Department of Engineering Technology and Industrial Distribution

Final Course Project Report

ESET 350

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Due Date: 28 April 2026
Date Turned In: 28 April 2026

An Aggie does not lie, cheat or steal, or tolerate those who do.

On my honor as an Aggie, all of the information contained in this report is my own work that I completed as part of this lab assignment. I have not used results or content from any unauthorized sources or fellow students.

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Overview:

For our final project, we constructed and analyzed the **MK120 Infrared Alarm System**. This system is designed to establish an invisible, continuous optical link between a dedicated transmitter board and a receiver circuit. The primary function of this system is to act as a reliable tripwire security system that emits a loud audible alert and visual warning whenever an object or person breaks the line of sight between the transmitter and receiver boards.

To operate effectively without any false triggering from ambient sunlight or room lighting, the transmitter modulates an infrared (IR) light beam at a specific high frequency of 4.8 kHz. The receiver has a phototransistor, which constantly monitors for this exact frequency. Essentially, as long as the receiver detects the 4.8 kHz pulsed IR Light, the system will remain in a passive monitoring state. However, when the beam is interrupted, the receiver circuit detects the signal loss and immediately triggers the alarm.

System Inputs:

- **Electrical Input:** The transmitter and receiver boards require an independent 9V DC power supply to operate. Standard 9V batteries were used to power each board for this project.
- **Sensing Input:** The main physical input to the system is the presence or absence of the 4.8 kHz pulsed infrared light beam, which is read by the phototransistor connected to the receiver board.

System Outputs:

- **Transmitter Output:** A continuous, invisible 4.8 kHz pulsed infrared light beam emitted by two IR LEDs.
- **Receiver Output:** When the optical link is broken, the receiver outputs a high-current drive signal, which activates a piezoelectric buzzer (Audible Output) and a red LED (Visual Output).

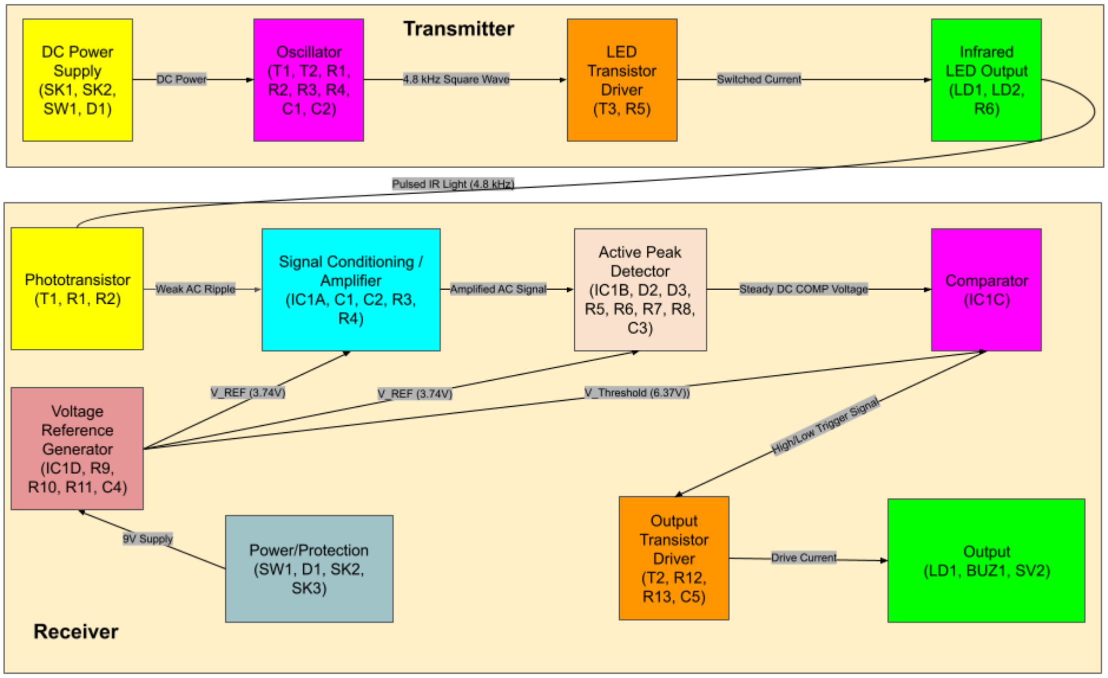

Fig. 1. Functional Block Diagram for the MK120 Transmitter and Receiver

As shown in **Fig. 1**, the system is divided into two independent signal paths:

Transmitter Signal Flow:

Regulated DC power feeds the oscillator, which then generates a continuous 4.8 kHz square wave. This weak signal triggers the LED transistor driver, which acts as a high-current switch that essentially forces the output LEDs to emit a 4.8 kHz pulsed infrared beam.

