ECE280 - Lab 9: AM Radio

Ace Abdulrahman (aka40)

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I have adhered to the Duke Community Standard in completing this assignment.

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Contents

1 Objectives

1. Generate an AM signal using a function generator and oscilloscope.
2. Use external modulator (computer audio output) to modulate the carrier signal from the function generator.
3. Use function generator to set up a transmitter that broadcasts music as an AM signal.
4. Use portable AM radio to pick up broadcast ed music
5. Build an envelope detector to implement and examine an AM demodulator.

2 Background

Asynchronous modulation is the process of modulating the waveform of a signal without the need of a phase synchronization with the sender carrier signal. As shown in figure 1, asynchronous modulation in the frequency domain results in two spectrum copies centered around the carrier frequency with an impulse function at the carrier frequency. Asynchronous demodulation is the process of demodulating a modulated signal to obtain the original signal without the need of phase synchronization.

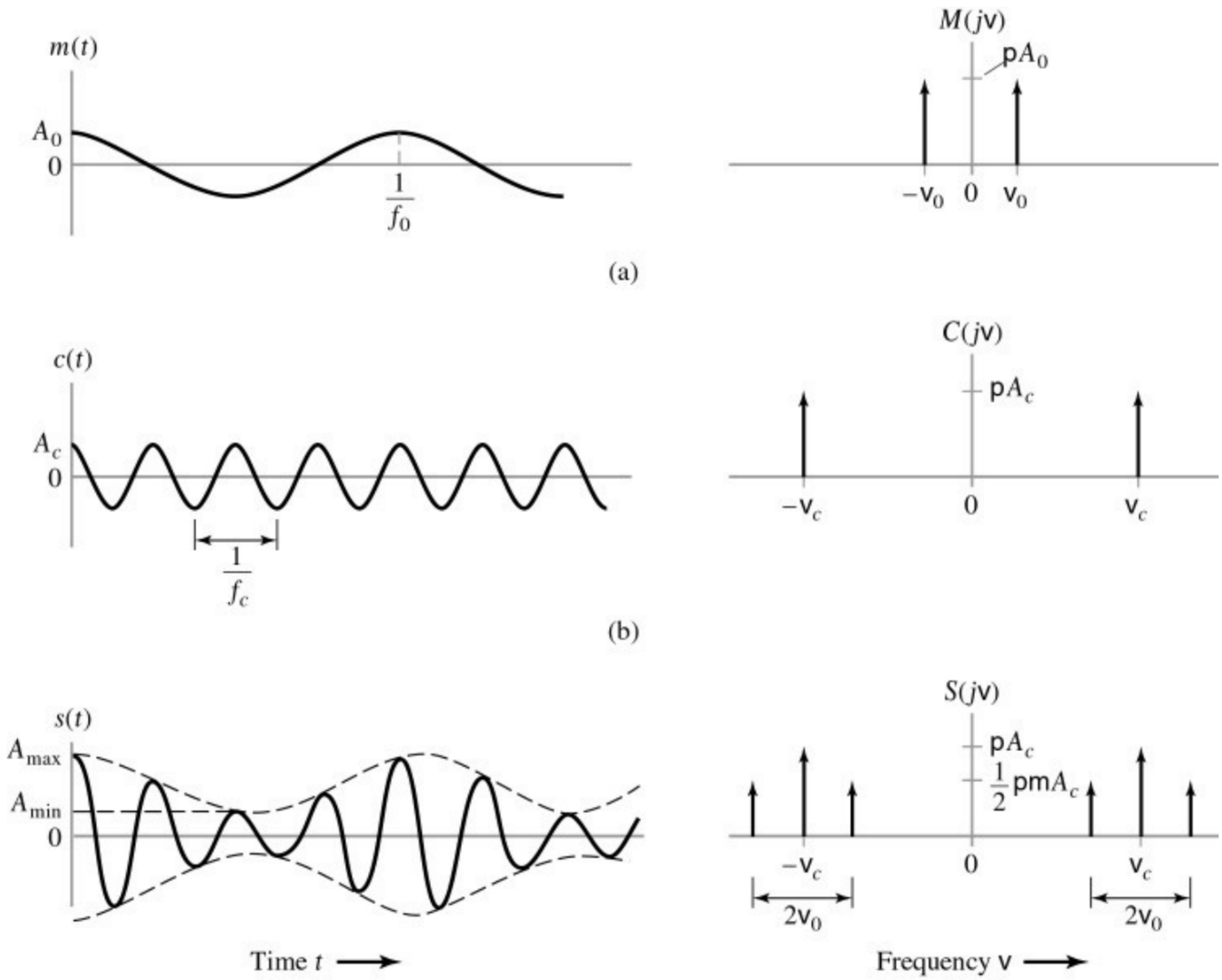

Figure 1: Amplitude modulation and demodulation example obtained from the lab manual.

