Embedded System & Microcontroller Application (4351102) - Summer 2024 Solution

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Question 1(a) [3 marks]

What is the definition of an embedded system? Provide an example of an embedded system.

Solution

An **embedded system** is a specialized computer system designed to perform specific tasks with dedicated functions. It combines hardware and software components that are integrated into a larger system.

Key Features:

- **Real-time operation**: Responds to inputs within specified time limits
- **Dedicated function**: Designed for specific applications
- **Resource constraints**: Limited memory, power, and processing capabilities

Example: Washing machine controller that manages wash cycles, water temperature, and timing automatically.

Mnemonic

"SMART Embedded: Specialized, Microprocessor-based, Application-specific, Real-time, Task-oriented"

Question 1(b) [4 marks]

Define a Real-Time Operating System (RTOS) and list three characteristics of RTOS.

Solution

RTOS is an operating system designed to handle real-time applications where timing constraints are critical for system operation.

Table 1. RTOS Characteristics

Characteristic	Description
Deterministic Response	Guaranteed response time for critical tasks
Priority-based Scheduling	High-priority tasks execute before low-priority tasks
Multitasking Support	Multiple tasks can run concurrently

Additional Features:

- **Task management**: Efficiently handles multiple concurrent processes
- **Interrupt handling**: Quick response to external events
- **Memory management**: Optimized for embedded applications

Mnemonic

"DPM RTOS: Deterministic, Priority-based, Multitasking"

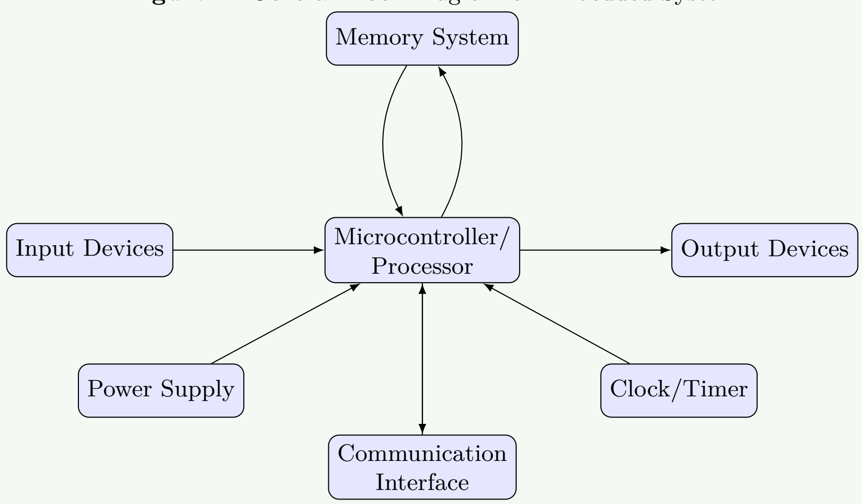
Question 1(c) [7 marks]

a) Draw the general block diagram of Embedded System
b) Explain the criteria for choosing a microcontroller for an embedded system.

Solution

a) General Block Diagram:

Figure 1. General Block Diagram of Embedded System



b) Microcontroller Selection Criteria:

Table 2. Microcontroller Selection Criteria

Criteria	Considerations
Processing Speed	Clock frequency, instruction execution time
Memory Requirements	Flash, RAM, EEPROM capacity
I/O Capabilities	Number of pins, special functions
Power Consumption	Battery life, sleep modes
Cost	Budget constraints, volume pricing
Development Tools	Compiler, debugger availability

Key Factors:
- **Performance requirements**: Processing speed and real-time constraints
- **Interface needs**: ADC, PWM, communication protocols
- **Environmental conditions**: Operating temperature, humidity

Mnemonic

"PMPICD Selection: Performance, Memory, Power, Interface, Cost, Development tools"

OR

Question 1(c) [7 marks]

Explain the pin configuration of the ATmega32.

Solution

ATmega32 is a 40-pin microcontroller with four 8-bit I/O ports and various special function pins.
Port Configuration:

Table 3. Port Configuration

Port	Pins	Functions
Port A	PA0-PA7	ADC channels, general I/O
Port B	PB0-PB7	SPI, PWM, external interrupts
Port C	PC0-PC7	TWI, general I/O
Port D	PD0-PD7	USART, external interrupts, PWM

Special Pins:
- **VCC/GND**: Power supply pins
- **AVCC/AGND**: Analog power supply for ADC
- **XTAL1/XTAL2**: Crystal oscillator connections
- **RESET**: Active low reset input
- **AREF**: ADC reference voltage

Pin Functions:
- **Dual-purpose pins**: Most pins have alternate functions
- **Input/Output capability**: All port pins are bidirectional
- **Internal pull-up**: Software configurable for input pins

Mnemonic

"ABCD Ports: ADC, Bus interfaces, Communication, Data transfer"

Question 2(a) [3 marks]

Explain the data memory architecture of ATMEGA32.

