Scientific Calculator

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1 Introduction

This project implements a dual-mode scientific calculator using the ATmega328P microcontroller. The system features:

- Standard arithmetic operations (+, -, *, /)
- Advanced scientific functions (sin, cos, ln, $\sqrt{x}$, arctan(x))
- Dynamic mode switching between normal and scientific operations
- 16x2 LCD display interface
- Numerical approximation methods for function calculations

2 Components Used

The following components were used:

- Arduino Uno
- Breadboard
- Push buttons
- Resistors (220Ω) and wiring
- Liquid Crystal Display(LCD)
- Potentiometer
- Power source

3 System Design

3.1 Hardware Configuration

TABLE I: Core Hardware Components

Component	**Specification**
Microcontroller	ATmega328P (Arduino Uno)
Display	16x2 LCD with HD44780 controller
Input	12-button matrix (10 numeric, 2 control)
Power	5 V DC regulated supply
Interface	4-bit parallel LCD communication

4 Circuit Design

The calculator system integrates three main components: a 16×2 LCD display, a 7-segment display with 7447 BCD decoder, and a matrix of push buttons. The complete interconnection scheme is detailed below.

LCD Pin	Function	Arduino Pin
VSS	Ground	GND
VDD	Power (+5V)	5V
V0	Contrast	Potentiometer
RS	Register Select	12
RW	Read/Write	GND
EN	Enable	11
D4-D7	Data bits [4:7]	5,4,3,2
A	Backlight (+)	5V
K	Backlight (-)	GND

TABLE II: LCD to Arduino pin connections

4.1 LCD Interface Configuration

The HD44780-compatible LCD module connects to the Arduino using a 4-bit parallel interface:

4.2 7-Segment Display Interface

The system implements BCD-to-7-segment conversion using the 7447 decoder IC:

7447 Pin	Signal	7-Segment Pin
$\overline{a}$	Segment a	a
$\overline{b}$	Segment b	b
$\overline{c}$	Segment c	c
$\overline{d}$	Segment d	d
$\overline{e}$	Segment e	e
$\overline{f}$	Segment f	f
$\overline{g}$	Segment g	g

TABLE III: 7447 to 7-segment display mapping

The BCD input connections from Arduino:

7447 BCD Input	Weight	Arduino Pin
D	MSB (8)	5
C	4	4
B	2	3
A	LSB (1)	2

TABLE IV: BCD input connections

4.3 Input Button Matrix

The calculator features a 12-button input matrix with the following configuration:

Button Group	Functions	Arduino Pins
Primary	Digits 0-9	6,7,8,9,10
Secondary	Digits 6-9	A0,A1,A2,A3,A4
Special	Shift/Alt	A5
Mode	Function Toggle	13

TABLE V: Button matrix connections

4.4 Power Distribution

The power supply network follows these connections:

- **Main Power**: Arduino 5V → 7447 V_{CC} pin
- **Ground**: Common ground between all components
- **Display Current Limiting**:
  - 7-segment common anodes → 220 Ω resistors → Arduino analog pins
  - LCD backlight current limited by onboard resistor

TABLE VI: Microcontroller Pin Mapping

Pin	Component	Function
PD2-PD7	LCD	Data/control lines
PB0-PB5	Buttons	Primary input (0-5)
PC0-PC5	Buttons	Secondary input (6-9, =, mode)

5 Implementation Details

5.1 Hardware Interface

- LCD connected in 4-bit mode for efficient pin usage
- Button matrix with hardware debouncing (10 kΩ pull-up resistors)
- Potentiometer-adjusted LCD contrast (10 kΩ)

6 Modifier Function Mapping

6.1 Secondary Modifier (Position 12) + Number Keys

6.2 Primary Modifier (Position 1) + Number Keys

7 Results

The scientific calculator successfully demonstrated the following capabilities:

- **Basic Arithmetic Operations**:
  - Accurate computation of addition, subtraction, multiplication, and division.
  - Proper handling of decimal inputs and results.
- **Scientific Functions**:
  - Trigonometric functions (sin, cos, arctan) computed using Taylor series approximations.
  - Logarithmic functions (ln, $\log_{10}$) implemented with iterative methods.

TABLE VII: Scientific Operations Mapping

Number Key	Symbol	Function
0	+	Addition
1	-	Subtraction
2	×	Multiplication
3	÷	Division
4	=	Equal/Calculate
5	BS	Backspace
6	sin	Sine
7	cos	Cosine
8	e^x	Exponential
9	$\sqrt{}$	Square Root

TABLE VIII: Advanced Math Functions Mapping

Number Key	Symbol	Function
0	$\sin^{-1}$	Arcsine
1	$\cos^{-1}$	Arccosine
2	$\tan^{-1}$	Arctangent
3	log	Base-10 Logarithm
4	ln	Natural Logarithm
5	(	Left Parenthesis
6	)	Right Parenthesis
7	a^b	Exponent
8	.	Decimal Point
9	AC	All Clear

  - Exponential and square root functions working within defined limits.
- **Display Systems**:
  - 16×2 LCD correctly showed input expressions and computed results.
  - 7-segment display provided supplementary output for single-digit results.
- **Mode Switching**:
  - Reliable toggling between standard and scientific modes using the mode button.
  - Proper interpretation of modifier keys for secondary functions.
- **Performance Metrics**:
  - Response time: ¡ 200 ms for basic operations.
  - Numerical precision: 6 significant digits for floating-point results.
  - Power consumption: ¡ 100 mA during operation at 5 V.
- **Error Handling**:
  - Detection of invalid operations (e.g., division by zero, log(0)).
  - Clear display of ”ERROR” for undefined results.

8 Conclusion

This project successfully implemented a dual-mode scientific calculator using the ATmega328P microcontroller. Key achievements include:

- **Integrated Design**:
  - Combined hardware and software systems for reliable computation and display.
  - Efficient pin utilization through multiplexed input and 4-bit LCD communication.
- **Functional Versatility**:
  - Seamless transition between basic and advanced mathematical operations.
  - Implementation of complex functions using numerical approximation methods.
- **Educational Value**:
  - Demonstrated practical applications of embedded systems design.
  - Highlighted trade-offs between computational accuracy and resource constraints.
- **Areas for Improvement**:
  - Enhanced precision using floating-point libraries.
  - Additional functions (hyperbolic, statistical) in future iterations.
  - Reduced power consumption through sleep modes.

The system meets its design objectives, providing a functional platform for further development in embedded computational devices. This implementation serves as a foundation for more advanced calculator designs with expanded capabilities.