Understanding Photoamplifier Setup and Operation

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This application note is intended to provide the user of Allegro™ MicroSystems photoelectric smoke detector products, A5358 and A5366, information regarding the theory of operation, characterization, and calibration of the photoamplifier. It is suggested that the user familiarize themselves with the data sheet and refer to the typical application (page 8 of the data sheet).

PHOTOAMP OPERATION

The IC detects smoke as follows. In normal or standby mode, during the STROBE active pulse, the photoamp is biased on. The positive supply for the photoamp is V_{DD} and the negative supply is STROBE (V_{DD} – 5 V). This ensures changes in V_{DD} levels will keep a constant 5 V across the photoamp, maintaining stability. The photoamp uses capacitive feedback (an internal ~10 pF capacitor and external C2) to set up the normal gain of the pin 3 deflected voltage (resultant from the intensity of light reaching the IR detector and voltage drop across the shunt resistor). When IRED first goes active high, the photoamp auto zeros and then starts amplifying. The output voltage of the photoamp is sampled when the IRED pin transitions from a high level to a low. This sample level is then strobed by the smoke comparator (internally referenced to ~V_{DD} – 3.5 V) to determine if a valid smoke condition is present. If the output of the photoamp is more negative than the V_{DD} – 3.5 V reference, a smoke condition exists. The photoamp gain increases ~10% after a local alarm is detected (after three consecutive valid smoke conditions). The amplitude of the pin 3 input voltage can be changed by 1) selection of the resistor across the photodiode detector (higher resistance, the greater the negative input amplitude), 2) the intensity of light, which is controlled by the IR emitter/detector pair selected, or 3) the drive circuit for the IR emitter. The gain of the photoamp is controlled by the selection of C1 and C2 (as outlined in the data sheet). The high or supervisory gain uses the same photoamp with external capacitor C1 selected. The dc bias level controlled by adjusting the 5 kΩ potentiometer common to C1, C2, and the photodiode detector sets sensitivity. Changes in this resistance will add or subtract a dc offset to the photoamp so that the photoamp output level can be moved closer to (increased sensitivity) or farther from (decreased sensitivity) the smoke comparator V_{DD} – 3.5 V reference.

The use of RX1 and RX2 is only applicable if you are using the reduced-sensitivity feature, also known as HUSH or timer mode. As explained in the data sheet, reduced sensitivity is invoked by a high-to-low transition on the TEST pin (#16). In this mode, the internal reference to the smoke comparator is switched from V_{DD} – 3.5 V to whatever voltage is present on the HUSH pin (#15). RX1 and RX2 form a voltage divider to provide the HUSH voltage. If you are not using this feature, the HUSH pin should be connected to ground and RX1 and RX2 can be omitted. This will disable the hush feature. US patent number Re. 33,920 may cover the reduced sensitivity feature. Any sale or use of the hush feature in a smoke alarm in the US would be a possible infringement of this patent.

The photoamp inputs are MOS with very-high input impedance and susceptible to antenna effects. Noise, cross coupling, board or part surface leakage on passive components at pins 1, 2, and/or 3 can affect the photoamp performance. Minimize PC board conductor length to these pins and locate all external components including the photo chamber as close as possible. Shield these pins with good PC board layout practices. The user may find it necessary to add additional decoupling to the C1, C2, and photodiode common point. Additionally, it is always good practice to add a decoupling capacitor (e.g., 1 μF) from V_{DD} (pin 5) to V_{SS} (pin 14), located as close as possible at the device pins.

Allegro does not evaluate suppliers of IR emitter/detector pairs. We cannot recommend a supplier but can suggest: EG&G VACTEC is a supplier of both emitter and detectors. They are located at 10900 Page Blvd., St. Louis, MO 63162. The user should select a low-capacitance IR detector.

