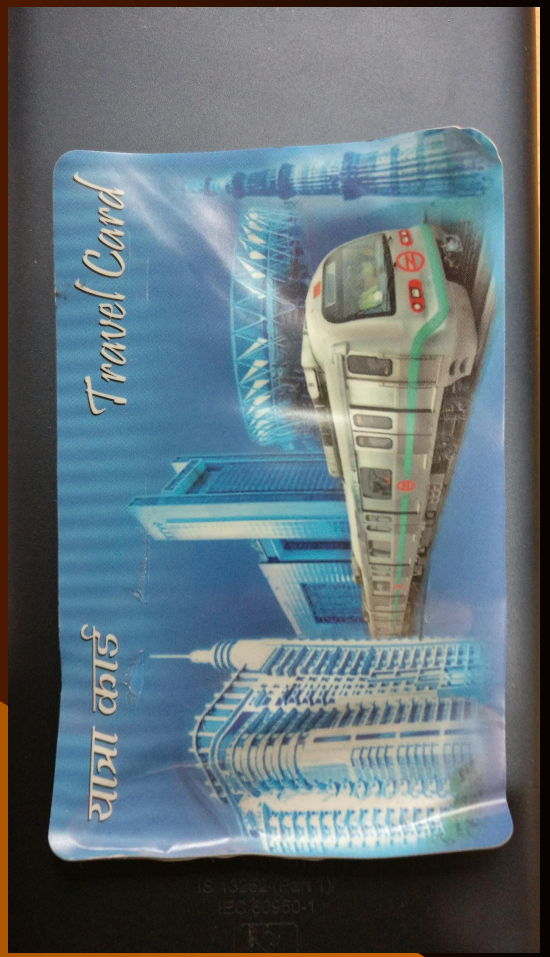
- Communication: Mobile phone, Landline phone, Modem.
- Entertainment: TV, TV Remote!, Set top box, Music system, Noise cancelling headphone, digital picture frame.
- Convenience: Washing machine, RO Water Purifier, Microwave oven, Shaving razors (certain kinds).

Examples of Embedded Systems at Home - 2

- Comfort: Air conditioner, fancy hot water geyser, Mood lamp.
- Health: Treadmill, blood sugar and pressure measurement, Fitness Tracker watches.
- Utilities: Electricity (electronic) meter, RFID tags.
- Transport: Car, Scooter/Motorcycle, Electric bicycle.

Unbelievable Examples





https://www.element14.com/community/thread/15217/l/tis-msp430c092-mixed-signal-microcontroller-in-gillette-razors?displayFullThread=true

Embedded Computers in Home Gadgets? Why?

Let us consider two examples:

1. air conditioner
2. washing machine

Air Conditioner

- A Compressor using an AC motor, coolant and heat exchanger
- Mode Selector Switch to select cooling: Low, Medium, High
- Relay/Contactor
- Thermostat (Bi-metallic strip type)

Air Conditioner with Embedded Computer

- A Compressor using an AC motor, coolant and heat exchanger
- Digital Display of Temperature: Set-point and ambient
- Remote Control Operation
- Relay/Contactor
- Semiconductor/Thermocouple based temperature sensor

Washing Machine

- Outer Enclosure, middle container and inner tumbler.
- Two pipes in middle container: Water inlet and outlet with valves.
- Inner tumbler with holes to let water fill.
- Selector switch with time setting

Washing Machine with Embedded Computer

- Two pipes in middle container: Water inlet and outlet with valves.
- Inner tumbler with holes to let water fill and agitator.
- Selector switch with various settings for clothes type, wash cycle.
- Digital Display for modes, time for wash cycle
- Water level sensor, dirt sensor etc.
- Motor direction control for agitation.
- Ability to resume wash cycle after power failure, audible alerts etc.

Embedded System: Some Observations

- Embedded Systems is a big, fast growing industry (For India alone, US$ 500 billions by 2020; 500*1000*7 Crore Rupees = 35 Lakh Crore Rupees.)
- Microcontrollers form quite common core for embedded systems.
- The Software running on this core makes the embedded system tick…

Related Fields

- Physical Computing
- Cyber Physical System
- Internet of Things (IoT)
- Embedded Systems

Comparing Embedded System (ES) and General Purpose (GP) Computing Systems

- ES are dedicated to specific tasks.
- ES can be implemented using wide variety of processors, even generic or custom.
- ES are cost sensitive.
- ES operate under real time constraints

ES Vs. General Purpose Computing Systems

- ES are often designed to operate in extreme environmental conditions.
- ES usually run out of ROM.
- ES have resource constraints.
- ES are infrequently reprogrammed.
- ES have hard reliability and correctness requirements.

Demystifying Terminology

- Computer: CPU, Memory and I/O Ports.
- Microprocessor: CPU on a single chip
- Microcomputer: Microprocessor + Memory + I/O on a single PCB
- Microcontroller: Microcomputer on a single chip
- System on Chip (SoC): Microcontroller + programmable analog!