3 Exercise 1: AM Signal in Time and Frequency Domains

3.1 Procedure

1. Generate a 1 V peak to peak, 50 kHz sinusoid using the function generator and display it on the oscilloscope.
2. Set function generator's modulation scheme to AM and internal generation of modulating signal with frequency 1 kHz.
3. Start with modulation index of 0.5 and measure the the maximum and minimum voltage using the oscilloscope to calculate the experimental modulation percentage.
4. Experiment with different modulation indices and verify that the experimental modulation percentage matches the value set in the function generator.

3.2 Measurements, Data, and Figures

Modulation Percentage	$V_{\min}(V)$	$V_{\max}(V)$	μ
50%	0.25	0.735	0.4923
15%	0.42	0.565	0.1471
80%	0.11	0.9	0.782
115%	-0.07	1.06	1.141

Table 1: Modulation Percentages, Measured Voltage Levels, Calculated Modulation Factors

3.3 Discussion Questions

- How many peaks did you expect to see and where did you expect to them on the frequency axis?
  Three peaks were expected centered around the f=50 kHz on the frequency axis.
- Record your observations as the modulating frequency changed.
  As the modulation frequency is increased, the width between the peaks in the power spectrum in the oscilloscope increases.
- Record your observations as the carrier frequency changed.
  As the carrier frequency increases, the power spectrum is shifted to the right.
- Verify each modulating factor you calculated. Were they accurate to the chosen percentage?
  Yes, the modulating factors were accurate to the chosen percentages, because the calculated modulating factors were within 5% of the chosen percentages for all tested modulation levels.

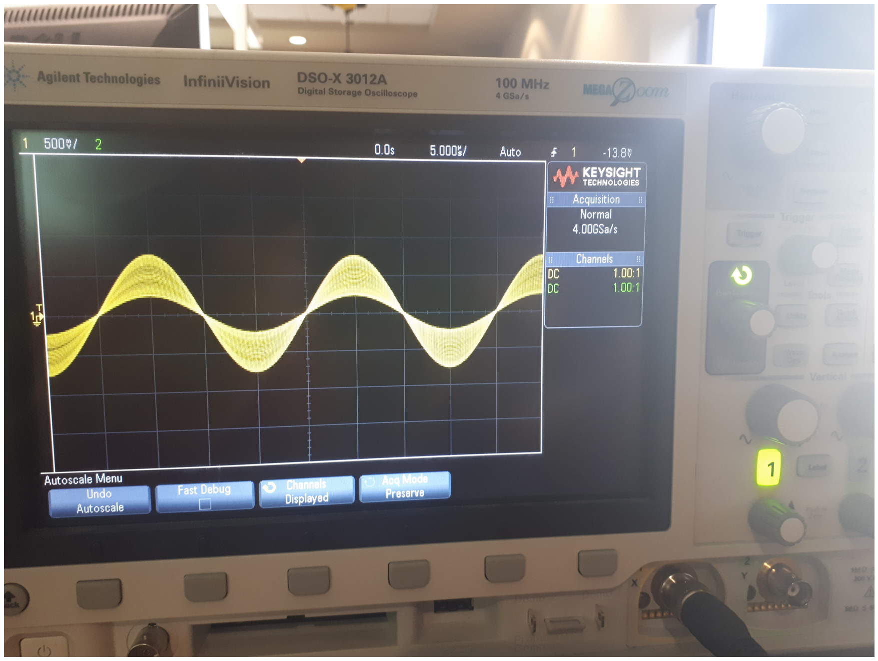

Figure 2: Oscilloscope display of the envelope of the AM waveform and its power spectrum