Receiver Signal Flow:

The IR beam is detected by the phototransistor and converted into a weak AC ripple. Then, the signal conditioning block amplifies this ripple, and the active peak detector converts it into a steady DC “COMP” voltage. Next, the comparator constantly evaluates the COMP voltage against a hardcoded threshold. As soon as the beam is obstructed, the COMP voltage drops, which causes the comparator to output a HIGH trigger signal. This switches on the output transistor driver, allowing the current to flow into the final output block to activate the piezoelectric buzzer.

Theory of Operation:

The overall transmitter circuit schematic with color-coded sections is shown in **Fig. 2.** The Infrared Transmitter is split into 4 parts: the DC Power Supply, the Oscillator, the LED Transistor Driver, and the Infrared Output.

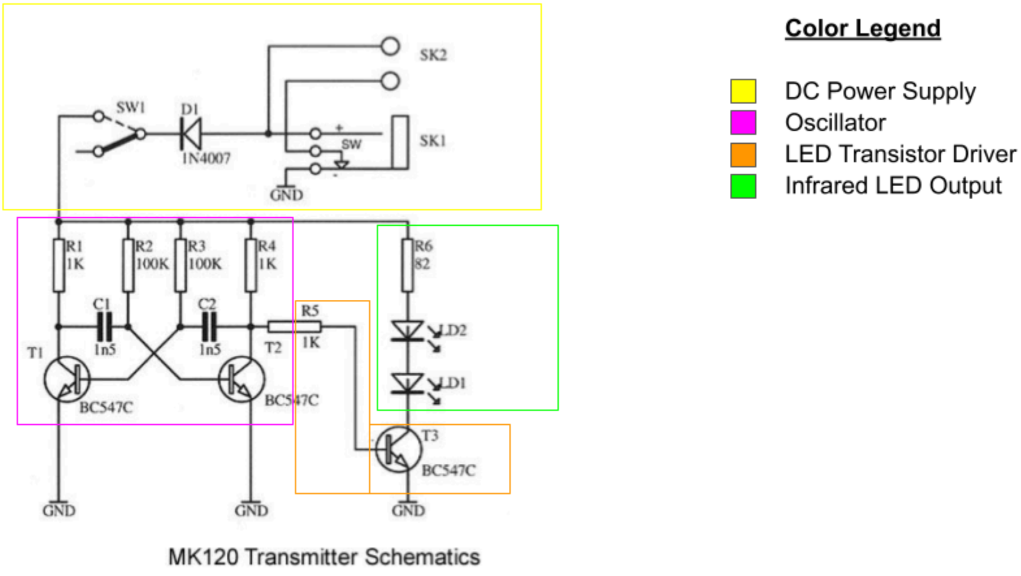

Fig. 2. Overall Circuit Schematic for MK120 Transmitter

The DC Power supply consists of SW1, D1, SK1, and SK2. SW1 is the main on/off switch. Diode D1 protects the circuit from reverse battery connection. If the battery polarity is correct, D1 is forward-biased, allowing current to flow to the rest of the circuit. While the SW1 switch is on, the forward drop of the diode is 0.6-0.8 V. The voltage across the battery is 8.15 V, corresponding to the diode's forward drop.

The Oscillator consists of T1, T2, R1, R2, R3, R4, C1 and C2. This stage generates a repeating square-wave control signal. Transistors T1 and T2 are cross-coupled through capacitors C1 and C2, forming a classic astable multivibrator. The two transistors alternately switch on and off. When T1 is ON, its collector voltage is approximately 0 V (saturation), and it helps drive T2 OFF, pulling T2's collector to ~7.4V. As the timing capacitor charges through the resistor network, the state eventually reverses. This process repeats continuously, producing oscillation. The collector outputs of T1 and T2 are approximately complementary square waves, at a frequency of about 5 kHz.