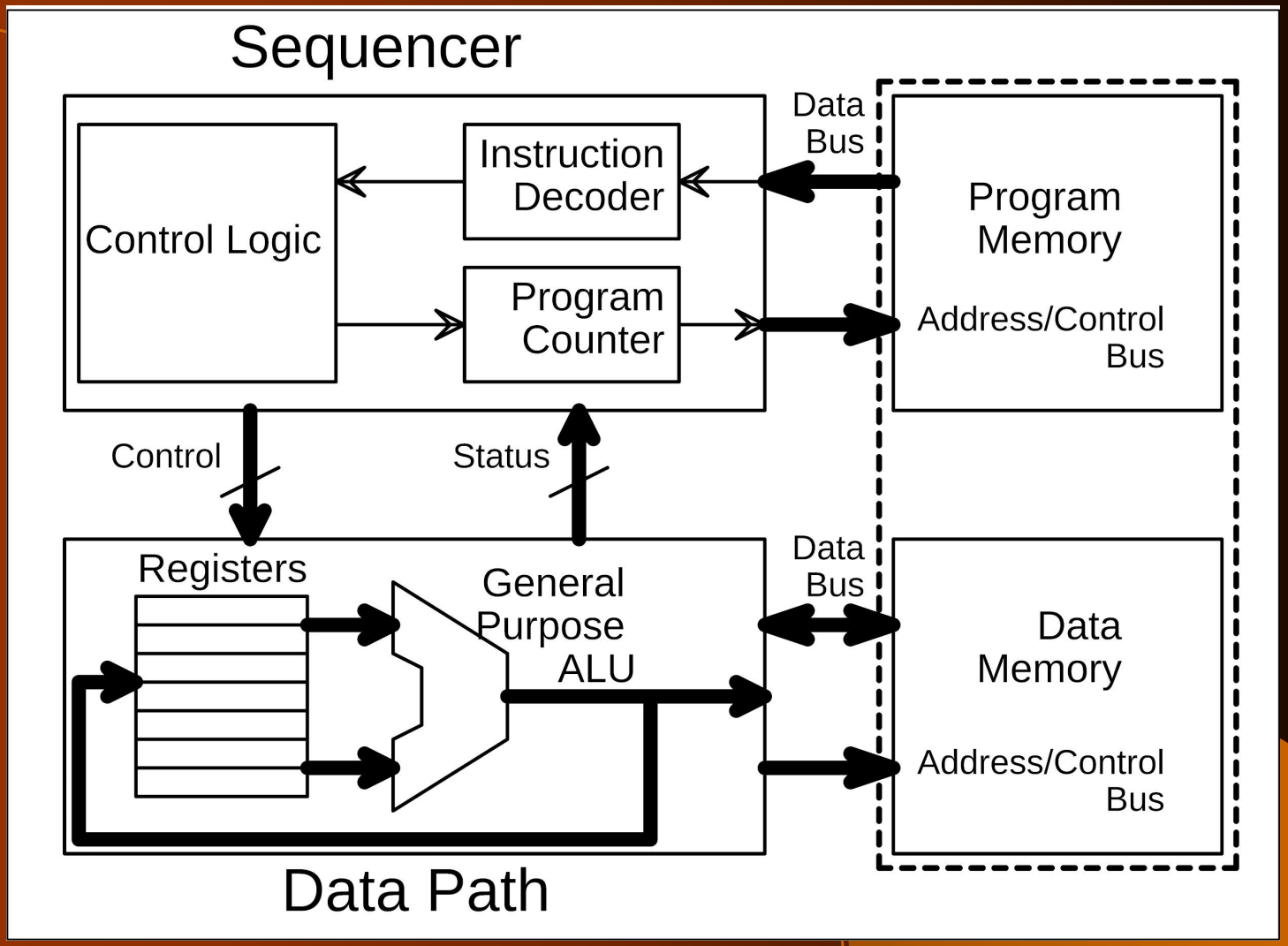
System on Chip

- Microcontroller + programmable Analog subsystem on a single substrate
- General context: Microprocessor/Microcontroller + custom functional units on a single substrate

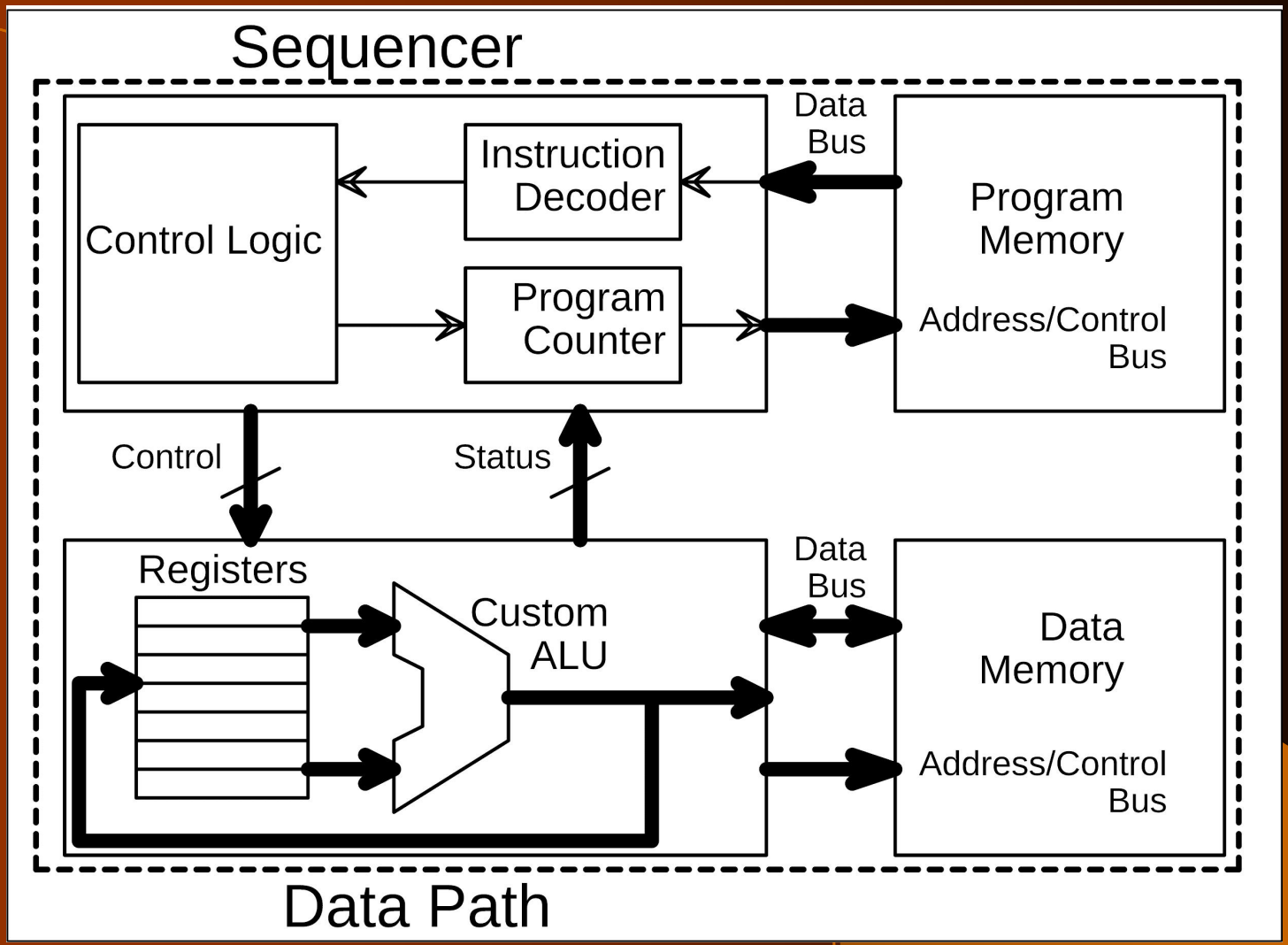
Implementing the Embedded Computer

- General Purpose Processor (GPP)
- Application Specific Processor (e.g. Microcontroller, Digital Signal Processor)
- Single Purpose Computer