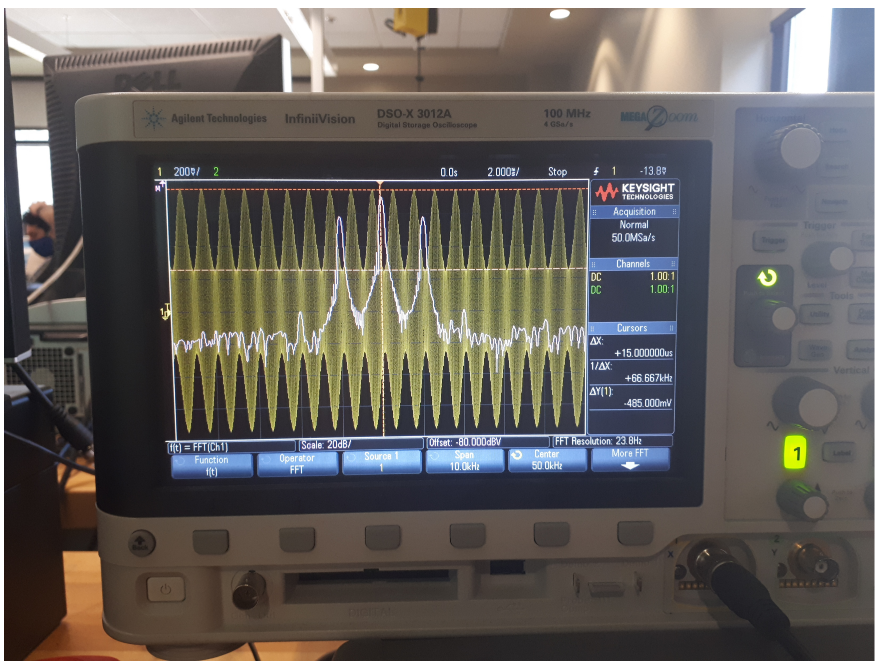

Figure 3: Oscilloscope display of power spectrum

3.4 Choosing a Modulation Factor

The modulating frequency should be chosen such that there is large enough information transmitted through the signal without overlap. This can be achieved by obtaining minimum voltage that is close to zero but not negative in value. Among the modulation percentages tested, 80% gave the lowest non-negative minimum voltage. At modulation percentage of 115%, the minimum voltage reached negative values. This indicates that the optimal modulation percentage is between 80% and 115%.

4 Exercise 2: Using an External Modulating Signal

4.1 Procedure

- Generate a 1 V peak to peak, 50 kHz sinusoid using the function generator and display it on the oscilloscope (same as exercise 1).
- Use an AUX cable to connect the output of the computer to the input of the external modulation of the function generator located at the back of the generator.
- Set the function generator to external AM (EXT AM)
- Set the volume of the computer to max before playing an audio that covers wide range of frequencies on the computer.
- Display time and frequency domains in the oscilloscope.
- Through visual analysis, determine the range of the sidebands in the frequency domain.

