IR Gesture Recognition for Auto Displays

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INTRODUCTION

The trend for bigger, wider displays is a challenge for touch-based control in modern automobiles. Drivers must reach farther and spend time focusing on the display rather than the road. One solution is to augment the automotive touchscreen with voice recognition, haptic feedback, and gesture control. These options minimize distraction when engaging the car's Human Machine Interface (HMI) interface.

Analog Devices has recently introduced two gesture sensors, the **MAX25205** and the **MAX25405** See Table 1.

- The MAX25205 is a low-cost sensor with 20cm of range and a true positive rate of 95%.
- The MAX25405 is a higher performance sensor, with integrated lens, that enables 40cm of range and a true positive rate of 97.5%.

The fusion of touch, voice, haptic feedback, and gesture is a feasible HMI solution that reduces distractions. Analog Devices has developed a solution featuring ten intuitive and easily recognizable gestures. More than ten gestures becomes distracting.

Applications that utilize gesture detection include swiping, to pick up the call, end it, or dismiss it. Using proximity to make icons larger and easier to touch. Using the linger to click function to go to the next HMI page. Using the rotation gesture to adjust the music level or scroll through the phone book. The addition of haptic feedback to acknowledge the recognition of a gesture helps keep the driver's eyes on the road. A demo video showing the fusion of touch, gesture, and haptic feedback is available **here**.

Voice control is a great addition to the HMI but has some major drawbacks if used on its own:

1. Wind and road noise from open windows/moon roof.
2. Audio interference from the stereo system, loud conversation from passengers, engine noise and road noise.
3. Voice commands could be an annoyance to someone sleeping.
4. Difficulty detecting different dialects among many languages.
5. Computational complexity that may require a connection to internet. The solution may not work in locations without cellular coverage or limited coverage. Large lag time on 3G and 4G networks and coverage limitations can be unacceptable.

Ultimately these drawbacks for voice only control create a negative user experience. The following selection guide will show what sensor is best suited to add gesture to the automotive HMI.

Figure 1. Automotive Gesture Sensor

GESTURE RECOGNITION SYSTEM PERFORMANCE METRICS

The following sections discuss the key performance metrics for gesture sensor systems considerations for implementation:

Performance Metrics:

1. **Number of Gestures Supported**
2. **Proximity of the User's Hand to the Sensor**
3. **Maximum Detection Distance**
4. **Coverage Area**
5. **Solution Robustness**
6. **Ease of Use**
7. **Low Solution Cost**

Figure 2. Gesture Sensor Helps the Driver Keep Eyes on the Road and Off of the Infotainment Display

1. NUMBER OF GESTURES SUPPORTED

A key strategy in providing intuitive robust gesture performance is to support a few gestures that work very well versus many non-intuitive, difficult to detect gestures. The MAX25205 and MAX25405 system supports two detection modes. Dynamic gesture detection and static hand proximity location. Only the linger to click is a combination of both - performed in proximity mode. The system recognizes the following gestures:

1. Swipes (L/R/U/D)
   Swipes are single linear motions - either left, right, up, or down.

2. Rotation (CW/CCW)
   Rotations can be clockwise or counterclockwise with the ability to detect full 360 degree and partial rotations for fine control.

3. Wave
   A wave gesture is swiping to the right across at least half of the field of view (FOV), then left at least 10cm, then right again to exit the FOV.

4. Air Click
   An air-click gesture is bringing the palm of the hand directly toward the sensor and then directly away from the sensor in one quick smooth motion.

5. Linger to Click
   In proximity mode the user can divide the sensors FOV into grided sections. When the hand lingers in a section for a user defined amount of time a linger to click event is set.

6. Flicks
   A flick gesture differs from a swipe gesture by traversing a smaller portion of the sensors FOV. It is a simple flick of the wrist. **Figure 3** shows how a flick gesture is performed. By design, the flick gesture has an almost instantaneous response. To enable the flick gesture all other gestures are disabled. This helps reduce latency in the algorithm. A typical use case is rear seat infotainment system where the user is flipping through pages of an article.

