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Electronic Design and Fabrication of the PHAD Sensor

by David J Gonski

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14. ABSTRACT
This report provides the technical information needed to fabricate all sensor assemblies, cabling, and harnesses to assemble the main electronics unit for the Persistent Harmonic Acoustic Detector (PHAD) sensor. The electronic circuitry described in the report is for illustrative purposes only. To fabricate the PHAD amplifier and PHAD microphone preamplifier printed circuit boards, the source files must be provided to the fabrication house. The mechanical design, software, and algorithm for the PHAD sensor are not discussed in this report.

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Summary

This report provides the technical information needed to fabricate all sensor assemblies, cabling, and harnesses to assemble the main electronics unit for the Persistent Harmonic Acoustic Detector (PHAD) sensor. The electronic circuitry described is for illustrative purposes only. To fabricate the PHAD amplifier and PHAD microphone preamplifier printed circuit boards, the source files must be provided to the fabrication house. The mechanical design, software, and algorithm for the PHAD sensor are not discussed in this report.

1. Introduction and Overview of the PHAD Sensor

This section describes the overall electronic design of the Persistent Harmonic Acoustic Detector (PHAD) sensor. The large and small PHAD sensor arrays have some distinctive differences, which will be addressed here, but many aspects of the two arrays are the same. The main electronics unit is functionally the same for both arrays, but the mechanical design has some differences that will be described during the detailed descriptions for each.

1.1 Background

The purpose of the PHAD sensor is to detect low-frequency acoustic signals of interest at a distance. The large and small arrays both contain eight acoustic sensors and have the same geometric shape, with the large array having a much larger sensor spacing. The PHAD small array is completely contained within the main electronics unit. All acoustic sensors, signal conditioning, signal acquisition, global positioning, and data egress are contained within the main electronics unit, which is a metal enclosure approximately 24 inches in length and width and 16 inches in height. The main electronics unit for the PHAD sensor large array contains everything mentioned previously except for the acoustic sensors. The large array has the acoustic sensors distributed along a much-larger baseline using electrical conduit to define the array geometry. Due to the much-larger array geometry and longer sensor cabling, a preamplifier is integrated into each microphone assembly to increase the signal-to-noise ratio and reduce electromagnetic interference pickup during the cable runs back to the main electronics unit.

1.2 PHAD Acoustic Sensor

The same acoustic sensor is used in both the large and small PHAD arrays. The Knowles Electronics Model No. VEK-H-30320-000 microphone assembly contains a microphone element, Knowles Model No. EK-30436-PO3, packaged in a plastic housing. A sintered metal windscreen on the top of the housing allows the acoustic signal to reach the microphone element and also helps to make the entire assembly weather resistant. The microphone element power and signal leads egress from the bottom of the assembly inside a shielded cable using an epoxy-based potting compound to seal the assembly and provide weather protection and strain relief of the cable. The microphone assembly, as delivered from the manufacturer, contains an 8-inch-long pigtailed cable, which allows easy integration based on the application.

1.3 PHAD Main Electronics Unit

The main electronics unit is controlled by a National Instruments CompactRIO real-time embedded industrial controller, which uses precision analog-to-digital (A/D) converters for data acquisition. The controller runs a proprietary LabView VI program developed by the US Army Combat Capabilities Development Command (CCDC) Army Research Laboratory (ARL) to set the operating parameters including sampling rate, filtering, data egress, precision timing, positioning, and communications. The controller has a unique IP address so that each PHAD array can be uniquely identified.

The controller requires a GPS signal, which is acquired using a GPS antenna located near the top center of the main electronics unit. The GPS antenna cable connects to the controller using a feedthrough bulkhead connector located on the main electronics unit housing.

The main electronics unit contains signal conditioning electronics consisting of a variable gain amplifier with the gain being user selectable values of 1, 10, 100, or 1000 using a rotary switch mounted to the housing of the main electronics unit. The gain is selected based on the expected signal level, any known noise sources, and estimated noise from wind or turbulence. The data analyst can provide guidance on the optimal gain once the sensor is on site and operational so that any environmental and noise issues can be addressed for best performance of the sensor.

The controller outputs the digitized acoustic signals, time, and position through an RJ-45 network connection. A bulkhead mounted RJ-45 feedthrough connector located on the main electronics unit housing passes the signals to a hub/router using a CAT-6 ethernet cable.

Power for the main electronics unit is provided through a connector mounted to the main electronics unit housing. The electronics unit requires approximately 1 Amp at 12 V DC, but any power source from 9–18 V DC can be used.

1.4 PHAD Small Array

The PHAD small array has the sensor array integrated into the top plate of the main electronics unit. The sensors connect directly to the variable gain amplifier by splicing an additional cable and connector to the microphone assembly provided by the manufacturer.

The amplifier gain control switch and the connectors for power, GPS, and data egress are located on the bottom face of the main electronics unit. There are holes drilled at each corner and the center of the bottom face of the main electronics unit

to drain off any moisture should leakage or condensation within the unit become an issue. The electronics unit sits atop a leveling stand so that the bottom of the electronics unit is approximately 3 inches above the ground.

The average sensitivity of the small array sensors is 18 mV/Pascal within the frequency of interest at an amplifier gain setting of 1. The gain can be set to 1/10/100/1000 (initial value of 100 is recommended) based on expected signal and noise levels as part of the installation procedure. A calibration should be performed on each microphone in the array to compensate for variations in sensor responses at the signal of interest.