Solution

ATmega32 data memory consists of three sections organized in a unified address space.
Memory Organization:

Table 4. Memory Organization

Section	Address Range	Size	Purpose
General Registers	0x00-0x1F	32 bytes	Working registers R0-R31
I/O Registers	0x20-0x5F	64 bytes	Control and status registers
Internal SRAM	0x60-0x45F	2048 bytes	Data storage and stack

Key Features:
- **Unified addressing**: All memory accessible through single address space
- **Register file**: R0-R31 for arithmetic and logic operations
- **Stack pointer**: Points to top of stack in SRAM

Mnemonic

"GIS Memory: General registers, IO registers, SRAM"

Question 2(b) [4 marks]

Explain the Program Status Word.

Solution

SREG (Status Register) contains flags that reflect the result of arithmetic and logic operations.
SREG Bit Configuration:

Table 5. SREG Bit Configuration

Bit	Flag	Description
Bit 7	I	Global Interrupt Enable
Bit 6	T	Bit Copy Storage
Bit 5	H	Half Carry Flag
Bit 4	S	Sign Flag
Bit 3	V	Overflow Flag
Bit 2	N	Negative Flag
Bit 1	Z	Zero Flag
Bit 0	C	Carry Flag

Flag Functions:

- **Arithmetic operations**: C, Z, N, V, H flags updated automatically
- **Conditional branching**: Flags used for decision making
- **Interrupt control**: I flag enables/disables global interrupts

Mnemonic

"I THSVNZC: Interrupt, Transfer, Half-carry, Sign, oVerflow, Negative, Zero, Carry"

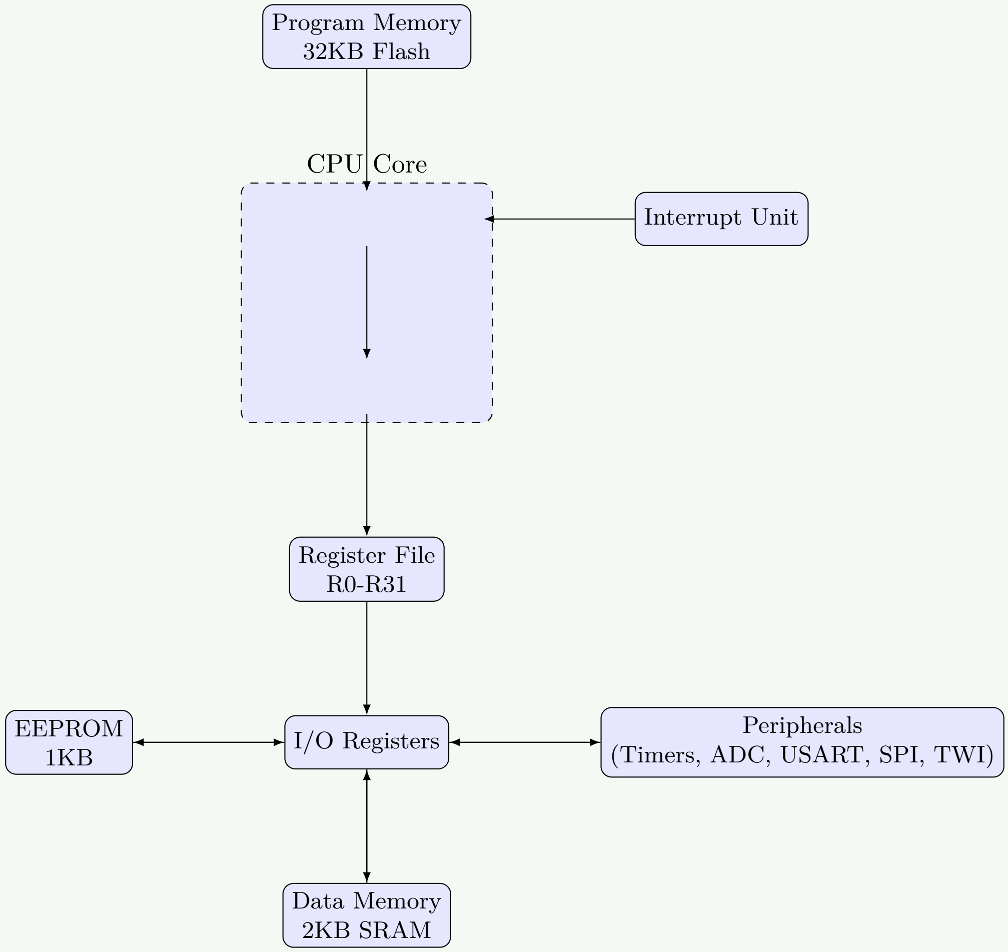
Question 2(c) [7 marks]

Draw and explain the architecture of ATMEGA32.

