Theme 1	Analog sensing for field and industrial applications.
Theme 2	Digital logic systems for automation and safety control.
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Theme 4	Discrete Logic Design and VLSI Principles for Industrial Systems.
Theme 5	Fail-safe timing and power management protection systems.

Theme 1: Analog sensing for industrial applications.

1. Supply Ripple Phase Comparator

In dual-rail supplies, ripple on positive and negative rails should be equal and opposite. Use a passive subtractor and precision rectifier to detect asymmetric ripple between rails, flagging a fault when imbalance exceeds a threshold — revealing failing filter capacitors before output degrades visibly.

2. Portable Battery Checker

Technicians often carry spare batteries but cannot easily determine whether they are still usable. Design a compact battery tester that checks the condition of AA or 9 V batteries. The circuit should apply a small load to the battery and use voltage thresholds to indicate GOOD, WEAK, or DEAD using LEDs, allowing users to quickly decide whether the battery should be kept or replaced.

3. Analog Window Voltage Monitor

Industrial sensor outputs and field transmitters often operate within a defined voltage range (for example, 1–5 V). If the signal goes outside this window due to wiring faults, sensor drift, or supply issues, the control system may behave unpredictably. Design an analog window comparator circuit using two op-amps (or comparators) that monitors an input signal and indicates whether the voltage is below range, within range, or above range. The circuit should use resistor reference networks and LED indicators to clearly show the signal condition without requiring a microcontroller or digital processing.

4. Ambient Light Level Indicator

Workspaces such as soldering benches or small indoor setups often require sufficient lighting. Design a circuit using an LDR (Light Dependent Resistor) that measures ambient light and displays the brightness level using LEDs. The circuit should indicate whether the lighting condition is DIM, NORMAL, or BRIGHT, helping users quickly judge if additional lighting is needed.

5. Vibration Presence Detector

Rotating machinery such as pumps and motors produce vibration that increases when bearings wear or loads become unbalanced. Design a circuit using a piezoelectric disc as the sensing element, whose output is amplified and rectified into a DC level representing vibration intensity. A single comparator stage drives a warning LED when vibration exceeds a safe threshold.

6. Photodiode Signal Integrity Tester

Optical sensors in industrial counters and encoders degrade when lenses become dirty or emitters weaken. Design a circuit where a photodiode receives light from an LED emitter, and the photodiode current is converted to voltage using a transimpedance amplifier. Two comparator stages drive LEDs indicating STRONG, WEAK, or FAILED signal, helping technicians service optical sensors in the field

7. Signal Frequency Range Indicator

Technicians sometimes need a quick way to check whether a sensor or oscillator signal is operating near its expected frequency without relying on an oscilloscope. Design a circuit that accepts a sinusoidal input and converts it into pulses using a zero-crossing detector. These pulses should then be processed using simple timing and filtering stages to produce a voltage related to the signal frequency. A threshold stage with LEDs should indicate whether the frequency falls within an acceptable range or deviates from it, enabling a quick pass/fail check.

8. Overheat Warning Indicator

Technicians servicing power electronics often need a quick way to judge whether a component such as a power transistor or motor winding is operating within a safe temperature range. Because these parts are frequently enclosed inside equipment housings, rising temperatures may go unnoticed until performance degrades or damage occurs. Design a circuit that monitors temperature using an NTC thermistor placed on the component surface as part of a resistor divider. The resulting voltage should be compared against multiple reference thresholds so that LEDs turn on progressively as temperature rises—for example, one LED indicating elevated temperature, additional LEDs activating at higher limits to signal increasing thermal stress. This allows a technician to quickly assess whether the component temperature is within acceptable limits or approaching an unsafe condition.

9. Analog Signal Slope Polarity Indicator

In some field measurements, it is useful to know whether a monitored signal is increasing or decreasing over time. Design a circuit that observes an analog input voltage and indicates the direction of change. The circuit should illuminate one LED when the signal is rising and another LED when the signal is falling. The design should rely on analog signal processing techniques such as differentiator networks and transistor switching.