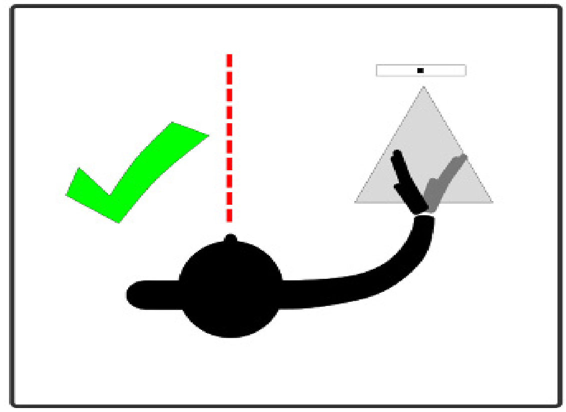

Figure 3. Performing Flick Gesture

2. PROXIMITY OF THE USER'S HAND TO THE SENSOR

The tracking algorithm provides object x- and y- location, proximity (relative z-position), region selection, and linger-to-click. Distance accuracy is rough. It can be used to determine if the object is near or far. Hand proximity information can be used to make the touch screen easier to control. Examples include making icons larger when the hand approaches. Icon selection can then be done with a linger to click eliminating the need to touch the screen.

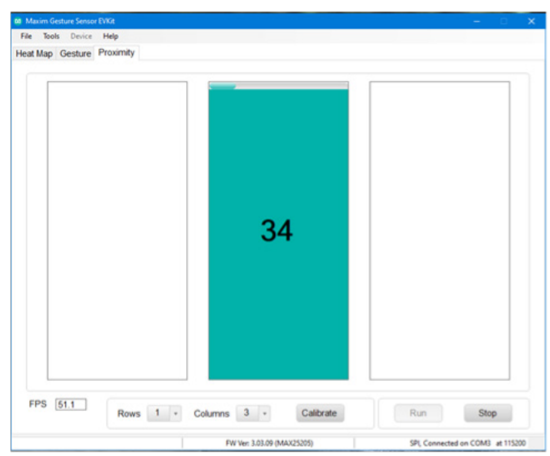

Figure 4. Linger to Click Gesture

Figure 4 shows the linger to click function. When the hand stays steady for two seconds as shown by the upper count down bar, a linger to click event fires. The "34" represents percent of maximum signal, measured in 1% increments. 100 percentage represents the highest signal level or closest distance. This is useful in measuring the rough position of the hand, near or far. The MAX25205 supports a 1 x 3 row column region while the MAX25405 supports a 2 x 3 row column region.

3. MAXIMUM DETECTION DISTANCE

Analog Devices has developed two gesture sensors for two different distance requirements. The MAX25205 can be used up to 20cm, while the MAX25405 includes a lens that enables a detection distance up to 40cm. The lens enhances image quality, which results in a higher true positive rate. The equation for true positive rate (TPR) is shown below where TP is the number of true positives and FN is the number of false negatives gestures detected.

$$TPR = \frac{TP}{\text{TOTAL \# OF RECORDED GESTURES}} = \frac{TP}{TP + FN}$$

Table 1. Gesture Sensor Selection Guide

	MAX25205	MAX25405
Left/Right Gesture	20cm	40cm
Up/Down Gesture	20cm	40cm
Rotation Gesture	15cm	30cm
Wave (typical)	10cm	10cm
Air Click (typical)	10cm	10cm
Linger to Click (typical)	10cm	10cm
Proximity	3 x 1 zones	3 x 2 zones
Effective FOV	+/- 20 deg	+/- 30 deg
True Positive Rate	95.0%	97.5%

The 20cm range of the MAX25205 make it ideal for close range applications like lighting control or replacing simple switches. The longer range of the MAX25405 is advantageous for front and rear seat infotainment systems.

4. COVERAGE AREA

A wide coverage area makes the gesture recognition system easy to use. The effective field of view for the MAX25205 is +/-20 degrees, while the MAX25405 is +/-30 degrees. A wider FOV helps improve the range over when rotation gestures can be detected.