Solution

ATmega32 Architecture:

Figure 2. ATmega32 Architecture



Architecture Components:

Table 6. Architecture Components

Component	Description
Harvard Architecture	Separate program and data memory buses
RISC Core	131 instructions, mostly single-cycle execution
ALU	8-bit arithmetic and logic operations
Register File	32 × 8-bit working registers

Memory System:

- **Program memory**: 32KB Flash for storing instructions
- **Data memory**: 2KB SRAM for variables and stack
- **EEPROM**: 1KB non-volatile data storage

Peripheral Features:

- **Three timer/counters**: 8-bit and 16-bit timers
- **8-channel ADC**: 10-bit resolution
- **Communication interfaces**: USART, SPI, TWI

Mnemonic

"HRAM Micro: Harvard architecture, RISC core, ALU, Memory system"

OR

Question 2(a) [3 marks]

Explain Program Counter of ATMEGA32.

Solution

Program Counter (PC) is a 16-bit register that holds the address of the next instruction to be executed.
PC Characteristics:

Table 7. PC Characteristics

Feature	Description
Size	16-bit (can address 64KB program memory)
Reset Value	0x0000 (starts execution from beginning)
Increment	Automatically incremented after instruction fetch
Jump/Branch	Modified by jump, branch, and call instructions

PC Operations:

- **Sequential execution**: PC increments by 1 for most instructions
- **Branch instructions**: PC loaded with target address
- **Interrupt handling**: PC saved on stack, loaded with interrupt vector

Mnemonic

"SRIB PC: Sequential, Reset, Increment, Branch"

OR

Question 2(b) [4 marks]

Explain the role of clock and reset circuits in an AVR microcontroller.

Solution

Clock System:

Table 8. Clock Sources

Clock Source	Description
External Crystal	High accuracy, 1-16 MHz typical
Internal RC	Built-in 8 MHz oscillator
External Clock	External clock signal input
Low-frequency Crystal	32.768 kHz for RTC applications

Reset Circuit Functions:

- **Power-on Reset**: Automatic reset when power is applied
- **Brown-out Reset**: Reset when supply voltage drops
- **External Reset**: Manual reset through RESET pin
- **Watchdog Reset**: Reset from watchdog timer timeout

Key Features:

- **Clock distribution**: System clock drives CPU and peripherals
- **Reset sequence**: Initializes all registers to default values
- **Fuse bits**: Configure clock source and reset options

Mnemonic

"CEIL Clock: Crystal, External, Internal, Low-frequency"

OR

Question 2(c) [7 marks]

Explain TCCRn and TIFR Timer Register

Solution

TCCRn (Timer/Counter Control Register):

Table 9. TCCRn Registers

Register	Function
TCCR0	Controls Timer0 operation mode
TCCR1A/B	Controls Timer1 (16-bit) operation
TCCR2	Controls Timer2 operation mode

TCCR Bit Functions:

- **Clock Select (CS)**: Selects clock source and prescaler
- **Waveform Generation (WGM)**: Sets timer mode (Normal, CTC, PWM)
- **Compare Output Mode (COM)**: Controls output pin behavior

TIFR (Timer Interrupt Flag Register):

Table 10. TIFR Flags

Bit	Flag	Description
TOV	Timer Overflow	Set when timer overflows
OCF	Output Compare	Set when compare match occurs
ICF	Input Capture	Set when input capture event occurs

Timer Operations:

- **Mode selection**: Normal, CTC, Fast PWM, Phase Correct PWM
- **Interrupt generation**: Flags trigger interrupts when enabled
- **Output generation**: PWM signals for motor control, LED dimming

Mnemonic

"TCCR WGM: Timer Control, Clock, Register, Waveform Generation Mode"

Question 3(a) [3 marks]

Distinguish different data types for programming AVR in C.

Solution

AVR C Data Types:

Table 11. AVR C Data Types

Data Type	Size	Range	Usage
char	8-bit	-128 to 127	Characters, small integers
unsigned char	8-bit	0 to 255	Port values, flags
int	16-bit	-32768 to 32767	General integers
unsigned int	16-bit	0 to 65535	Counters, addresses
long	32-bit	-2^{31} to 2^{31}-1	Large calculations
float	32-bit	$\pm 3.4 \times 10^{38}$	Decimal calculations

Special Considerations:

- **Memory efficient**: Use smallest suitable data type
- **Port operations**: unsigned char for 8-bit ports
- **Timing calculations**: unsigned int for timer values

Mnemonic

"CUIL Float: Char, Unsigned, Int, Long, Float"

Question 3(b) [4 marks]

Write a C program to toggle all the bits of Port C 200 times.

Solution

```c
#include <avr/io.h>
#include <util/delay.h>

int main() {
    DDRC = 0xFF;        // Set Port C as output
    unsigned int count = 0;

    while(count < 200) {
        PORTC = 0xFF;   // Set all bits high
        _delay_ms(100); // Delay
        PORTC = 0x00;   // Set all bits low
        _delay_ms(100); // Delay
        count++;        // Increment counter
    }
    return 0;
}
```

Program Explanation:

- **DDRC = 0xFF**: Configures all Port C pins as outputs
- **Toggle operation**: Alternates between 0xFF and 0x00
- **Counter**: Tracks number of toggle cycles
- **Delay**: Provides visible timing for toggle operation

Mnemonic

"DTC Loop: DDR setup, Toggle bits, Count iterations, Loop control"

Question 3(c) [7 marks]

a) LED are connected to Pins of PORTB. Write an AVR programs to show the count from 0 to FFh on the LED

b) Write an AVR C program to get a byte of data from Port C. If it is less than 100 send it to Port B; otherwise, send it to Port D.