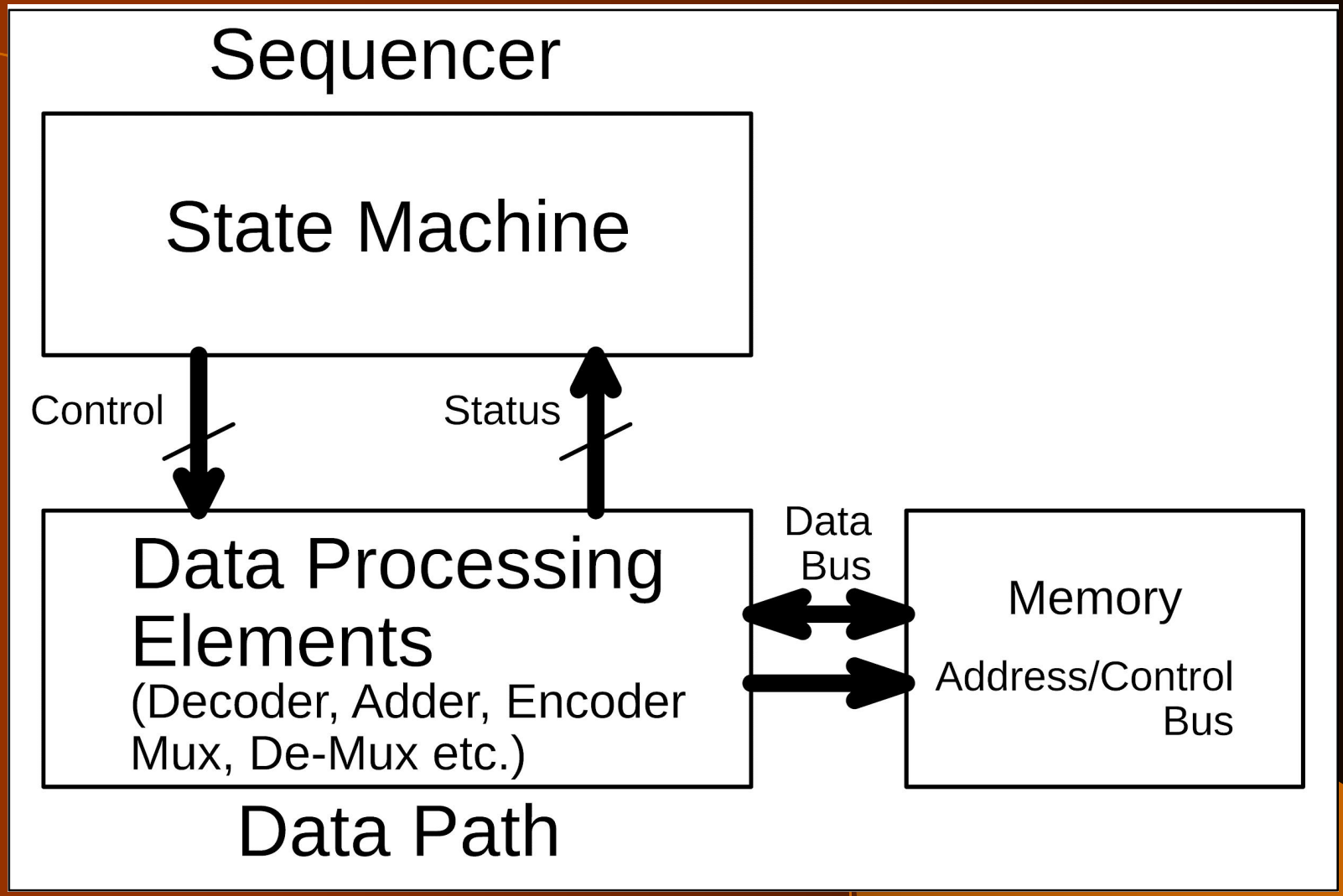
General Purpose Processor



Application Specific Processor

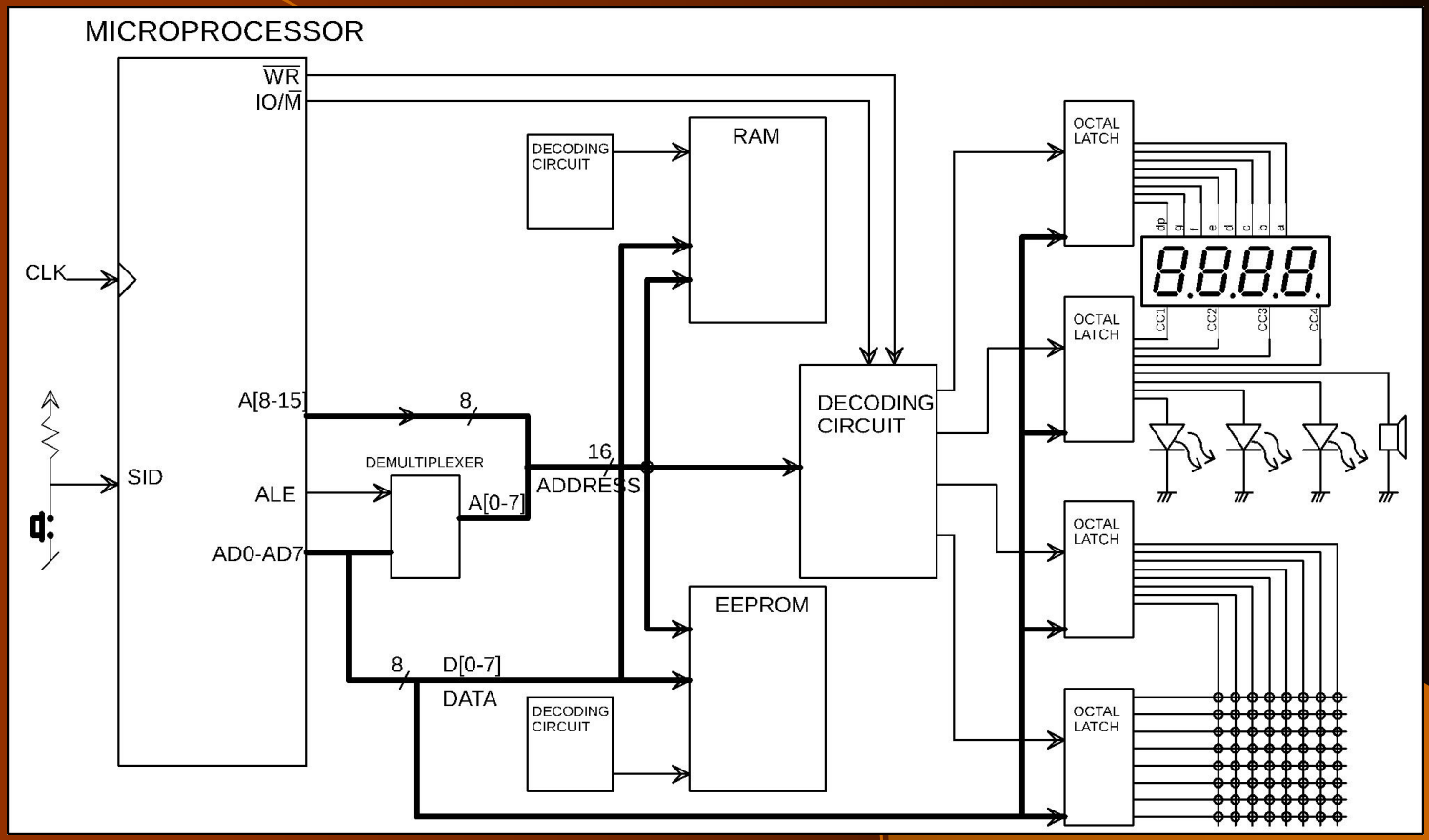