The LED Transistor Driver consists of T3 and R5. The oscillator signal cannot directly supply sufficient current to the IR LEDs. Therefore, transistor T3 is used as a current-switching driver stage. The square-wave signal from the oscillator is applied to the base of T3 through resistor R5. When base current flows, T3 turns ON and conducts collector current through the LED branch. When the base current stops, T3 turns OFF. R5 limits the base current and protects the transistor.

The Infrared LED Output consists of LD1, LD2, and R6. This stage converts electrical current into infrared light. Two IR LEDs are connected in series with resistor R6, which limits current to a safe value. When T3 turns ON, current flows from the supply through R6 and the LEDs into T3. Approximate LED current: 2.885V/82Ω = 35 mA. The LEDs emit pulsed infrared light at the oscillator frequency. Although the LEDs may appear continuously ON to the eye, the switching occurs too quickly to be visually detected.

The overall receiver circuit schematic with color-coded sections is shown in **Fig. 3.** The receiver contains seven major sections: power input, phototransistor sensor, amplifier stages, peak detector, reference generator, comparator, and output driver.

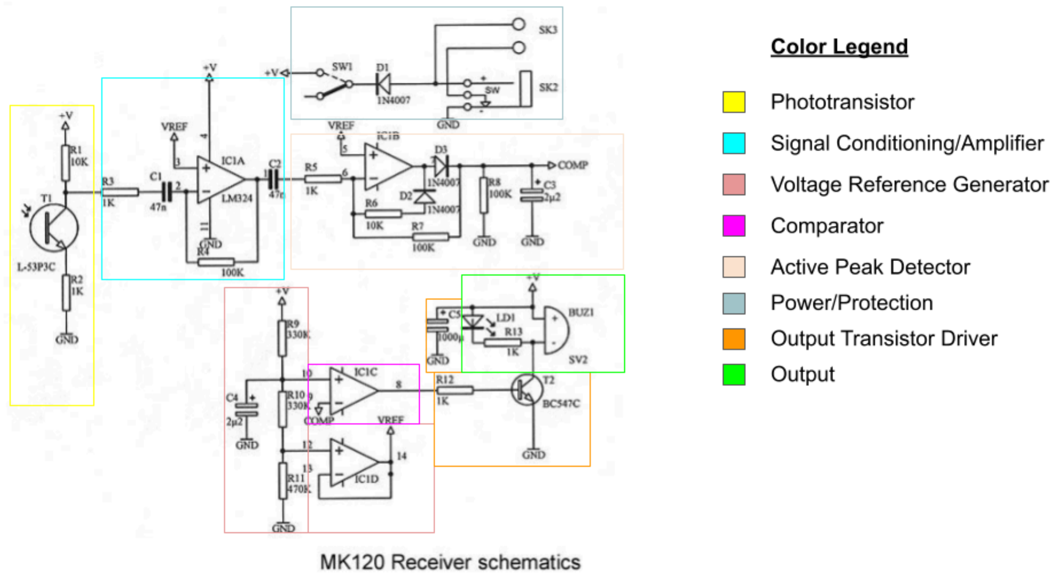

Fig. 3. Overall Circuit Schematic for MK120 Receiver

The Power Input consists of SK3, SK2, SW1, and D1. This section provides DC power to the receiver. As in the transmitter, the diode prevents reverse polarity damage. A 9 V battery produces an internal operating rail of 8.2 V after the diode drop.

The Phototransistor Sensor consists of T1, R1, and R2. The phototransistor converts incoming infrared light into an electrical current. When IR light strikes the device, the transistor's conduction increases. When the beam is blocked, conduction decreases. This changing current creates a changing voltage across the surrounding resistor network. Typical behavior consists of Beam present → increased conduction, and Beam blocked → reduced conduction. Therefore, the collector and emitter node voltages shift depending on the received light intensity.