Solution

a) Binary Counter Display:

```
#include <avr/io.h>
#include <util/delay.h>

int main() {
    DDRB = 0xFF;            // Port B as output
    unsigned char count = 0;

    while(1) {
        PORTB = count;      // Display count on LEDs
        _delay_ms(500);     // Delay for visibility
        count++;            // Increment counter
        if(count > 0xFF)    // Reset after 255
            count = 0;
    }
    return 0;
}
```

b) Conditional Data Transfer:

```
#include <avr/io.h>

int main() {
    DDRC = 0x00;    // Port C as input
    DDRB = 0xFF;    // Port B as output
    DDRD = 0xFF;    // Port D as output

    while(1) {
        unsigned char data = PINC;  // Read from Port C

        if(data < 100) {
            PORTB = data;           // Send to Port B
            PORTD = 0x00;          // Clear Port D
        } else {
            PORTD = data;           // Send to Port D
            PORTB = 0x00;          // Clear Port B
        }
    }
    return 0;
}
```

Key Programming Concepts:

- **Port direction**: DDR registers configure input/output
- **Data reading**: PIN registers read input values
- **Conditional logic**: if-else statements for decision making

Mnemonic

"RCC Data: Read input, Compare value, Conditional output"

OR

Question 3(a) [3 marks]

Write AVR C program to send values of -3 to +3 Port B

Solution

```c
#include <avr/io.h>
#include <util/delay.h>

int main() {
    DDRB = 0xFF;              // Port B as output
    signed char values[] = {-3, -2, -1, 0, 1, 2, 3};
    unsigned char i = 0;

    while(1) {
        PORTB = values[i];    // Send value to Port B
        _delay_ms(1000);      // 1 second delay
        i++;                  // Next value
        if(i > 6) i = 0;      // Reset index
    }
    return 0;
}
```

Program Features:

- **Signed data**: Uses signed char for negative values
- **Array storage**: Values stored in array for easy access
- **Cyclic operation**: Continuously cycles through all values

Mnemonic

"SAC Values: Signed char, Array storage, Cyclic operation"

OR

Question 3(b) [4 marks]

Write AVR C program to send hex values for ASCII characters 0,1,2,3,4,5,A,B,C and D to port B.

Solution

```c
#include <avr/io.h>
#include <util/delay.h>

int main() {
    DDRB = 0xFF;    // Port B as output

    // ASCII hex values array
    unsigned char ascii_values[] = {
        0x30,  // '0'
        0x31,  // '1'
        0x32,  // '2'
        0x33,  // '3'
        0x34,  // '4'
        0x35,  // '5'
        0x41,  // 'A'
        0x42,  // 'B'
        0x43,  // 'C'
        0x44   // 'D'
    };

    unsigned char i = 0;
```

```c

    while(1) {
        PORTB = ascii_values[i];  // Send ASCII value
        _delay_ms(500);           // Delay
        i++;                      // Next character
        if(i > 9) i = 0;          // Reset index
    }
    return 0;
}
```

ASCII Values Table:

Table 12. ASCII Values

Character	Hex Value	Binary
'0'	0x30	00110000
'1'	0x31	00110001
'A'	0x41	01000001
'B'	0x42	01000010

Mnemonic

"HAC ASCII: Hex values, Array storage, Cyclic transmission"

OR

Question 3(c) [7 marks]

A door sensor is connected to bit 1 of Port B, and an LED is connected to bit 7 of Port C. Write an AVR C program to monitor the door sensor and, when it opens (PIN is HIGH), turn on the LED. Also draw Flow chart.

Solution

C Program:

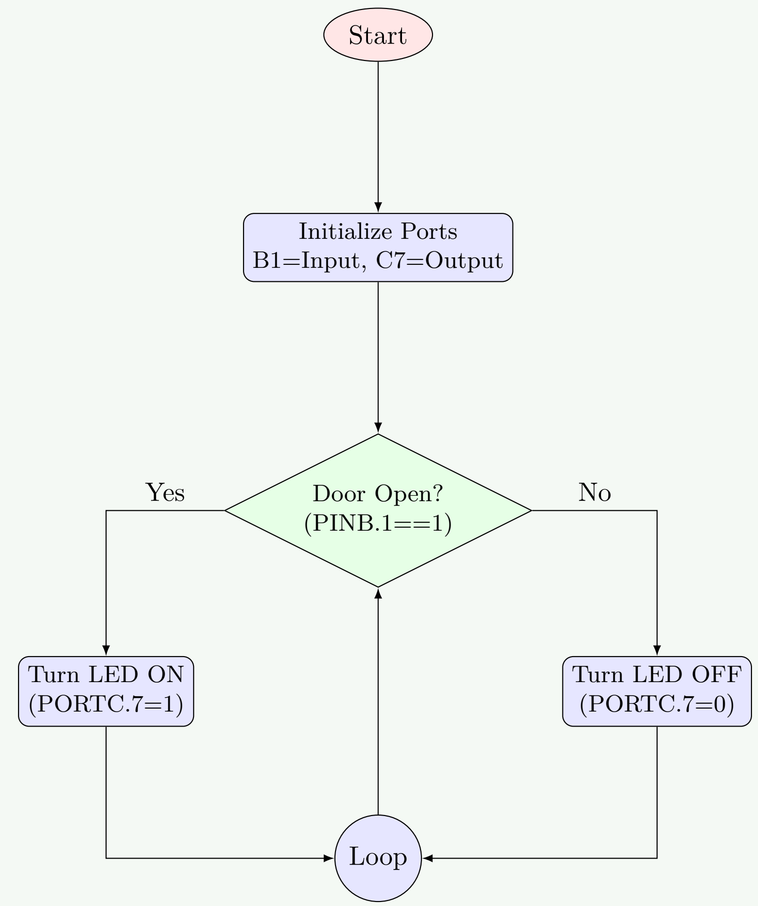
```c
#include <avr/io.h>

int main() {
    DDRB = 0xFD;    // Port B bit 1 as input (0), others output (1)
    DDRC = 0xFF;    // Port C as output
    PORTB = 0x02;   // Enable pull-up for bit 1

    while(1) {
        if(PINB & 0x02) {      // Check if door sensor is HIGH
            PORTC |= 0x80;     // Turn ON LED (bit 7)
        } else {
            PORTC &= 0x7F;     // Turn OFF LED (bit 7)
        }
    }
    return 0;
}
```

Flow Chart:

Figure 3. Door Sensor Logic Flowchart



Bit Operations:

- **Input reading**: `PINB & 0x02` checks bit 1
- **LED control**: `PORTC |= 0x80` sets bit 7
- **LED off**: `PORTC &= 0x7F` clears bit 7

Mnemonic

"BIC Door: Bit manipulation, Input monitoring, Conditional LED control"

Question 4(a) [3 marks]

Explain ADMUX ADC Register

Solution

ADMUX (ADC Multiplexer Selection Register):

Table 13. ADMUX Bits

Bit	Name	Description
Bit 7-6	REFS1:0	Reference Selection
Bit 5	ADLAR	ADC Left Adjust Result
Bit 4-0	MUX4:0	Analog Channel Selection

Reference Selection (REFS1:0):

- **00**: AREF, Internal Vref turned off

- **01**: AVCC with external capacitor at AREF pin
- **10**: Reserved
- **11**: Internal 2.56V reference

Channel Selection (MUX4:0):
- **00000-00111**: ADC0-ADC7 (single-ended inputs)
- **Other combinations**: Differential inputs with gain

Mnemonic

"RAM ADMUX: Reference, Alignment, Multiplexer"

Question 4(b) [4 marks]

Explain Different LCD Pins.

Solution

16x2 LCD Pin Configuration:

Table 14. LCD Pins

Pin	Symbol	Function
1	VSS	Ground (0V)
2	VDD	Power supply (+5V)
3	V0	Contrast adjustment
4	RS	Register Select (Data/Command)
5	R/W	Read/Write select
6	E	Enable signal
7-14	D0-D7	Data bus (8-bit)
15	A	Backlight anode (+)
16	K	Backlight cathode (-)

Control Pin Functions:
- **RS = 0**: Command register selected
- **RS = 1**: Data register selected
- **R/W = 0**: Write operation
- **R/W = 1**: Read operation
- **E**: Enable pulse triggers operation

Mnemonic

"VCR EDB LCD: Vpower, Contrast, Register select, Enable, Data Bus"

Question 4(c) [7 marks]

Write a Program to toggle all the bits of PORTB continually with 20μs delay. Use Timer0, normal mode and no Prescaler to generate delay

Solution

```
#include <avr/io.h>
```

```c

void delay_20us() {
    TCNT0 = 0;          // Clear timer counter
    TCCR0 = 0x01;       // No prescaler, normal mode
    while(TCNT0 < 160); // Wait for 20us (8MHz/1 * 20us = 160)
    TCCR0 = 0;          // Stop timer
}

int main() {
    DDRB = 0xFF;        // Port B as output

    while(1) {
        PORTB = 0xFF;   // Set all bits high
        delay_20us();   // 20us delay
        PORTB = 0x00;   // Set all bits low
        delay_20us();   // 20us delay
    }
    return 0;
}
```

Timer Calculation:

- **Clock frequency**: 8 MHz (assumption)
- **Timer resolution**: 1/8MHz = 0.125μs per count
- **Required counts**: 20μs / 0.125μs = 160 counts

Timer0 Configuration:

Table 15. Timer0 Settings

Setting	Value	Description
Mode	Normal	Counts from 0 to 255
Prescaler	1	No prescaling
Clock source	System clock	8 MHz

Mnemonic

"TNP Timer: Timer0, Normal mode, Prescaler none"

OR

Question 4(a) [3 marks]

Short note Two wire Interface (TWI)

Solution

TWI (Two Wire Interface) - I2C Protocol:

Key Features:

Table 16. TWI Features

Feature	Description
Two wires	SDA (data) and SCL (clock)
Multi-master	Multiple masters can control bus
Multi-slave	Up to 127 slave devices
Address-based	7-bit or 10-bit device addressing
Bidirectional	Data flows in both directions

Bus Characteristics:

- **Open-drain**: Requires pull-up resistors (4.7kΩ typical)
- **Synchronous**: Clock provided by master
- **Start/Stop conditions**: Special sequences for communication

Mnemonic

"SDA SCL TWI: Serial Data, Serial CLock, Two Wire Interface"

OR

Question 4(b) [4 marks]

Explain ADCSRA ADC Register

Solution

ADCSRA (ADC Control and Status Register A):

Table 17. ADCSRA Register

Bit	Name	Function
Bit 7	ADEN	ADC Enable
Bit 6	ADSC	ADC Start Conversion
Bit 5	ADATE	ADC Auto Trigger Enable
Bit 4	ADIF	ADC Interrupt Flag
Bit 3	ADIE	ADC Interrupt Enable
Bit 2-0	ADPS2:0	ADC Prescaler Select

Prescaler Settings (ADPS2:0):

Table 18. Prescaler Settings

Binary	Division Factor	ADC Clock (8MHz)
000	2	4 MHz
001	2	4 MHz
010	4	2 MHz
011	8	1 MHz
100	16	500 kHz
101	32	250 kHz
110	64	125 kHz
111	128	62.5 kHz

Control Functions:

- **ADEN**: Must be set to enable ADC operation
- **ADSC**: Set to start conversion, cleared when complete
- **Prescaler**: ADC clock should be 50-200 kHz for optimal accuracy

Mnemonic

"EASCID ADC: Enable, Auto-trigger, Start, Conversion, Interrupt, Divider"

OR

Question 4(c) [7 marks]

Write a Program to generate a square wave of 16 Khz frequency on pin PORTC.3. Assume Crystal Frequency 8 Mhz

Solution

```c
#include <avr/io.h>
#include <avr/interrupt.h>

int main() {
    // Configure PC3 as output
    DDRC |= (1 << PC3);

    // Timer1 CTC mode configuration
    TCCR1A = 0x00;                      // Normal port operation
    TCCR1B = (1 << WGM12) | (1 << CS10); // CTC mode, no prescaler

    // Calculate OCR1A value for 16 kHz
    // Period = 1/16000 = 62.5us
    // Half period = 31.25us
    // OCR1A = (8MHz * 31.25us) - 1 = 249
    OCR1A = 249;

    // Enable Timer1 Compare A interrupt
    TIMSK |= (1 << OCIE1A);

    // Enable global interrupts
    sei();

    while(1) {
        // Main loop - square wave generated by interrupt
    }
    return 0;
}

// Timer1 Compare A interrupt service routine
ISR(TIMER1_COMPA_vect) {
    PORTC ^= (1 << PC3);    // Toggle PC3
}
```

Frequency Calculation:

Table 19. Frequency Calculation

Parameter	Value	Formula
Target frequency	16 kHz	Given
Period	62.5 μs	1/16000
Half period	31.25 μs	Period/2
Timer counts	250	8MHz $\times$ 31.25μs
OCR1A value	249	Counts - 1

Timer Configuration:

- **Mode**: CTC (Clear Timer on Compare)
- **Prescaler**: 1 (no prescaling)
- **Interrupt**: Compare match toggles output pin

Mnemonic

"CTC Square: CTC mode, Timer interrupt, Compare match"

Question 5(a) [3 marks]

Difference between Polling and Interrupt

Solution

Polling vs Interrupt Comparison:

Table 20. Polling vs Interrupt

Aspect	Polling	Interrupt
CPU Usage	Continuously checks status	CPU free until event occurs
Response Time	Variable, depends on polling frequency	Fast, immediate response
Power Consumption	Higher due to continuous checking	Lower, CPU can sleep
Programming	Simple, sequential code	Complex, requires ISR
Real-time	Not suitable for critical timing	Excellent for real-time systems

Mnemonic

"PIE Method: Polling inefficient, Interrupt efficient, Event-driven"

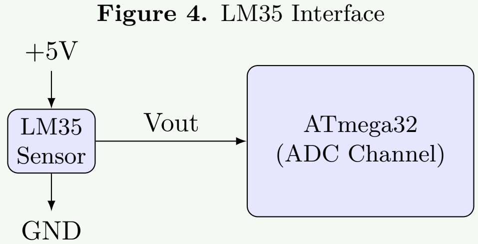
Question 5(b) [4 marks]

Explain LM35 Interface with AVR ATmega32.