Single Purpose Processor



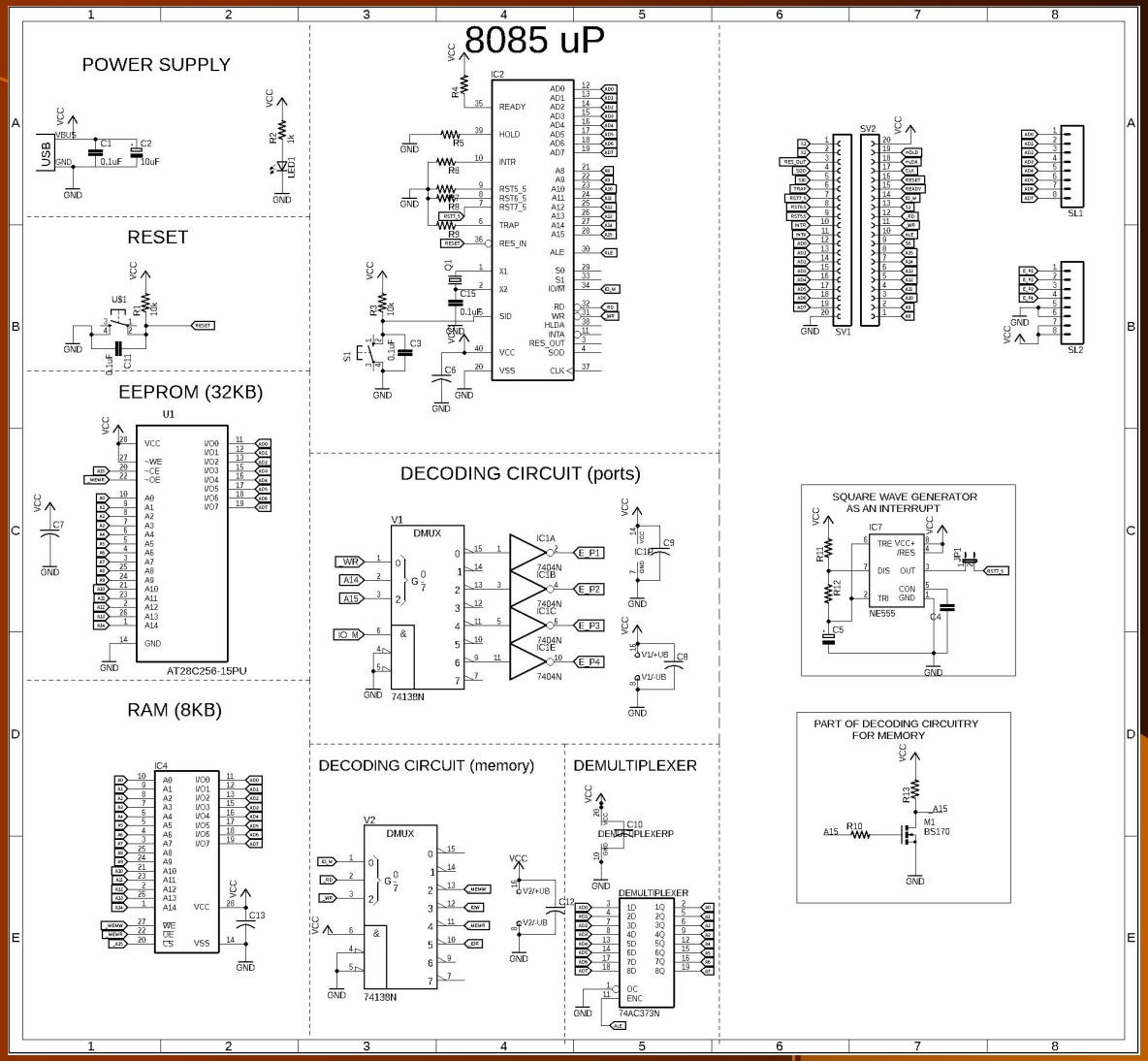
General Purpose Processor Based Embedded Computer