The Signal Conditioning/First Amplifier consists of C1, R3, IC1A, and R4. The sensor signal is very small and must be amplified. Capacitor C1 AC-couples the signal into op-amp IC1A. This removes DC offsets caused by ambient light and passes only changing signals. The non-inverting input is biased at VREF (≈3.74 V), allowing the LM324 to amplify AC signals while operating from a single positive supply. The gain is $Av = -R4/R3$, which is -100.

The Active Peak Detector/Second Amplifier consists of IC1B, R5, R6, R7, D2, D3, R8, and C3. This section further amplifies the received waveform and converts it into a DC level proportional to signal strength. Diodes D2 and D3 rectify the amplified AC signal. Capacitor C3 stores the peak value, while resistor R8 slowly discharges the capacitor when the signal disappears. The RC time constant is $(100k\Omega) * (2.2\mu F) = 0.22$ seconds. Therefore, the detector output does not instantly collapse when the beam is interrupted. Instead, it decays over a fraction of a second, improving stability and reducing false alarms.

The Voltage Reference Generator/Third Amplifier consists of R9, R10, R11, IC1D, and C4. This stage generates stable reference voltages used by the amplifiers and comparator. IC1D is configured as a voltage follower (buffer), which provides a low-impedance reference voltage VREF. For a 9 V supply, VREF is approximately in the mid-lower portion of the supply range (typically around 3–4 V depending on actual battery voltage). This reference allows all op-amp stages to operate correctly on a single supply.

The Comparator/Fourth Amplifier consists of IC1C. The comparator determines whether the received signal is strong enough to indicate an unbroken beam. One input receives the COMP voltage from the peak detector. The other input receives the threshold reference voltage. The Operation is as follows: If COMP > threshold (5.37 V): beam detected, alarm OFF; If COMP < threshold (5.37 V): beam interrupted, alarm ON. Thus, IC1C converts the analog signal into a digital-like high/low output.

The Output Transistor Driver consists of T2, R12, BUZ1, LD1, R13, and C5. The comparator output drives transistor T2 through resistor R12. When T2 is OFF (standby), its collector sits at a maximum expected voltage of ~6.4 V. When T2 turns ON, the collector drops to a minimum expected voltage of ~0 V, providing a current path to ground for the buzzer and LED. This activates both visual and audible alarms. R13 limits LED current. C5 provides local filtering and helps stabilize the supply during buzzer operation.

In summary, when the transmitter and receiver are aligned, the phototransistor receives pulsed IR light. The signal is amplified, detected, and interpreted as a valid beam. The comparator keeps the alarm off. When the beam is blocked, the received signal disappears. The detector voltage falls below the threshold, causing the comparator to switch states. Transistor T2 turns on, activating the buzzer and indicator LED. The MK120 system demonstrates multiple analog circuit concepts, including transistor switching, RC timing networks, active amplification, signal filtering, peak detection, threshold comparison, and transistor power driving.

Testing:

The MK120 project kit was purchased, and the system was constructed by manual soldering of components onto the printed circuit boards. Bench measurements were conducted using three pieces of equipment. A digital multimeter (DMM) was used to capture the static DC bench measurements across the critical components. An oscilloscope was used to capture the time-varying AC signals, switching frequencies, and dynamic responses. Lastly, standard 9V DC batteries were used to separately power the transmitter and receiver boards throughout the testing portion of this project.

Testing was done by powering both boards and aligning the transmitter’s infrared LEDs directly at the receiver’s phototransistor to initiate the optical link. The system was tested and measured in all of the operational states. For instance, in the ON state (beam present), the optical link remains intact, which allows the receiver to successfully detect the 4.8 kHz beam and keep the piezoelectric buzzer from emitting the alarm noise. In the OFF state (beam gone), a physical object obstructs the optical link, which causes the receiver to lose the signal and trigger the audible and visual alarms. Additionally, distance testing was performed by taking oscilloscope measurements while moving the transmitter closer to and further away from the receiver to test how the sensor responds to changes in signal strengths over distance.

Voltages at all the major components' nodes were measured using the DMM to make sure the logic levels, voltage drops, and biasing in all states matched the expected values. These measurements are evident below in **Table 1**.