4.2 Measurements, Data, and Figures

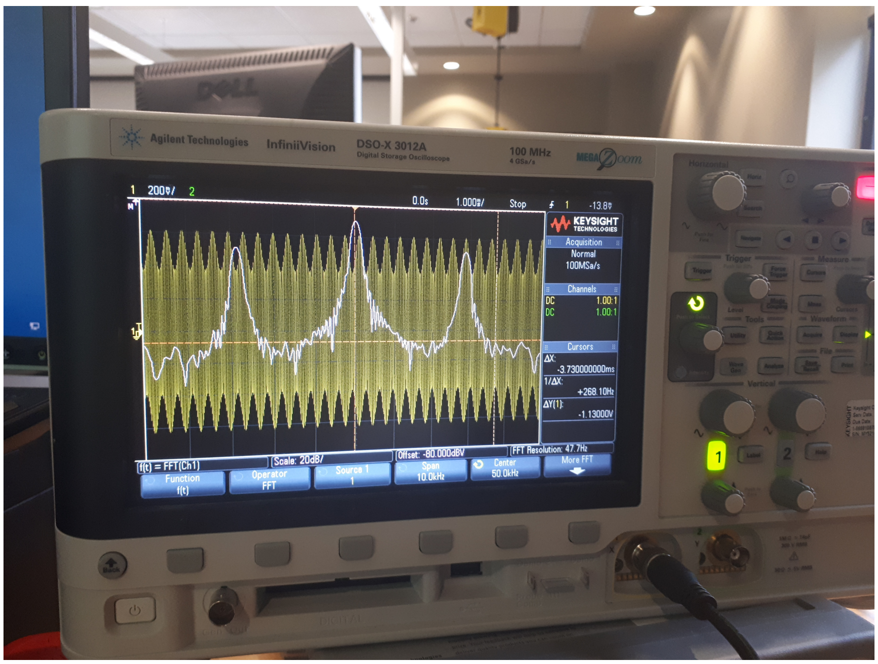

Figure 4: Oscilloscope display of sweep.wav file

4.3 Discussion Questions

- What are the frequency ranges of the two sidebands?
  The frequency ranges for the two sidebands are from 0 Hz to 3.7 kHz.
- Are the sidebands mirror images of each other?
  Yes, as displayed in figure 4, the sidebands are mirror images of each other.

5 Exercise 3: Broadcasting your Signal

5.1 Procedure

- Continuing with the same setup from exercise 2, generate a 1.5 V peak to peak sinusoid with carrier frequency between 500 Hz to 1.6 kHz

- Connect a BNC-Banana cable to the function generator's output and the provided breadboard's +/- ports.
- Make sure the volume of the computer is set to max before playing music.
- Use the provided portable AM radio to tune into the broadcasted station at the chosen carrier frequency (ensure that the antenna is fully extended).
- Measure how far away the radio can be from the transmitter before the music is indistinguishable at different peak to peak voltages.

5.2 Discussion Questions

- How far can you move away from the transmitter and still recognize the music signal from your station?
  The music signal can be recognized from up to 3 inches away from the stations at 1.5 V peak to peak. At 10 V peak to peak, the music can be recognized from up to 25 inches away from the station.
- Did the strength of the received signal change as you varied the peak-to-peak voltage of the carrier signal?
  Yes, the higher the peak to peak voltage, the stronger the received signal, hence the farther away from the station the music can be recognized.
- Did the fidelity of the received signal change as you varied the peak-to-peak voltage of the carrier signal?
  Yes, the higher the peak to peak voltage, the greater the clarity/fidelity of the received signal. This is especially noticeable at distances farther away from the transmitter.

6 Exercise 4: AM Demodulation using an Envelope Detector

6.1 Procedure

- Continuing with the same setup from exercise 3, build an envelope detection circuit (low pass filter) on the breadboard by connecting a diode in series with 10 kilo-Ohm resistor and a 1 nano-Farad capacitor that are connected in parallel.
- Connect the circuit to the function generator.
- Set up the carrier signal with the following characteristics: 100kHz, 5 V peak to peak, 0.5 modulation index, and modulating frequency of 1 kHz.
- Display the time and frequency domain (using FFT button on the oscilloscope) of your AM signal in the oscilloscope.