Solution

LM35 Temperature Sensor Interface:

Figure 4. LM35 Interface



LM35 Characteristics:

Table 21. LM35 Characteristics

Parameter	Value	Description
Output	10mV/°C	Linear temperature coefficient
Range	0°C to 100°C	Operating temperature range
Supply	4V to 30V	Power supply range
Accuracy	±0.5°C	Temperature accuracy

Interface Code:

```c
#include <avr/io.h>

void ADC_init() {
    ADMUX = 0x40;   // AVCC reference, ADC0 channel
    ADCSRA = 0x87;  // Enable ADC, prescaler 128
}

unsigned int read_temperature() {
    ADCSRA |= (1 << ADSC);      // Start conversion
    while(ADCSRA & (1 << ADSC)); // Wait for completion

    // Convert ADC value to temperature
    // Temperature = (ADC * 5000) / (1024 * 10)
    unsigned int temp = (ADC * 5000) / 10240;
    return temp;
}
```

Mnemonic

"LAC Temperature: LM35 sensor, ADC conversion, Calculation formula"

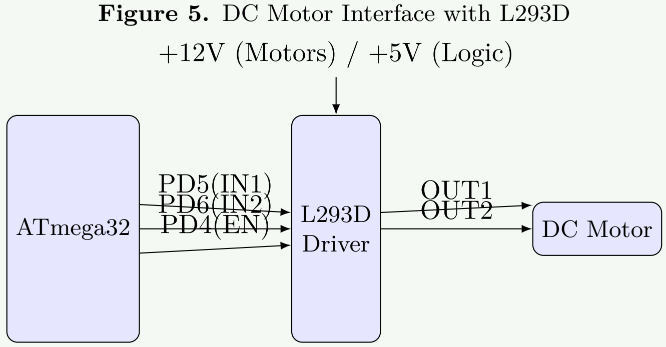
Question 5(c) [7 marks]

Write a program to interface DC Motor with AVR ATmega32.

Solution

DC Motor Interface Circuit:

Figure 5. DC Motor Interface with L293D



Motor Control Program:

```c
#include <avr/io.h>
#include <util/delay.h>

void motor_init() {
    DDRD |= (1 << PD4) | (1 << PD5) | (1 << PD6); // Set as output
}

void motor_forward() {
    PORTD |= (1 << PD4);   // Enable motor
    PORTD |= (1 << PD5);   // IN1 = 1
    PORTD &= ~(1 << PD6);  // IN2 = 0
}

void motor_reverse() {
```

```c
    PORTD |= (1 << PD4);   // Enable motor
    PORTD &= ~(1 << PD5);  // IN1 = 0
    PORTD |= (1 << PD6);   // IN2 = 1
}

void motor_stop() {
    PORTD &= ~(1 << PD4);  // Disable motor
}

int main() {
    motor_init();

    while(1) {
        motor_forward();    // Forward for 2 seconds
        _delay_ms(2000);

        motor_stop();       // Stop for 1 second
        _delay_ms(1000);

        motor_reverse();    // Reverse for 2 seconds
        _delay_ms(2000);

        motor_stop();       // Stop for 1 second
        _delay_ms(1000);
    }
    return 0;
}
```

L293D Truth Table:

Table 22. L293D Truth Table

EN	IN1	IN2	Motor Action
0	X	X	Stop
1	0	0	Stop
1	0	1	Reverse
1	1	0	Forward
1	1	1	Stop

Mnemonic

"LED Motor: L293D driver, Enable control, Direction pins"

OR

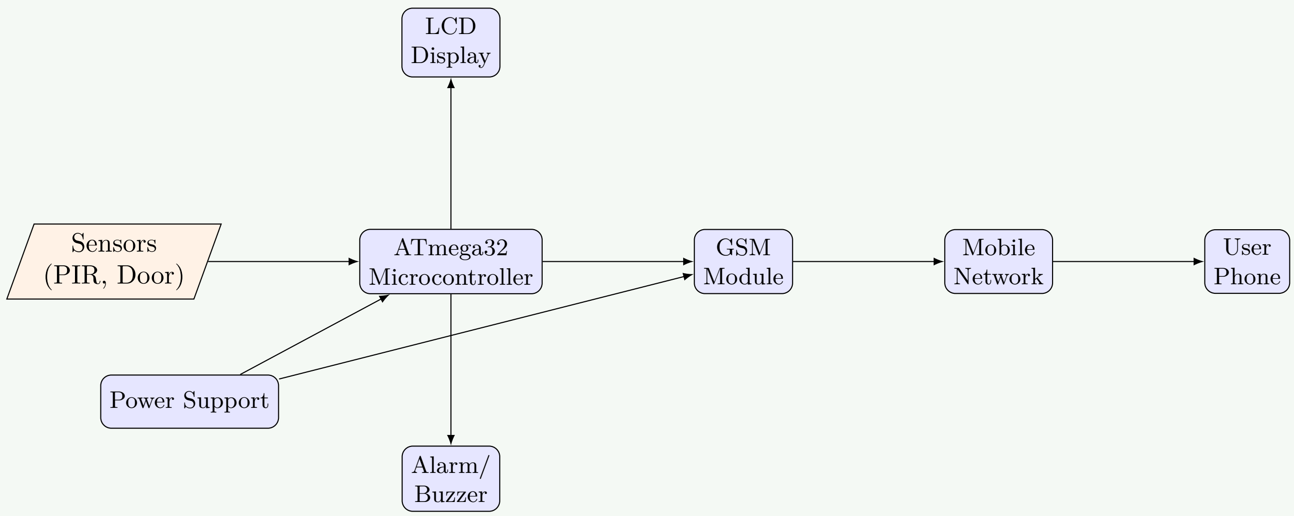
Question 5(a) [3 marks]