Block diagram of 8085 Based Roulette

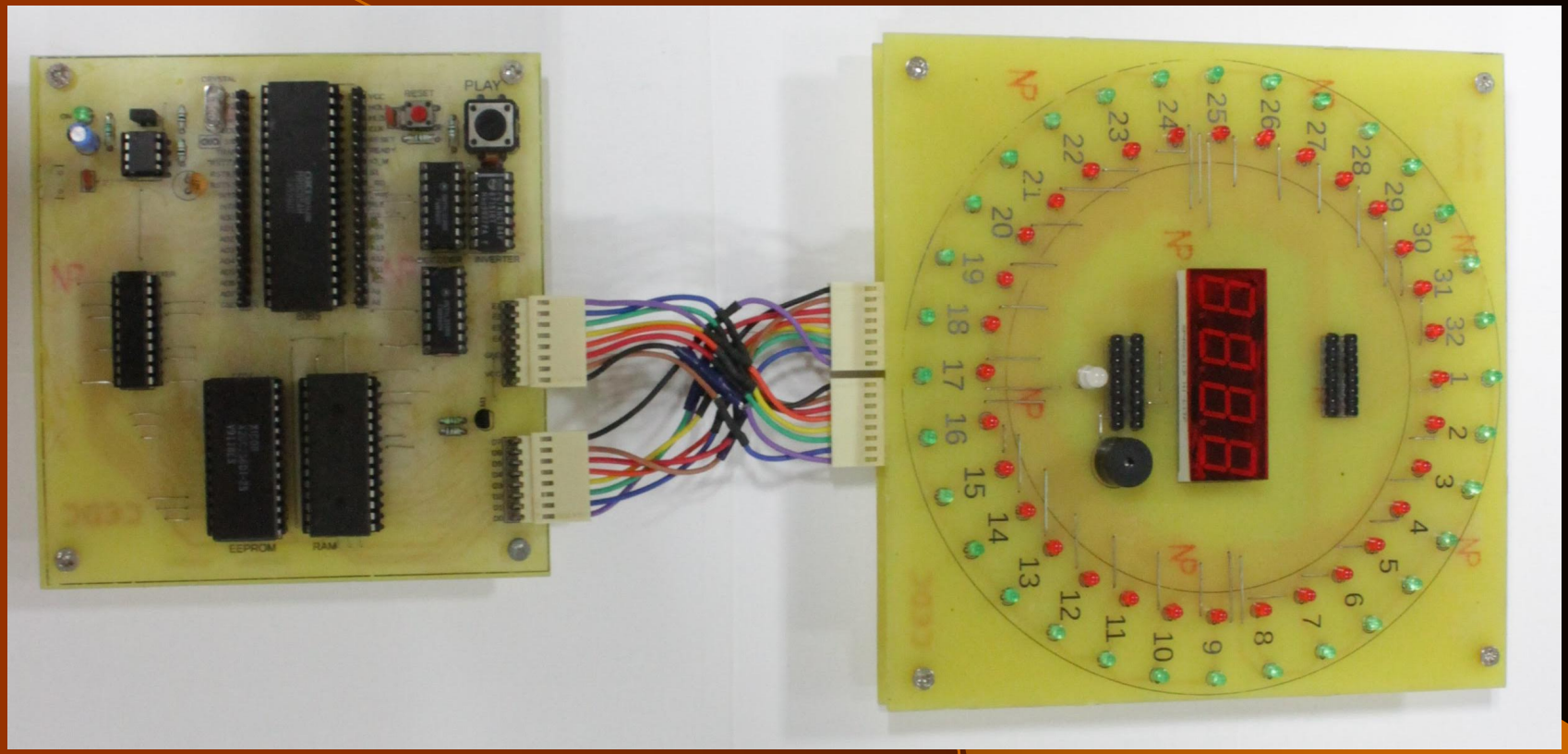


General Purpose Processor Based Embedded Computer

Schematic diagram of 8085 Based Roulette

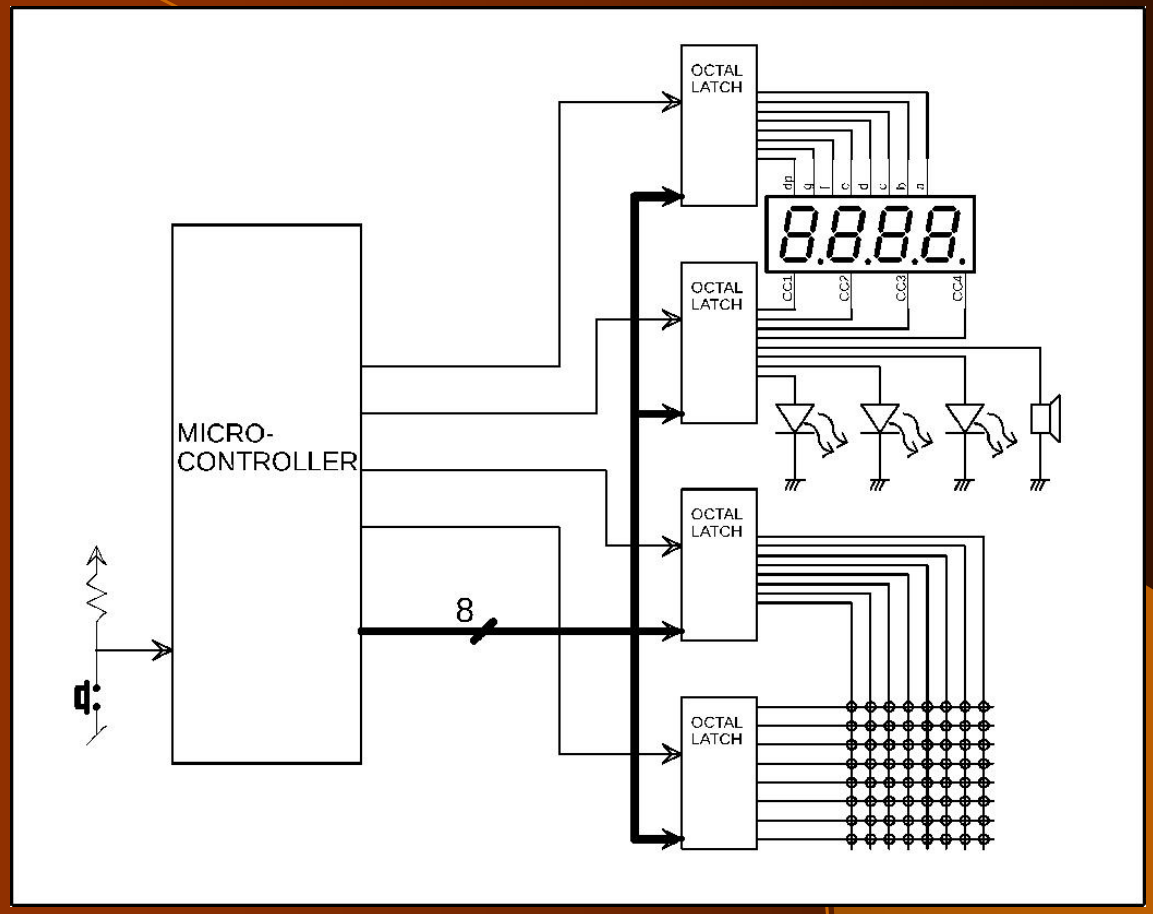


Photograph of the 8085 based Roulette Wheel Game



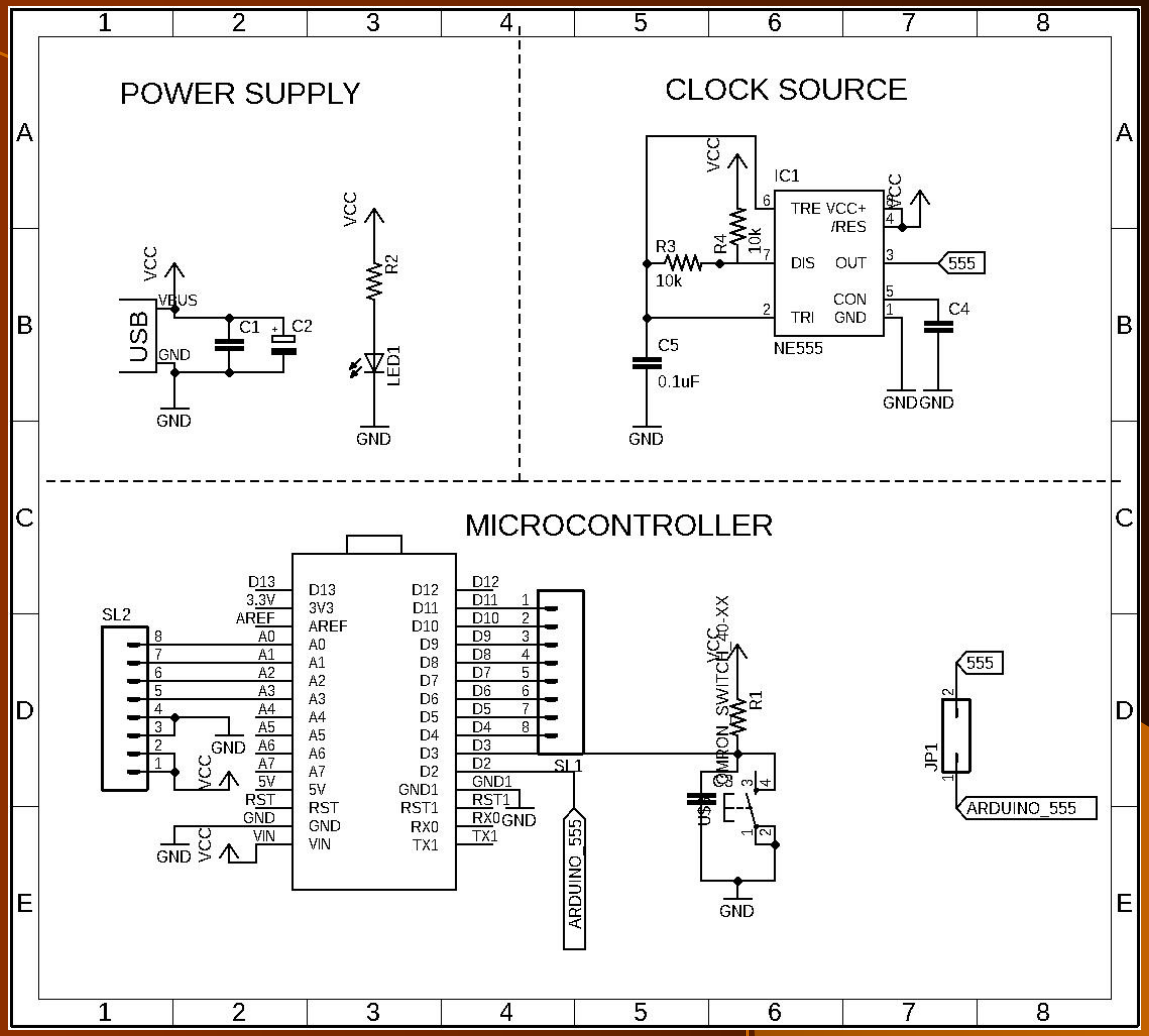
Application Specific Processor Based Embedded Computer