PHOTOAMP DIAGNOSTIC TEST MODE

The IC provides a "diagnostic test mode" or "calibration mode" to facilitate checking sensitivity and calibrating the smoke detector. This mode is described below and in the A5358 and A5366 datasheet. To enter this mode, the TEST pin (pin 16) must be pulled below V_{SS} potential and continuously source ~400 µA. This can be accomplished by connecting a 12 kΩ resistor from pin 16 to a –5 V power supply. The test mode will be entered after one clock cycle. This pin 16 sourcing condition must be maintained or else the test mode will be terminated after one clock cycle. With pin 16 sourcing ~400 µA, the functions of other pins change and provide test points for sensitivity and low battery adjustments as follows:

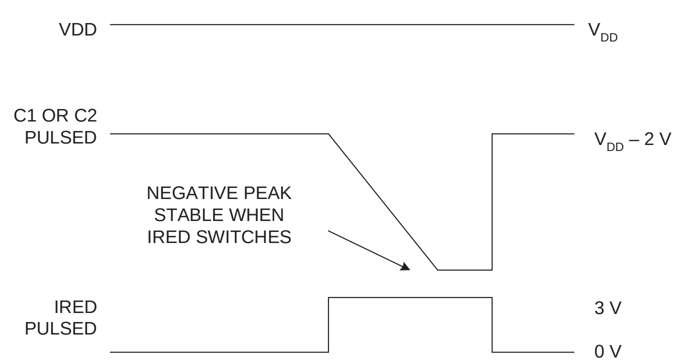
Pin	Pin #	State of Pin	Expected Output	Comments
IRED	6	Output	0 to 3 V pulse	Every OSC cycle
STROBE	4	Output	V_{DD} – 5 V	Always active
I/O	7	Input = HIGH	Photoamp output as pulses on pin 1 or pin 2.	Dependent on pin 15 state. See pin 15.
HORN1	8	Output	Consecutive smoke cycles. LOW after three consecutive no-smoke cycles; HIGH after three consecutive smoke cycles.	Smoke integrator output.
FEEDBACK	10	Input	HIGH increases gain (hysteresis) ~10% in normal.	Normal mode = pin 7 HIGH and pin 15 LOW.
LED	11	Output	LOW if V_{DD} < low battery.	Low battery indicator.
OSC	12	Input	Clock input	Can drive
HUSH	15	Input with I/O pin 7 HIGH	Pin 15 LOW = normal gain selected, photoamp output on pin 1. Pin 15 HIGH = supervisory or high gain selected, output on pin 2.	Output occurs as pulses

Additional comments regarding the diagnostic test mode: an easy way to verify the user has properly entered the test mode is to measure the STROBE voltage (pin 4) and verify it is at V_{DD} – 5 V. In the test mode, the photoamp feedback path is reconfigured and not representative of normal operation. *Pins 1 and 2 are prone to oscillation caused by loading effects of measuring devices such as oscilloscopes and external components C1 and C2. When measuring either C1 or C2 as an output with an oscilloscope, the external capacitor on that pin should be removed to ensure an accurate measurement.* The user can monitor HORN1 (pin 8) instead. This pin is not as sensitive to loading and will go high after three consecutive smoke detections as described above when in the test mode. *Also, the user must short out the 1 kΩ resistor between V_{DD} and IR emitter.* This will ensure that the IR emitter is operating at the full V_{DD} potential. *This is necessary when in the test mode because the IRED pin is pulsed at the OSC frequency and can deplete the charge on the 100 µF capacitor*.

PHOTOAMP CHARACTERIZATION

The following photoamp procedures outline suggested steps for designers to use during the design phase of the smoke detector module. *It is important for the designer to fully understand how the system works and that repeatable results are obtained using multiple PC boards and components.* Evaluations should be repeated at various V_{DD} levels to ensure stability. The designer should have a good knowledge of the "diagnostic test mode" described earlier and adhere to the notes following the table.

Step 1: *Verify photoamp output signals in clear air*. Power up the detector with V_{DD} = 9 V in clear or smoke-free air with C1 open. The piezo horn can be disconnected because we are not concerned if an alarm condition exists during this step. Enter the test mode as described above and verify STROBE = V_{DD} – 5 V. With a dc voltmeter on the common point to C1, C2, and the photodiode, adjust the 5 kΩ potentiometer to achieve V_{DD} – 2 V. Disconnect the dc voltmeter. With an oscilloscope, measure normal gain photoamp output pulses on pin 1 (pin 7 = V_{DD}, pin 15 = V_{SS}). Make sure signals are stable when IRED transitions from a HIGH (~3 V) to a LOW (V_{SS} level), as illustrated in the figure below, and are not excessively noisy.