5. SOLUTION ROBUSTNESS

Analog Devices developed a special an automotive grade optical package for the MAX25205 and MAX25405 gesture sensors. It is highly robust in the adverse environmental conditions required for AEC-Q100 certification. The package is rated for a temperature range of -40C to 85C. It can handle 260C solder reflow the other consumer grade optical packages on the market, the sensor is hermetically sealed with a MSL1 moisture sensitivity rating, ensuring no moisture ingress on the sensor or its internal components. The result is long sensor lifetime.

Sunlight may intermittently enter the cabin and interfere with the sensor. Ambient light compensation is critical. Analog Devices employs several lines of defense for strong ambient and interfering pulsed light. The package includes an 875nm optical long pass filter to reject 68% of the sun's energy. The second is by operating in the 940nm dip in the solar irradiance curve. This minimizes the inband interference. See **Figure 5**.

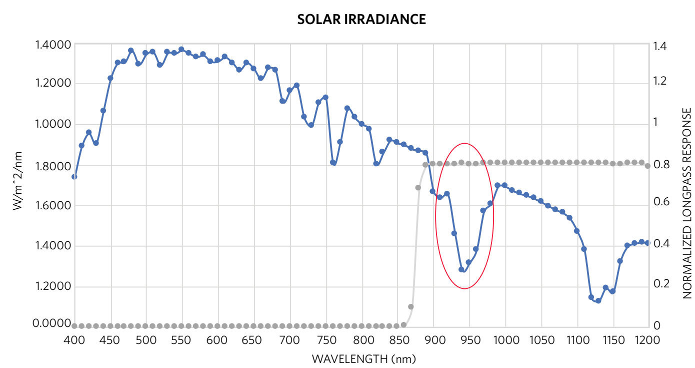

Figure 5. Solar Irradiance Curve

Third is the coarse ALC correction circuit which measures the ambient light and cancels it out. This prevents the ADC from saturating. Fourth is the Coherent Double Sampling (CDS) technique. With this method two measurements for each pixel are made to determine reflected light. First the ambient light and the reflected light from a pulse of an external IR LED are measured. A second measurement is then made with just the ambient light. These two measurements are subtracted leaving only the reflected IR light. Finally, the fifth line of defense is the detection algorithm. Strong ambient light is detected and can be used to reject corrupted frames. The result is 120klux of optical sunlight performance. This has been verified by real world test drives.

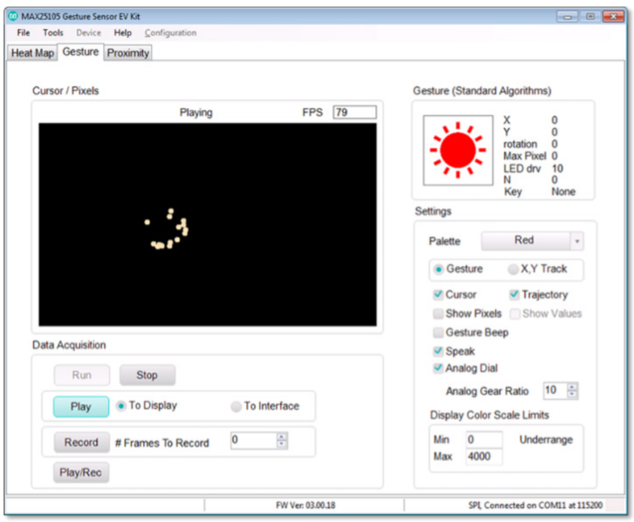

Figure 6. The MAX25205/MAX25405 GUI Utilizes Analog Device's Unique Algorithm that Corrects for Strong Sunlight

Figure 6 shows a false track generated by driving in strong the sunlight with the sensor pointed directly at the sun. The algorithm detects and rejects the sun's unique signature.

Figure 7. Typical Sun and Shade Patterns Through Trees

The direct normal irradiance of sun/shade pattern is shown in **Figure 7** will generate irradiance versus time as shown in **Figure 8**.