Table 1. DC Bench Measurements — Transmitter (left) and Receiver (center & right)

Transmitter			Receiver (1 of 2)			Receiver (2 of 2)		
Component	ON (V)	OFF (V)	Component	Present (V)	Gone (V)	Component	Present (V)	Gone (V)
V(battery)	8.15	8.5	battery	8.2	8	R1	-0.63	-0.01
V(D1)	0.756	0.0009	phototransistor	8.5	8.2	R2	-0.06	-0.00009
V(LD1)	1.09	0.001	D1	0.6	0.737	R3	0	0.0004
V(LD2)	1.09	0.001	D2	3.08	-0.06	R4	0.001	0
V(Switch)	0.005	0	D3	-2	-2.4 to -1.8	R5	0	0
V(R1)	4.6	0	R6	0	0	R7	0	0
V(R2)	8.34	0	R8	0	0	R9	0	0
V(R3)	7.185	0	R10	0	0	R11	0	0
V(R4)	4.735	0	R12	0	6	R13	0	6.4
V(R5)	2.022	0						
V(R6)	2.885	0						

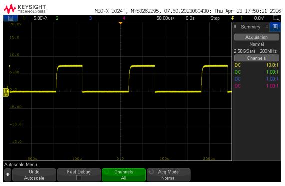

Fig. 4. T1 collector – astable multivibrator output.

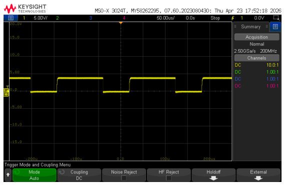

Fig. 5. T2 collector – complementary square wave output.

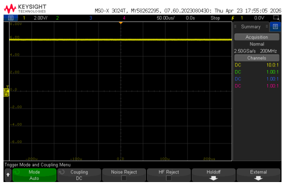

Fig. 6. T3 collector – LED driver transistor switched output.

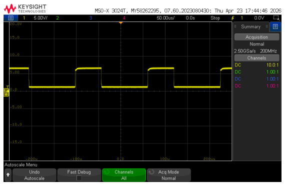

Fig. 7. LED1 node – pulsed IR drive voltage waveform.

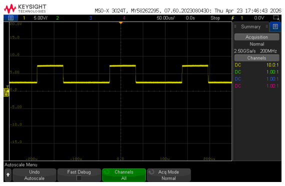

Fig. 8. LED2 node – pulsed IR drive voltage waveform.

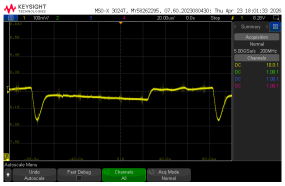

Fig. 9. Phototransistor output – beam aligned close.

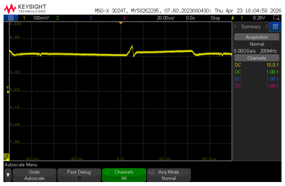

Fig. 10. Phototransistor output – beam aligned far.

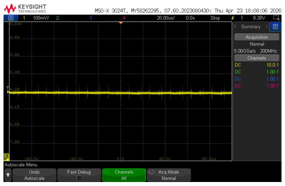

Fig. 11. Phototransistor output – beam fully blocked.

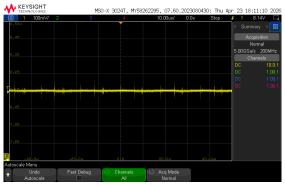

Fig. 12. Output T2 collector – alarm active (beam gone).

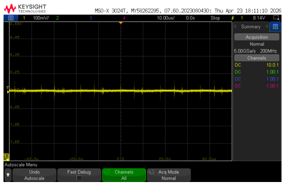

Fig. 13. Output T2 collector – alarm inactive (beam present).

Ultimately, all of the results matched the theoretical expectations: Transistors T1 and T2 produced alternating ~4.8–5 kHz square waves **(Fig. 4, Fig. 5)**. The LED drive current of ≈ 35 mA (2.885 V / 82 Ω) successfully produced the pulsed infrared light **(Fig. 6, Fig. 7, Fig. 8)**. The phototransistor's signal grew stronger as the transmitter was moved closer **(Fig. 9, Fig. 10)**, but dropped to zero when the beam was blocked **(Fig. 11)**. Finally, measurements at R12 and R13 confirmed that output transistor T2 only turned on (0 V → 6.0/6.4 V) when the beam was broken **(Fig. 12, Fig. 13)**. No failures were observed.