Verify stability vs. V_{DD} level (12 V to 6 V) and that the amplitude of the negative-going pulse measured on pin 1when IRED switches low stays consistent. Power down, reconnect the C1 capacitor, open C2, and power back up to 9 V with the oscilloscope on pin 2. Enter the test mode and repeat the same measurements while in the high-gain mode (pin 7 = V_{DD}, pin 15 = V_{DD}). The common-mode voltage specification (V_{IC} in datasheet, page 4) of the photoamp should be maintained. Also verify the IR emitter (with the 1 kΩ resistor shorted) is working consistently over supply voltage range. It is best to measure the pin 3 input deflection voltage while the IR emitter is active, however; this can be difficult because the voltage is typically 1mV or less in the normal-gain mode.

There are many variables that affect the photoamp output that are unique to the PC board layout, component selection, and design approach. The designer may find it necessary to change several components and even the PC board layout to achieve stable waveforms. Some of the less obvious changes are to increase the 560 ohm compensation resistor on pin 2, add decoupling capacitors (e.g., 0.47 µF monolithic) from STROBE to photodiode anode and V_{DD} to photodiode anode, add decoupling capacitors (e.g., 1 µF monolithic) from IRED to V_{SS} and V_{DD} to V_{SS} (located at the IC), and increase the IRED pulse width by increasing the 100 kΩ resistor on pin 13. Once the designer is satisfied with photoamp operation and signal integrity, reconnect all components and proceed to Step 2.

Step 2: *Determine clear-air alarm level in normal mode*. Power up the detector with V_{DD} = 9 V in clear or smoke-free air. Slowly adjust the 5 kΩ potentiometer, going from a no-alarm condition until the alarm consistently first starts to sound. Next enter the test mode and verify STROBE (pin 4) is at V_{DD} – 5 V. Measure and record the dc voltage on the common point to C1, C2, and photodiode, relative to V_{DD}. This voltage is typically around (V_{DD} – 3.2 V) in clear air but will vary depending on the design. The designer should verify this voltage is consistent at various supply voltages and incorporate changes if necessary. Because the smoke comparator reference is typically V_{DD} – 3.5 V with the hush feature disabled, the clear-air alarm level = 3.5 V – recorded voltage.

The designer can further verify the detector operation by entering the test mode and measuring pin 1 with an oscilloscope. The negative peak of the photoamp output should cross the smoke comparator reference of V_{DD} – 3.5 V.

Step 3: *Determine minimum smoke alarm level in normal mode*. This step requires the use of a calibrated smoke source of the designer's choice. The designer must also determine the desired minimum smoke level to activate an alarm.

This is typically in the range of 1.5% to 2% optical obscuration per foot.

Power up the detector with V_{DD} = 9 V with a smoke source equivalent to the minimum desired level to activate an alarm. Slowly adjust the 5 kΩ potentiometer, going from a no-alarm condition until the alarm consistently first starts to sound. Remove the smoke source. The alarm should stop sounding. Next enter the test mode and verify STROBE (pin 4) is at V_{DD} – 5 V. Measure and record the dc voltage on the common point to C1, C2, and photodiode, relative to V_{DD}. This voltage will vary depending on the design and will be greater than V_{DD} – 2 V (absolute amplitude). The designer should verify this voltage is consistent at various supply voltages and incorporate changes if necessary.

The designer can further verify the detector operation by entering the test mode and measuring pin 1 with an oscilloscope while the desired smoke source is applied. The negative peak of the photoamp output should cross the smoke comparator reference of V_{DD} – 3.5 V.

If using the hush feature, the minimum smoke alarm level set up by the designer with hush activated will also need to be verified. This can be done out of the test mode while the smoke source is applied. In hush, the smoke comparator reference is changed from V_{DD} – 3.5 V to the voltage present on the HUSH pin 15.