6.2 Measurements, Data, and Figures

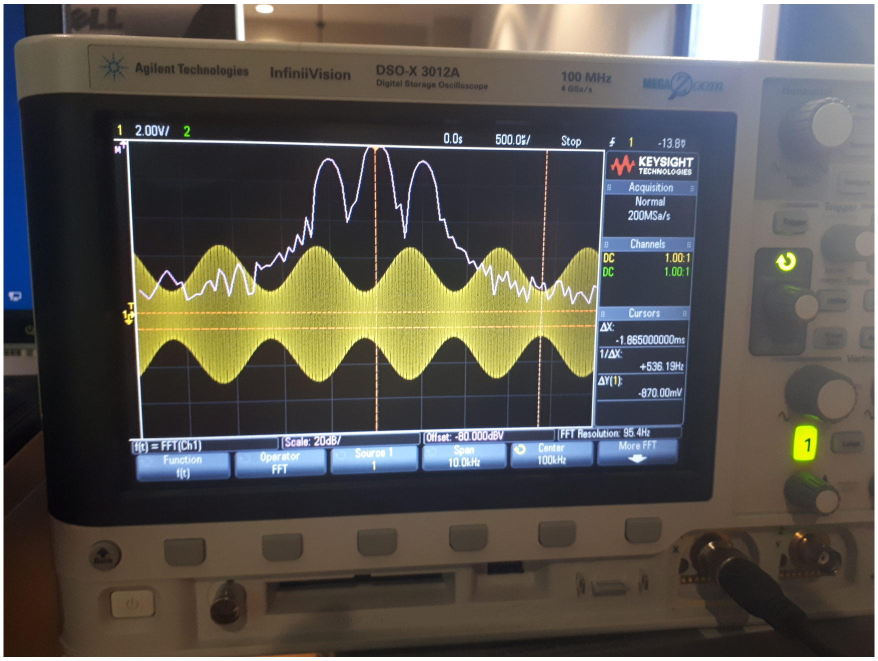

Figure 5: Input to the circuit in the time and frequency domains

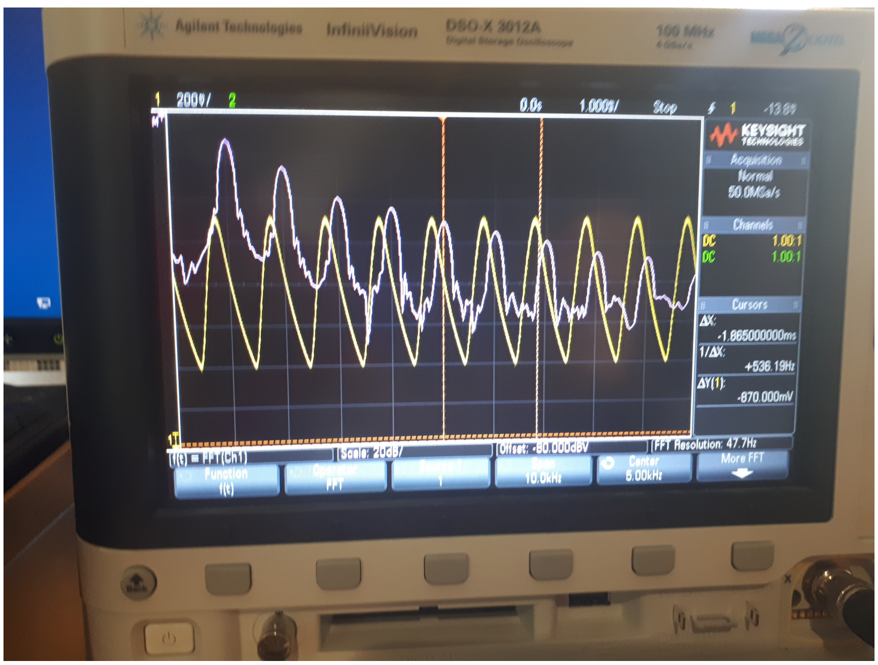

Figure 6: Output to the circuit in the time and frequency domains

6.3 Discussion Questions

- How many peaks do you observe in the input spectrum? Where are they located? Is this expected/unexpected?
  There are three peaks in the input spectrum that are centered around 100 kHz. This is expected as it matches the original signal.

- Comment on the time domains of the input and output to the circuit.

The input is the envelope of the carrier signal at frequency 100 kHz. The output of the time domain displays the effect of applying the low pass filter (steep attenuations).

- What did you expect the signal at the output of the envelope detector to look like? Have you recovered your original signal?
  The expected output is the original unprocessed signal. The output does not show that the original signal has been well recovered.

- Comment on the frequency domains of the input and output to the circuit.
  The frequency domain of the input displays 3 peaks centered around 100 kHz. The frequency domain of the output displays decaying/attenuating peaks at higher frequencies.

- Relate your frequency domain observations to your time domain observations of the input and output signals.
  The time domain observations of the input display low amplitude at the nodes; this represented by low amplitudes at frequencies far from 100 kHz in the frequency domain. The time domain observations in the time domain of the output displays attenuation after peaks; this is represented in the frequency domain by attenuating peaks as frequency increases beyond the cutoff.