Block diagram of Arduino Based Roulette

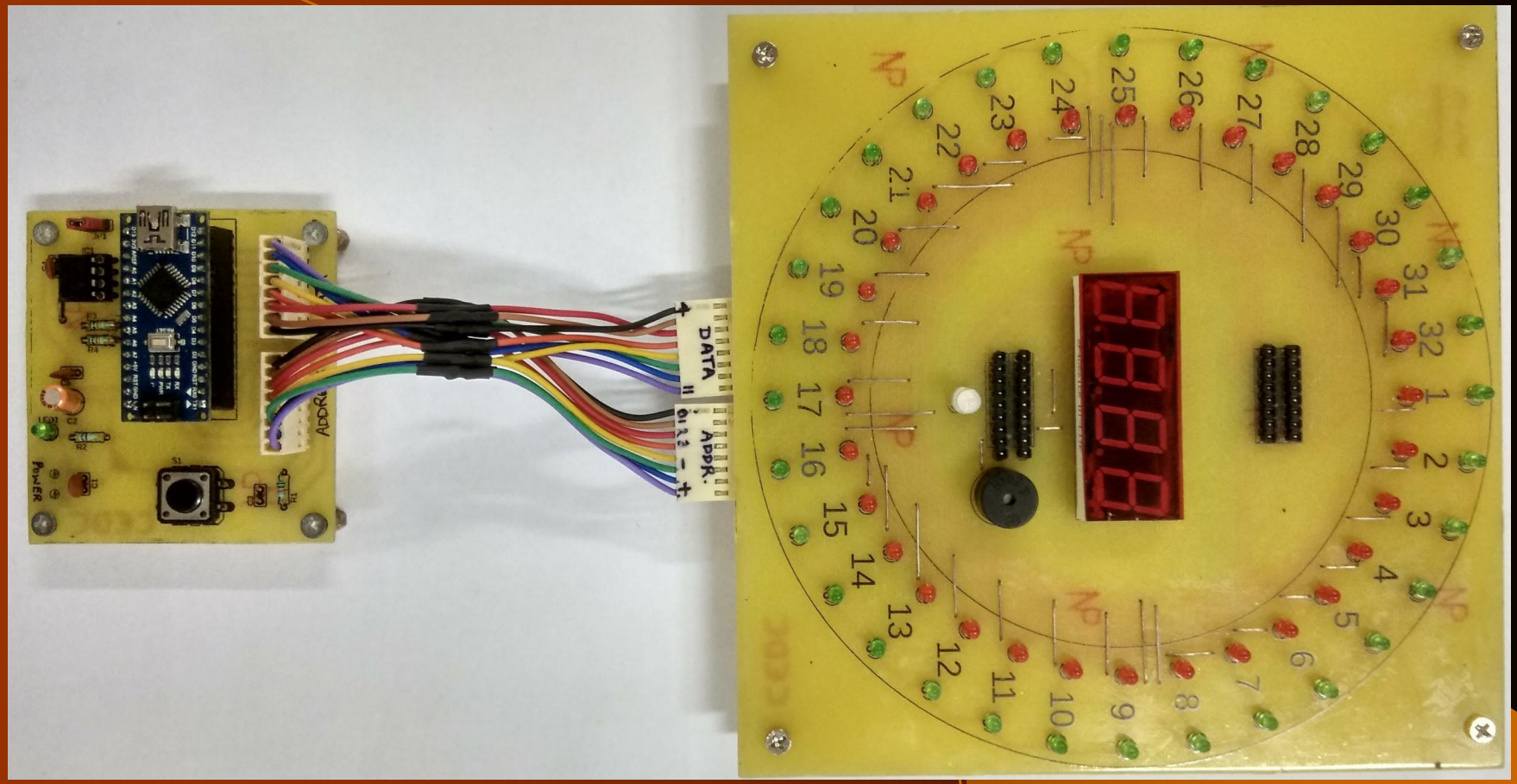


Application Specific Processor Based Embedded Computer

Schematic diagram of Arduino Based Roulette

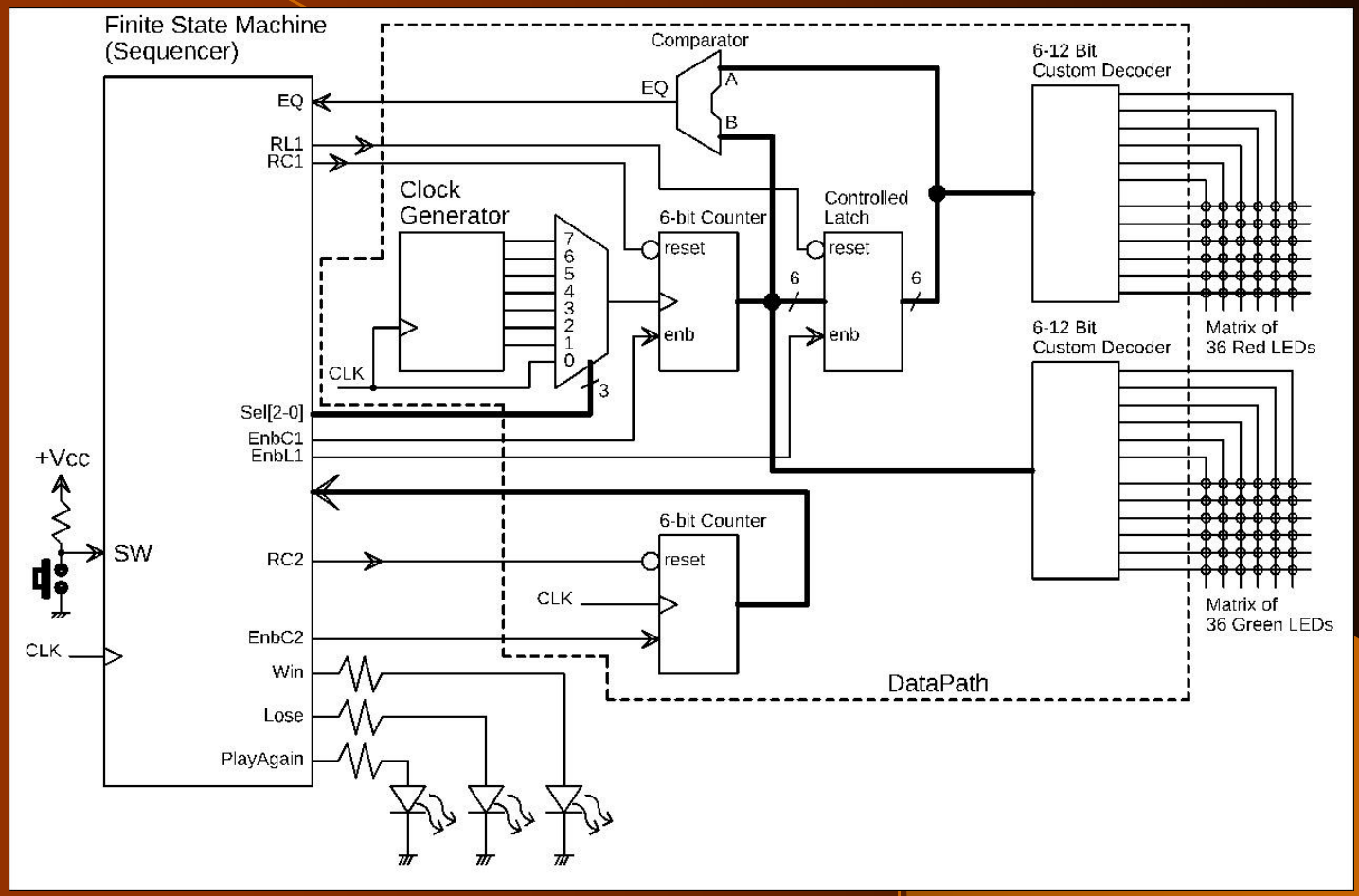


Photograph of the Arduino Based Roulette Wheel Game



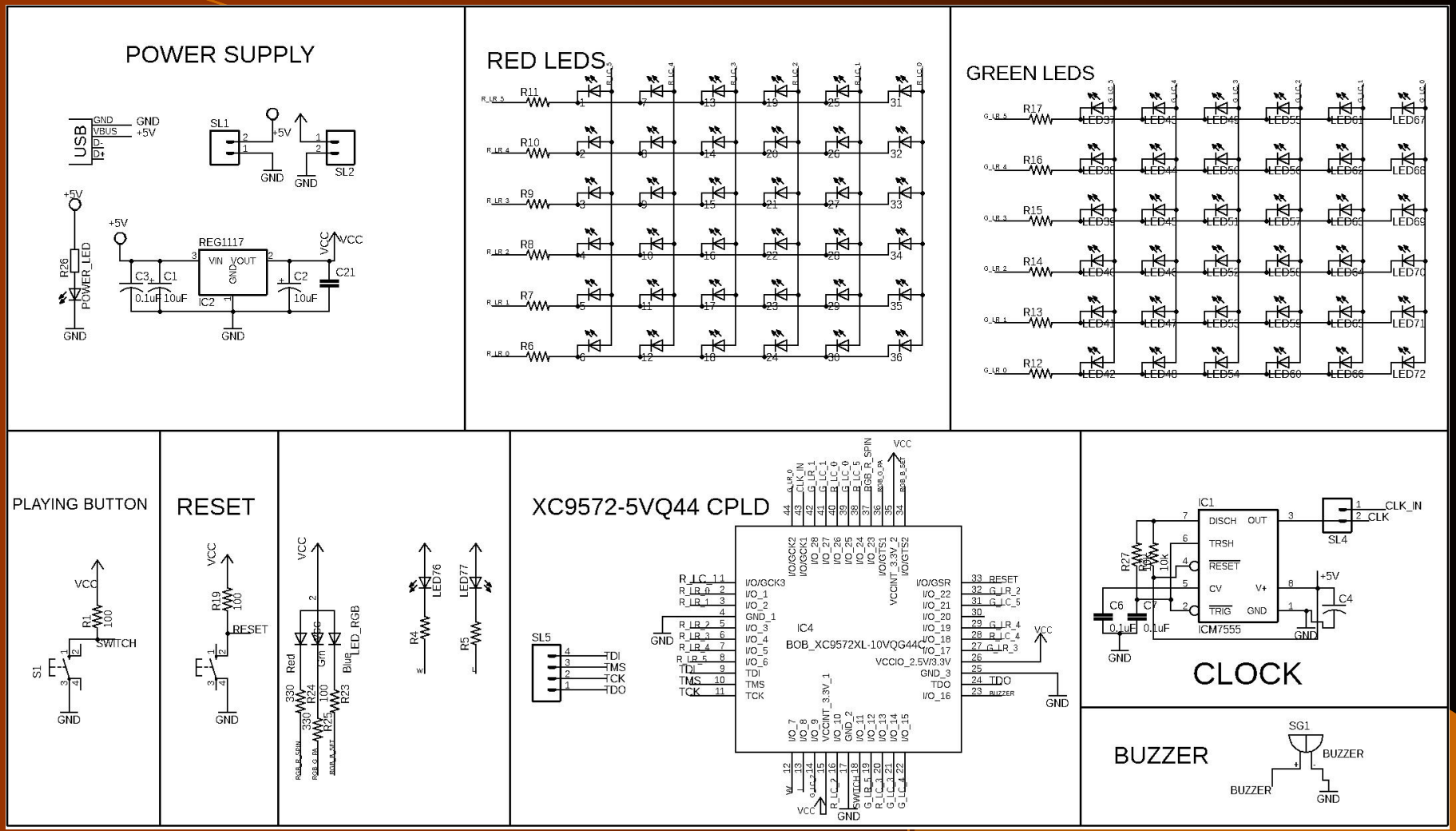
Single Purpose Computer Implementation

Block diagram of CPLD Based Roulette

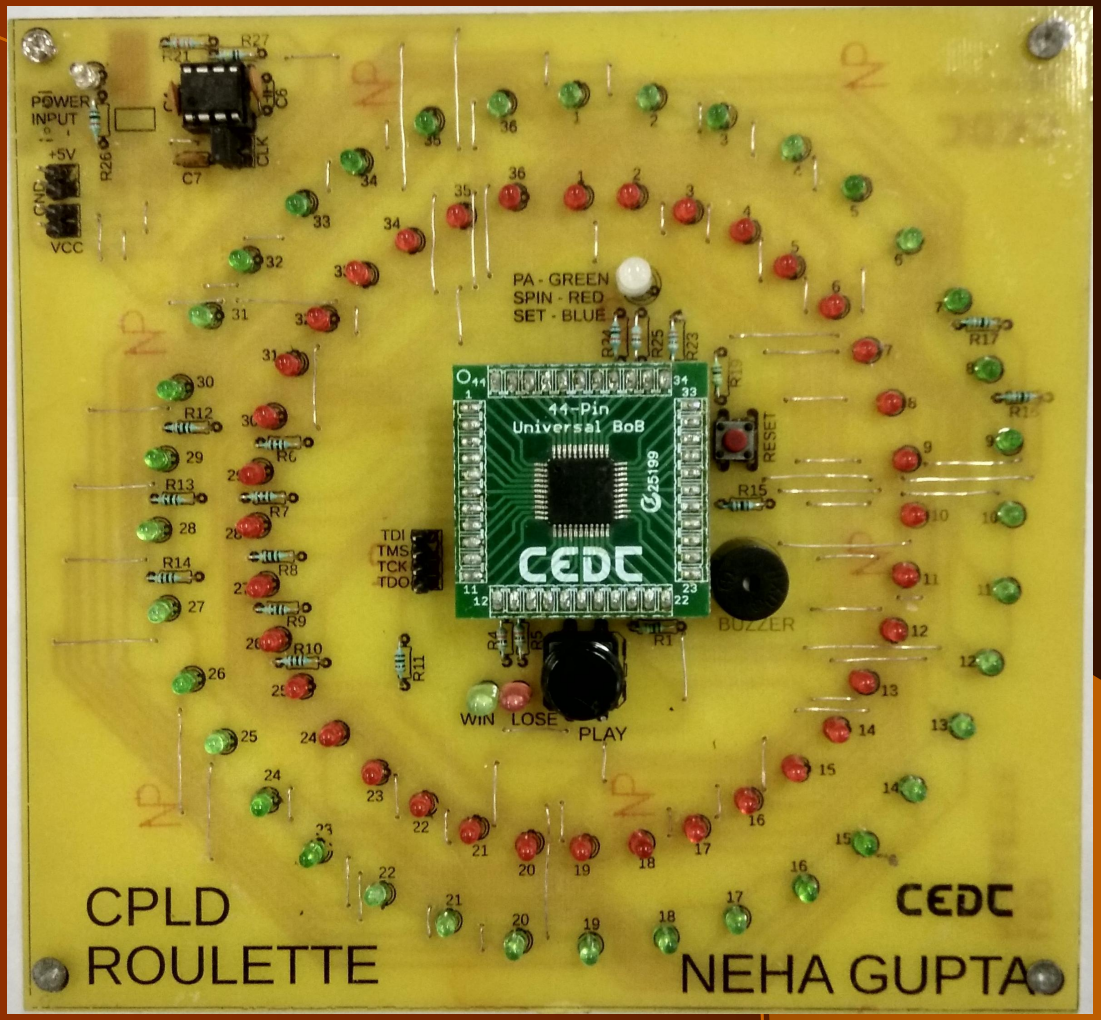


Single Purpose Computer Implementation

Schematic diagram of CPLD Based Roulette



Photograph of the Single Purpose Computer Implementation



Design Processes: Past and Present

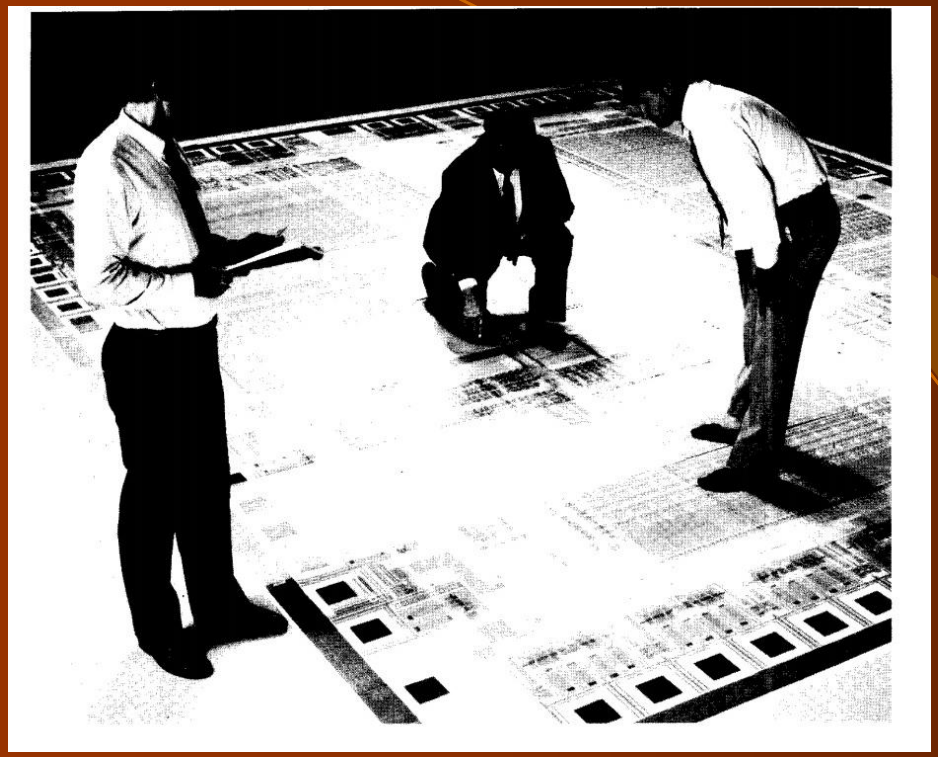


Image Source: The Art of Electronics, 2nd Edition

gl85.vhd

```
entity gl85 is
port(CLK : in bit;
     RESETOUT, SOD: out bit;
     SID, TRAP, RST75, RST65, RST55, INTR: in bit;
     INTABAR: out bit;
     A15,A14,A13,A12,A11,A10,A9,A8: out bit;