Step 4: *Determine maximum smoke alarm level in normal mode*. This step requires the use of a calibrated smoke source of the designer's choice. The designer must also determine the desired maximum smoke level to activate an alarm. This is typically in the range of 4% optical obscuration per foot, and is specified by controlling agencies. All detectors must enter alarm with smoke at this level, whether in normal or hush mode.

Power up the detector with V_{DD} = 9 V with a smoke source equivalent to the maximum desired level to activate an alarm. Slowly adjust the 5 kΩ potentiometer, going from a no-alarm condition until the alarm consistently first starts to sound. Remove the smoke source. The alarm should stop sounding. Next, enter the test mode and verify STROBE (pin 4) is at V_{DD} – 5 V. Measure and record the dc voltage on the common point to C1, C2, and photodiode, relative to V_{DD}.

This voltage will vary depending on the design and will be greater than or equal to V_{DD} – 2 V (absolute amplitude). The designer should verify this voltage is consistent at various supply voltages and incorporate changes if necessary.

The designer can further verify the detector operation by entering the test mode and measuring pin 1 with an oscilloscope while the desired smoke source is applied. The negative peak of the photoamp output should cross the smoke comparator reference of V_{DD} – 3.5 V.

If using the hush feature, the maximum smoke alarm level with hush activated will also need to be verified. This can be done out of the test mode while the smoke source is applied. In hush, the smoke comparator reference is changed from V_{DD} – 3.5 V to the voltage present on the HUSH pin 15.

Step 5: *Verify high or supervisory gain function in clear air*. High gain is used during the push-button test and during standby to periodically monitor the chamber sensitivity. Background reflections in the chamber are amplified to produce a valid smoke condition.

Power up the detector with V_{DD} = 9 V in clear or smoke-free air with C2 open. Enter the test mode as described above and verify STROBE = V_{DD} – 5 V. With a dc voltmeter on the common point to C1, C2, and photodiode, adjust the 5 kΩ potentiometer to achieve the same dc level as recorded in Step 4 above. Disconnect the dc voltmeter. With an oscilloscope measure high-gain photoamp output pulses on pin 2 (pin 7 = V_{DD}, pin 15 = V_{DD}). Verify pin 2 negative pulse amplitude crosses below the smoke comparator reference of V_{DD} – 3.5 V when IRED transitions from a high (~3 V) to a low (V_{SS} level) as illustrated in the figure. The designer should verify this voltage is consistent at various supply voltages and incorporate changes if necessary.

Any changes made that may affect minimum or maximum alarm trip points will require repeating of the above steps and procedures that are applicable.

PRODUCTION CALIBRATION

Production calibration becomes easy if the photoamp characterization process has been thorough. Two methods of calibration are described. Method #1 is recommended and uses a smoke source equivalent to the minimum smoke alarm level desired for set-up and calibration. Method #2 also uses a smoke source equivalent to the minimum smoke alarm level desired, but only as a final validation functional test. Variability between detector units (quantified during the characterization process) must be minimal for Method #2 to be successful.

Method 1: *Recommended – using a smoke source during calibration.* Power up the detector with a smoke source equivalent to the minimum desired level to activate an alarm. Slowly adjust the 5 kΩ potentiometer, going from a no-alarm condition until the alarm consistently first starts to sound. Remove from smoke source and return to clear-air conditions. The alarm should stop sounding. Next press the test button and verify the alarm sounds.

The hush feature (if used) can be verified in a similar method using the smoke source.

Method 2: U*sing a smoke source after calibration for functional verification.* Power up the detector in clear or smoke-free air. Enter the test mode (see above) by sourcing 400 μA from pin 16 and verify by measuring pin 4 = V_{DD} – 5 V. With a dc voltmeter referenced to V_{DD}, connect to the common point to C1, C2, and photodiode. Adjust the 5 kΩ potentiometer to achieve a dc level that is greater than Vmin as recorded in Step 3 but less than Vmax as recorded in Step 4 above. Exit the test mode. The alarm should not be sounding. Next, press the test button and verify the alarm sounds. Finally place the detector in a smoke source equivalent to the desired level to activate an alarm. Verify the alarm sounds.

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