- Describe in detail how you selected the value of C for your circuit. Justify your selection in terms of the singal parameters (e.g. carrier freqeuncy, message content).
  The resistance of the circuit was instructed to be 10 kilo-Ohms. The desired delay ($\tau = RC = \frac{1}{2\pi f_s}$) is between $\frac{1}{2\pi 10^5}$ s and $\frac{1}{2\pi 10^6}$ s. Solving for C ($C = \frac{\tau}{R}$) shows that 1 nano-Farad (capacitance of the capacitor used) falls between the range of acceptable values for capacitance in order to meet the desired delay.

- What must be (or can be) done to make the output of the signal more like the original message (modulating) signal?
  Increasing the delay allows for more time to process the input signal which will make the output more like the original message by allowing for better edge detection and decreasing the cutoff frequency. This can be implemented in the circuit by increasing the resistance of the resistor in the circuit.

7 Conclusions

In this laboratory, an AM signal was generated via a function generator. Furthermore, using computer audio output as an external modular the carrier signal from the function generator was modulated. In addition, an AM radio music station was setup and listened to via a portable AM radio. Lastly, an envelope detector circuit was built and used to demodulate the modulated signal in attempt to recover the original signal.

8 Extension

In this laboratory, a low pass filter circuit was built and used to create an envelope detector. However, how a low pass filter is related to an envelope detector and what the downsides are of using this method was not addressed. The purpose of this extension is to investigate these questions.

Figure 7 shows a picture of the circuit built to implement a low pass filter/envelope detector using a resistor, capacitor, and diode. The diode is connected in series to a resistor and capacitor placed in parallel (creating low pass filter). The diode's purpose is to rectify the incoming signal from the function generator by allowing the current flow when the positive input terminal is at a higher electrostatic potential than the negative input terminal. The capacitor stores the electric charge and slowly discharges it when the amplitude of the input signal falls.

The appropriate circuit time constant must be chosen by selecting the right resistance and capacitance for the elements such that the voltage of the capacitor traces the high peaks of the input signal without omitting lower peaks. This will result in demodulation of the modulated input signal by removing the high frequency components of the signal (the parallel capacitor and resistor function as a low pass filter that rejects the carrier frequency), effectively isolating the original signal.

Although simple, this envelope detector circuit has its downsides biggest of which is that the input signal must be band pass filtered around the original signal in order to avoid demodulation of several signals. Furthermore, if the input signal to the system was overmodulated (i.e., the original signal was overmodulated before being passed as input), the recovered signal will not resemble the original signal due to distortion.

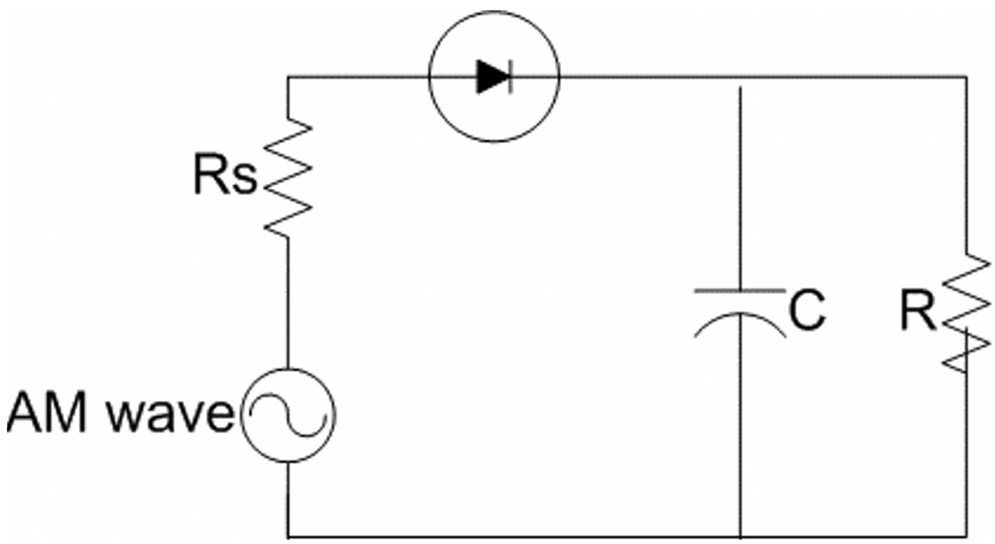

Figure 7: Envelope detector circuit built in this laboratory

9 Refrences

- https://wiki.analog.com/university/courses/electronics/electronics-lab-envelope-detector
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