     AD7,AD6,AD5,AD4,AD3,AD2,AD1,AD0: out bit;
     S0, ALE, WRBAR, RDBAR, S1, IOMBAR: out bit;
     READY, RESETINBAR: in bit;
     CLKOUT, HLDA: out bit;
     HOLD : in bit;
     DIN : in bit_vector(7 downto 0);
     VCC,GND: in bit);
end;

architecture structure of gl85 is

signal ID: bit_vector(19 downto 0);
signal I0,I1,I2,I3,I4,I5: bit;
signal B8BO,  B8BIN:  bit_vector(0 to 7);
signal B16BO, B16BIN: bit_vector(0 to 15);
signal T1, T2, T3, T4, T5, T6: bit;
signal ACCOUTEN, WRACC, WR2TEMP, WRAUXACC, ENBUSTOAUX: bit;
signal INA, LASTMC, CC6, CCBAR: bit;
signal RSTN, INTA, VINT, THALT, THOLD, TWAIT : bit;
signal M1, M2, M3, M4, M5: bit;
signal MDROUT, BIMC, ALUOUTEN, CC: bit;
signal CLKOUT_buf,TEMP_OUT: bit;
signal SEL16BUS,SEL_CNTR: bit;
signal WRB,WRC,WRBC,WRPCH,WRPCL,WRPC: bit;
signal BOUT,COUT,BCOUT,PCHOUT,PCLOUT,PCOUT,WRH,WRL,WRHL,
```

Synthesizable VHDL Code for 8085 Microprocessor

Embedded System Implementation at System Level

- Build Your Own. Good for volume applications.
- COTS (Components Off the Shelf) Approach.

eg. Use a regular PC Motherboard and custom application program. Use Raspberry Pi or BeagleBone Black SBC. Good for small quantity.

Demonstration of MSP430 Based Projects

Lecture - 1 Summary

Introduction to Embedded Systems

- Course Objectives, Prerequisites, Logistics for the course
- Demonstration of MSP430 Based projects
- Formal definition of Embedded Systems. Everyday examples of embedded Systems - household gadgets etc.
- (a) Physical Computing (b) Cyber Physical Systems (c) IoT and (d) Embedded Systems as closely related topics
- Comparing Characteristics of Embedded Systems and General Purpose Computing Systems.
- Microprocessor, Microcontroller and SoC Terminology
- Embedded System implementation: i). Processor level using (a) generic devices (b) full custom ASIC and c) single purpose computers ii). System Level

Thank you!