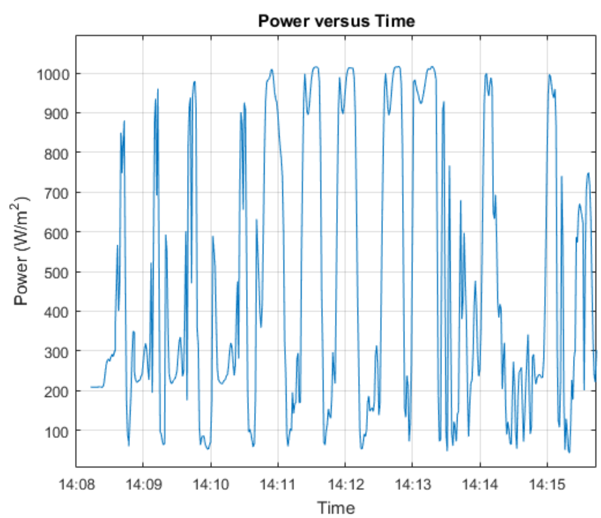

Figure 8. Direct Normal Irradiance Level From a Typical Test Drive

To evaluate the worst-case sun light level, the measurement was taken outside of the car pointed toward the sun. The measured irradiance is variable up to 1000W/m^2. Note that a gesture sensor mounted in the infotainment system in a car will rarely see this level of irradiance. The roof of the car blocks the sun and the windows filter out UV and broadband power. Both the MAX25205 and MAX25405 have been tested with worst-case direct normal solar irradiance and various shade patterns. After many rounds of testing, the algorithm was optimized to ensure no false positives were generated.

6. EASE OF USE

ADI has design a development platform to make rapid and easy gesture implementation possible. The EV kit has a modular design consisting of a sensor board and a controller board (See **Figure 9**). This allows the user to either use the sensor board as is or redesign the sensor board to best fit in their initial proof of concept platform (see **Figure 10**). The sensor board has a standardized 16pin connector that will allow a custom sensor board or EV kit sensor board to be plugged into the supplied controller board.

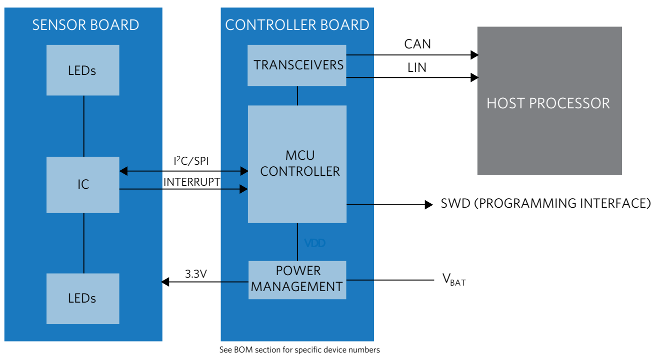

Figure 9. Gesture System Block Diagram

A GUI is also available on the ADI website. The GUI has a heatmap page for showing raw pixel data as well as some pixel preprocessing functions. In addition to the heatmap page there is a gesture page. This page shows the resulting gestures detected. It allows the gesture parameters and gesture configuration to be optimized based on customer requirements. Raw pixel data can be recorded and played back to see detailed raw pixel information, center of mass data and the gesture result. Raw pixel data can also be played back through the gesture algorithm with modified parameters. This allows the gesture parameters to be optimized based on real world data capture. The true positive rate, false positive rate as well as a few other metrics are calculated and recorded in a *.csv file. Data from several users can be saved and played back through the gesture detection algorithm to optimize true positive rate for a wide range of users. Lastly there is a proximity page. This page allows the user to test proximity function along with the linger to click event.".

Documents available to aid in rapid development are, Serial communications API, Gesture API, EV Kit user guide and a opto-mechanical design guide.

The development platform has been design to make it as easy as possible to proof the concept and get to an initial production design ASAP.