10. Duty Cycle Monitor for Control Signals

Many industrial control systems use PWM signals to regulate speed, power, or position. Design a circuit that analyzes a PWM control signal and activates an LED when the duty cycle exceeds a predefined percentage. The circuit should rely on analog filtering and threshold detection rather than digital processing.

Theme 2: Digital logic systems for automation and safety control.

1. **Dual Runway Landing Arbiter**
   At a busy airport, multiple aircraft may request permission to land at the same time. The airport has two runways available, allowing two aircraft to land simultaneously. When landing requests are received, the control system must decide which two aircraft should be granted landing clearance based on predefined selection rules. The system analyses the incoming request signals and assigns the two available runways to the appropriate aircraft while preventing other aircraft from landing at that moment. Design a digital circuit that detects the landing requests and generates the runway assignment signals for the selected aircraft.

2. **Smart Service Approval System**
   In a digital system, a controller selects one device from several devices using a binary input. The control signal is sent through a distribution circuit so that only the selected device receives the signal. To check whether the correct device was activated, the active device line is sent to an identification circuit that converts it into a binary code. This generated code is then compared with the original selection input to verify that the signal reached the correct device. Design a digital circuit that performs this activation and verification process.(demux+encoder)

3. **Binary Combination Lock with Decoy Inputs**
   Standard code locks are vulnerable to trial entry. Design a logic lock where four inputs must match a hardwired pattern, but two additional decoy inputs trigger an alarm latch if touched at all — requiring the user to both know the correct combination and actively avoid the decoys, using only gates and a latch.

4. **Event Counting System**
   In asynchronous digital systems, two signals competing to arrive first must be resolved without a clock. Implement a

metastability-aware arbiter using cross-coupled gates that determines which of two input edges arrived first and latches the winner, with a brief lockout preventing re-triggering — directly demonstrating a real problem in digital design.

5. **Single-Bit ALU Design**
   Design a basic arithmetic logic unit that accepts two single-bit binary inputs and a carry/borrow input and produces a result based on selected operations. The unit should be able to perform logical operations such as AND and OR, as well as arithmetic operations such as addition and subtraction. The operation performed by the unit should depend on control signals that select which function is executed. The circuit should generate the correct output result along with the carry or borrow signal when performing arithmetic operations. This design demonstrates how fundamental logic and arithmetic functions can be combined to form the core processing element of a simple CPU

6. **Operation Step Countdown Controller**
   In lab experiments and small test jigs, instructors often need to count how many times a button was pressed or a sensor was triggered without using microcontrollers. Design a 0–9 event counter using a counter IC (such as CD4029/7490/CD4017) with a debounced pushbutton input and LED indication, ensuring each count from 0 to 9 has a unique binary or decoded LED pattern and can be reliably reset to zero during demonstrations.

7. **3-Bit Bidirectional Shift Register**
   In a digital communication system, a small data buffer is used to temporarily store a 3-bit data word before transmitting it to another module. Depending on the control signal provided by the controller, the stored data must shift either to the left or to the right during each clock pulse. When shifting left, the bits move toward the higher position, and when shifting right, the bits move toward the lower position while a new bit can enter the register. Design a sequential circuit that stores a 3-bit data value and shifts the data either left or right based on a control

input. The circuit should update the stored value on every clock pulse and allow observation of the shifted data at the output.

8. **Dual-Mode Data Loading Register**

   In a digital communication system, data may be received from a processing unit as a parallel word but must be transmitted through a communication channel in a serial form. To support this operation, a temporary storage circuit is required that can load multiple bits of data simultaneously and then shift them out one bit at a time during successive clock pulses. Design a sequential circuit that can load a 3-bit data word in parallel and subsequently shift the stored data serially through the register based on a control signal. The circuit should update its contents on each clock pulse and allow observation of the serial output.