Explain basic block diagram of GSM based security system.

Solution

GSM Security System Block Diagram:

Figure 6. GSM Security System



System Components:

Table 23. System Components

Component	Function
Sensors	PIR, door/window sensors, smoke detector
Microcontroller	Process sensor data, control system
GSM Module	Send SMS alerts, make calls
Display	Show system status
Alarm	Local audio/visual alert

Mnemonic

"SGMA Security: Sensors, GSM module, Microcontroller, Alerts"

OR

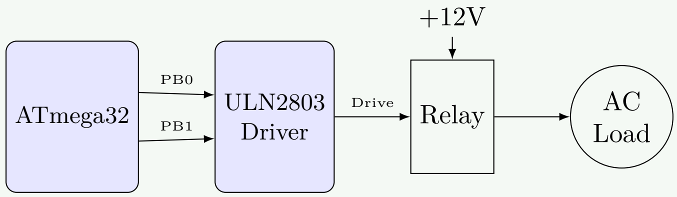
Question 5(b) [4 marks]

Explain Relay Interface with AVR ATmega32.

Solution

Relay Interface Circuit:

Figure 7. Relay Interface with ULN2803



Relay Interface Code:

```c
#include <avr/io.h>
#include <util/delay.h>

void relay_init() {
    DDRB |= (1 << PB0) | (1 << PB1); // Set as output pins
}

void relay1_on() {
    PORTB |= (1 << PB0);  // Activate relay 1
}

void relay1_off() {
    PORTB &= ~(1 << PB0); // Deactivate relay 1
}

int main() {
    relay_init();

    while(1) {
        relay1_on();        // Turn on relay 1
        _delay_ms(2000);
        relay1_off();       // Turn off relay 1
        _delay_ms(1000);
    }
    return 0;
}
```

ULN2803 Features:

- **8 Channels**: Eight Darlington pair drivers
- **High Current**: Up to 500mA per channel
- **Protection**: Built-in flyback diodes

Mnemonic

"ULN Relay: ULN2803 driver, Load control, Non-contact switching"

OR

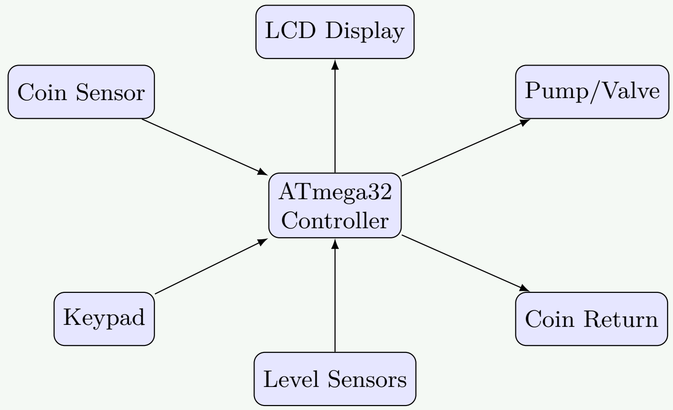
Question 5(c) [7 marks]

Draw and Explain Automatic Juice vending machine

Solution

Automatic Juice Vending Machine Block Diagram:

Figure 8. Juice Vending Machine



System Operation:

- **Initialization**: Display welcome message and juice menu
- **Coin Input**: User inserts coins, system validates amount
- **Selection**: User presses keypad to select juice type
- **Validation**: Check if enough money and juice available
- **Dispensing**: Activate pump and valve for selected juice
- **Completion**: Return change if any, display thank you message

Control Logic:

```
// Pseudo code for vending machine operation
void vending_machine() {
    display_menu();

    while(1) {
        if(coin_inserted()) {
            total_amount += validate_coin();
            update_display();
        }

        if(selection_made()) {
            juice_type = get_selection();
            if(total_amount >= juice_price[juice_type]) {
                if(juice_available[juice_type]) {
                    dispense_juice(juice_type);
                    return_change();
                    reset_system();
                } else {
                    display_error("Out of Stock");
                }
            } else {
                display_error("Insufficient Amount");
            }
        }
    }
}
```

Mnemonic

"CLPDV Juice: Coin sensor, LCD display, Pump motors, Dispensing unit, Valve control"