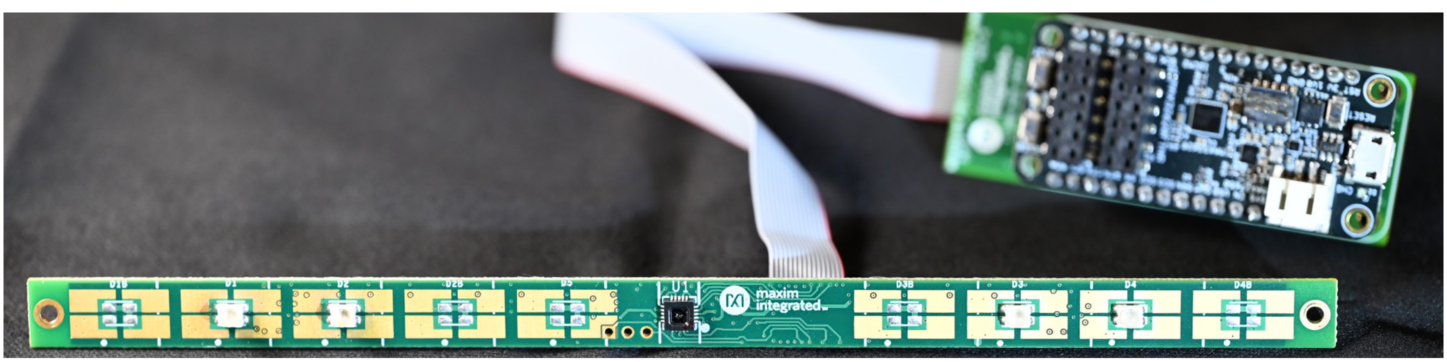

Figure 10. MAX25205 EV Kit

7. LOW SOLUTION COST

Analog Devices' gesture solutions are the only low-cost systems on the market today that supports swipes, rotations, flicks, waves, and proximity. These solutions are not cameras, they are low power, and they utilize low-cost processors. The MAX25205 can be used for detection distances up to 20cm. The MAX25405 can be used for detection distances up to 40cm and is designed to replace expensive camera-based gesture systems with total solutions costs over $100.

SUMMARY

Analog Devices provides infrared-based dynamic optical sensor gesture system to detect a broad range of gestures at extended distances, enabling drivers to focus on the road. These solutions can replace or enhance existing HMIs that use voice and touch based controls. This solution guide discussed seven key user needs for modern automotive HMIs including ten supported gestures, accurate proximity detection, 20cm and 40cm detection distances, +/-20 degrees to +/-30 degrees FOV coverage, AEC-Q100 robustness, ease of use, and low overall solution cost. (See Table 2. Gesture Sensor Selection Guide).

Below is a summary of Analog Devices Automotive Gesture Sensor Product Solutions. See the Product Selector Table to compare product specifications.

Table 1. Gesture Sensor Product Solutions

Applications	Product	Function
CID Dome Light Control Door Handler Side mirror Control	**MAX25205**	6 x 10 IR sensor array
CID Rear seat display Front passenger display	**MAX25405**	6 x 10 IR sensor array with lens

Table 2. Gesture Sensor Selection Guide

Gesture Performance	MAX25205	MAX25405
GESTURE PERFORMANCE		
Left/Right Gesture	20cm	40cm
Up/Down Gesture	20cm	40cm
Rotation Gesture	15cm	30cm
Wave (typical)	10cm	10cm
Air Click (typical)	10cm	10cm
Linger to Click (typical)	10cm	10cm
Proximity	3 x 1 zones	3 x 2 zones
Effective FOV	+/- 20 deg	+/- 30 deg
True Positive Rate	95.0%	97.5%

Related Resources

Application Note

Maxim Gesture Sensor EVKIT Serial API

Product Folders

MAX25205- Gesture Sensor for Automotive Applications

MAX25405- IR Gesture Sensor with Lens for Automotive Applications

Design Tools

Visual Studio C# GUI Framework

GUI

Firmware Framework

Videos

MAX25205 Gesture Sensor Demo

Learn more

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