9. **3-Bit Status Control Unit**

   A digital control system stores a 3-bit status value that represents the condition of a device. Based on two control signals, the system can perform different operations on this value such as keeping the current value, loading a new value, toggling the stored bits, or rotating the bits to the left. The system must update and display the correct 3-bit output according to the selected operation

10. **Digital Even/Odd Identifier**

    In A digital system receives one active signal among five input lines I1-I5, where each line represents a numbered request. The system must identify which input is active, determine whether the corresponding number is even or odd, and produce a single output signal indicating the result. If the detected input corresponds to an even number, the system outputs 1; if it corresponds to an odd number, the system outputs 0. The circuit must internally encode the active input, analyze the encoded value, and generate the final output accordingly.

Theme 3: Audio-based human interaction and safety sensing systems.

1. **Single-Transistor Audio Tester**

In audio labs and repair shops, technicians often need to quickly check whether a microphone or small audio source is functioning without setting up a full amplifier and speaker system. Design a simple testing circuit that accepts a microphone or audio-line input and produces an audible output through a small sound indicator. The system should allow users to clearly distinguish between silence, weak signals, and normal speech or tones during quick diagnostic checks.

2. Tap-to-Test Microphone Checker

Stage technicians and students often connect microphones before events but may not have an easy way to confirm whether the microphone capsule and wiring are functioning correctly. Design a microphone-checking circuit that responds to taps or loud speech by activating a visual indicator. The system should reliably detect intentional taps while ignoring most normal background noise.

3. Signal Mixer Circuit

In small audio setups or laboratory experiments, multiple audio sources often need to be combined into a single output channel. Directly connecting multiple sources can lead to interference and signal loss. Design a circuit that mixes two or more input signals into one output while maintaining signal clarity and minimizing distortion.

4. Signal Compressor Circuit

Design an analog audio signal compressor that accepts an audio input signal and automatically reduces large amplitude variations by compressing high signal peaks, thereby maintaining the output signal within a controlled amplitude range.

5. Adjustable Noise Level Warning Indicator

Workshops, laboratories, and makerspaces may require a simple way to monitor ambient noise and warn users when it exceeds a comfortable or safe level. Design a circuit that continuously observes environmental sound and activates an indicator when the noise level crosses an adjustable threshold set by the user.

6. Dual-Stage Audio Amplifier for Weak Sound Detection

In many environments such as electronics laboratories, workshops, or field repair situations, extremely weak audio signals from microphones or sensors are difficult to observe or monitor directly. Design a multi-stage amplification system capable of strengthening weak audio signals so they can be clearly monitored through an audible or visual indicator, enabling users to distinguish between silence, weak signals, and normal speech during testing applications.

7. Sound-Activated Oscillating Alarm

In certain safety or alert systems, a sudden loud sound should trigger a repeating alarm rather than a single brief indication. Design a circuit that detects a strong sound event and activates a repeating alarm signal that continues for a short duration, ensuring the alert is clearly noticeable.

8. Dual-Threshold Audio Indicator

During audio testing or monitoring tasks, it may be useful to determine whether an audio signal is either too weak or excessively strong. Design a circuit that analyzes the amplitude of an incoming sound signal and activates separate indicators for low-level signals and high-level signals outside the desired operating range.

9. Whistle-Activated Safety Indicator

In environments such as workshops or garages where workers may have occupied or dirty hands, operating switches can be inconvenient. Design a sound-controlled activation system that responds specifically to a whistle-like tone and activates a visual or audible indicator when the tone is detected.

10. 3-LED Audio Level Indicator

In music practice rooms or small audio setups, users often need a simple visual reference to determine whether their input signal level is too weak, within the optimal range, or excessively strong. Design a circuit that analyzes the incoming audio signal and drives three separate indicators corresponding to low signal level, optimal operating range, and excessive signal level.

Theme 4: Discrete Logic Design and VLSI Principles for Industrial Systems.

<u>Note: (Strictly no IC's Should be used)</u>

1. Smart Device Activation Logic *(Universal Logic Using NAND)*

In many embedded systems, devices must activate only under specific conditions determined by multiple control signals. Design a transistor-level logic circuit that activates an output LED when a sensor signal B is active while safety input A is inactive, or when an override input C is active. The circuit must implement the Boolean function $F(A,B,C) = \bar{A}B + AC$ using only NAND-based transistor structures, demonstrating how universal gates can be used to implement complex logic functions.

2. Industrial Machine Safety Logic *(Logic Function Implementation)*

Industrial machines often require multiple safety conditions to be satisfied before operation is permitted. Design a transistor-level logic circuit that controls a machine indicator LED based on the Boolean expression $F(A,B,C) = AB + \bar{A}C$, where the output becomes active when both safety switch A and control input B are active, or when the safety switch is inactive but an emergency override signal C is present. The circuit should clearly demonstrate the implementation of Boolean expressions using transistor logic.

3. Request Priority Controller *(4-Input Priority Encoder)*

In digital communication systems and microprocessors, multiple subsystems may request access to a shared resource at the same time. Design a 4-input priority encoder using transistor logic that identifies the highest-priority active input among four request signals and generates the corresponding binary output. LED indicators should be used to display the encoded output representing the selected request.

4. Digital Level Comparator for Monitoring ***(2-Bit Binary Comparator)***

In monitoring and control systems, digital values from sensors or counters are often compared to determine relative magnitude. Design a transistor-based digital circuit capable of comparing two 2-bit binary inputs and indicating whether one value is greater than, equal to, or less than the other. Separate LEDs should clearly display each of these comparison results.

5. Simple Arithmetic Processor Block ***(Half Adder)***

Arithmetic operations form the core of digital processors and computation units. Design a half adder using transistor-level logic gates that accepts two binary inputs and produces SUM and CARRY outputs. Both outputs should be indicated using LEDs to demonstrate the basic arithmetic operation performed by digital logic circuits.

6. Memory Element for Digital Systems ***(SR Latch)***

Digital systems often require a basic memory element to store the current state of a signal or control input. Design an SR latch using cross-coupled transistor logic capable of storing a single bit of information. The circuit should maintain its output state until new input signals modify the stored value, and the stored output should be displayed using LEDs.

7. Communication Error Detection Circuit ***(Parity Generator)***

Digital communication systems frequently use parity bits to detect transmission errors in binary data. Design a 3-bit even parity generator using transistor logic that produces an output parity bit ensuring that the total number of logic HIGH signals in the system remains even. The generated parity output should be displayed using an LED.

8. Digital Signal Selector *(2-to-1 Multiplexer)*

Electronic systems often require selecting one signal from multiple inputs, such as switching between sensors or communication lines. Design a 2-to-1 multiplexer using transistor logic in which a control signal determines which input is routed to the output. The selected output signal should be indicated using an LED.

9. Oscillator for Clock Generation *(Ring Oscillator)*

Digital systems require clock signals to synchronize operations such as counting, data transfer, and processing. Design a ring oscillator using an odd number of transistor inverter stages connected in a loop, generating a continuous oscillating signal. The oscillation should be observable using an LED indicator or measurement point.

10. Event Counter for Monitoring *(2-Bit Binary Counter)*

Counters are widely used in digital systems to track events such as button presses, pulses, or sensor activations. Design a 2-bit binary counter using transistor-based sequential logic that generates the sequence 00 → 01 → 10 → 11 → repeat, with LEDs used to display the current count value.

Theme 5: Fail-safe timing and power management protection systems.

1. Delayed Load Startup Module
Many small DC loads like fans and lamps draw a high inrush current if turned on immediately at power-up, potentially stressing lab supplies or demo setups. Design an ON-delay start module using an NE555 monostable, RC timing network, and transistor/relay or MOSFET that waits for a preset time before energizing the load, so that loads can be sequenced smoothly in lab experiments or small control panels.

2. Post-Shutdown Cooling Timer
Equipment such as soldering stations or power amplifiers often need their cooling fans or pumps to continue running for a short time after the main power is switched off to prevent heat build-up. Develop an OFF delay stop module using an NE555 monostable that is triggered when the main control signal goes low and keeps the fan or pump ON for an adjustable interval, providing repeatable cooling behaviour without any microcontroller.

3. Adjustable PWM Speed/Dimmer Controller
Simple DC motor speed control or LED strip dimming in hobby projects is often done by varying voltage, which is inefficient and unstable. Create an adjustable duty-cycle PWM controller driving a transistor/ MOSFET so that users can smoothly adjust motor speed or light brightness at constant supply voltage

4. Pulse Stretcher for Event Detection
In sensor systems with very narrow pulses (e.g., from encoders or limit switches), LEDs or slow circuits cannot reliably show or process such short events. Implement a pulse-stretching circuit using a 555 or transistor monostable that takes very short input pulses and outputs longer, fixed-width pulses that can be easily observed on an LED or interfaced to slower logic, making invisible events visible for debugging.

5. Activity Signal Watchdog Indicator
In portable electronic devices such as laptops, smartphones, or power

banks, internal subsystems often generate periodic activity signals to indicate normal operation. If this signal stops due to a system freeze or internal malfunction, a simple power LED may still remain ON, giving the impression that the device is functioning normally. Design a circuit that monitors a periodic activity signal and keeps an indicator active while the pulses continue to arrive. If the signal stops for longer than a preset time interval, the circuit should automatically turn the indicator OFF, providing a clear visual indication of a stalled or malfunctioning device.

6. Battery Undervoltage Cutoff with Hysteresis
In battery-powered field equipment (like solar-charged lanterns), lead-acid or Li-ion batteries can be permanently damaged if they are discharged below a critical voltage. Simple voltage dividers don't account for "voltage bounce" when a load is removed, causing the system to flicker on and off. Design a circuit using a voltage comparator (or a 555 used as a Schmitt trigger) and a MOSFET that disconnects the load when the battery hits a "low" threshold. It must include hysteresis, meaning the load stays off until the battery has recharged to a significantly higher, safe level, preventing rapid oscillations.

7. Auto-Retry Hiccup Mode Power Protector
Standard fuses are slow and must be replaced after a fault. In test environments, users often accidentally short-circuit outputs. A "crowbar" circuit is too aggressive, and a simple limiter generates too much heat. Implement a "Hiccup Mode" power protector. If the current exceeds a set limit (sensed via a low-ohm resistor and a transistor), the circuit should immediately cut power and then wait for a 5-second "cool down" period before automatically attempting to restart. If the short is still there, it should cut power again and repeat the cycle.

8. Two-Transistor Constant Current LED Driver
High-power LED strips are often driven by unregulated power supplies. A small spike in voltage can lead to "thermal runaway," where the LED draws more current, gets hotter, and eventually burns out. Resistors are inefficient for this. Design a constant-current limiter using two NPN transistors and a sense resistor. The circuit should "clamp" the current at exactly 100mA, regardless of whether the input voltage is 9V or 15V

9. Single-Cycle Pushbutton Pulse Generator

In industrial presses, a operator must push a button to cycle the machine. If they tape the button down to work faster, it bypasses safety. The machine should only cycle once per press. Design a "Monostable" circuit that produces a single 500ms pulse regardless of whether the input button is tapped for 1ms or held down for 1 hour. The circuit must "reset" only after the button is physically released.

10. Peak Voltage Spike Capture Circuit

In many industrial sensing systems, short-duration voltage spikes can occur due to sudden events such as pressure surges, mechanical shocks, or electrical disturbances. These spikes may be too brief to observe directly with standard indicators or monitoring equipment, yet they can reveal important information about system behavior. Design an analog circuit using an operational amplifier, a diode, and a capacitor that detects and captures the maximum voltage level reached by an incoming signal. The circuit should allow technicians to examine the highest spike level that occurred during operation for diagnostic or monitoring purposes.