1.5 PHAD Large Array

The PHAD large array passes the microphone signals from a distributed array through electrical conduit into the main electronics unit. The signals connect to the variable gain amplifier through a bulkhead harness mounted on the amplifier housing. The final connection from the array cable to the bulkhead harness must be completed on site during installation and assembly of the array by removing the lid from the main electronics unit.

The amplifier gain control switch and the connectors for power, GPS, and data egress are located on a side wall of the main electronics unit. The main electronics unit sits directly on the ground with a conduit connector close to the bottom on each of the four sides. The large array main electronics unit is a sealed enclosure.

The microphone assemblies contain a preamplifier that amplifies the signal by 20. Including the preamplifier gain, the average sensitivity of the large array sensors is 360 mV/Pascal within the frequency of interest at an amplifier gain setting of 1. The gain can be set to 1/10/100/1000 (initial value of 10 is recommended) based on expected signal and noise levels as part of the installation procedure. A calibration should be performed on each array sensor to compensate for variations in sensor responses at the signal of interest. The calibration should be performed after installation as the large array final assembly is done on site.

2. PHAD Amplifier Schematic

The PHAD amplifier schematic is shown in Fig. 1.

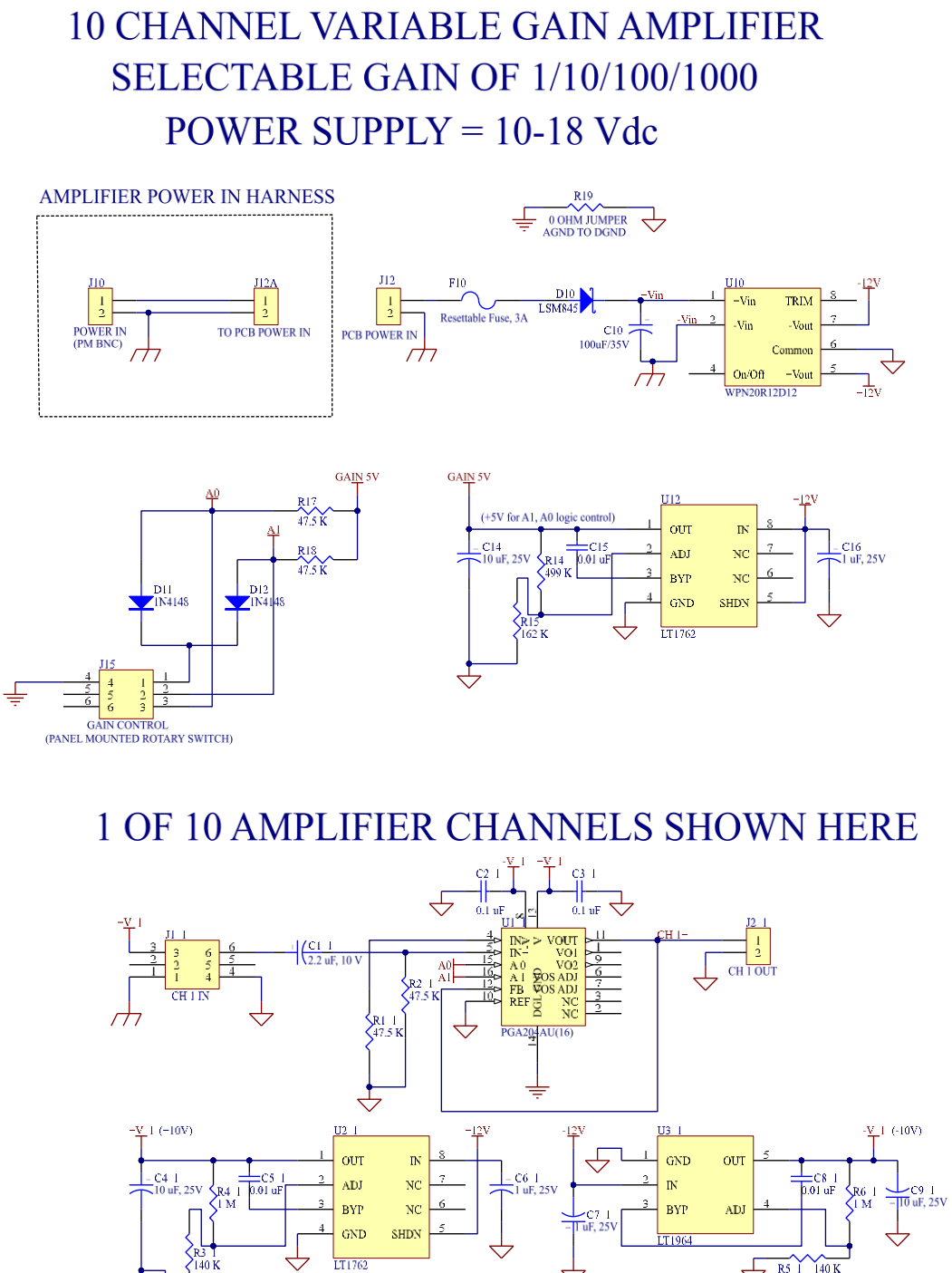

Fig. 1 PHAD amplifier schematic

3. PHAD Amplifier Printed Circuit Board

For clarity, only the top-side view of the printed circuit board (PCB) (top copper layer and top silk layer) is shown in Fig. 2.

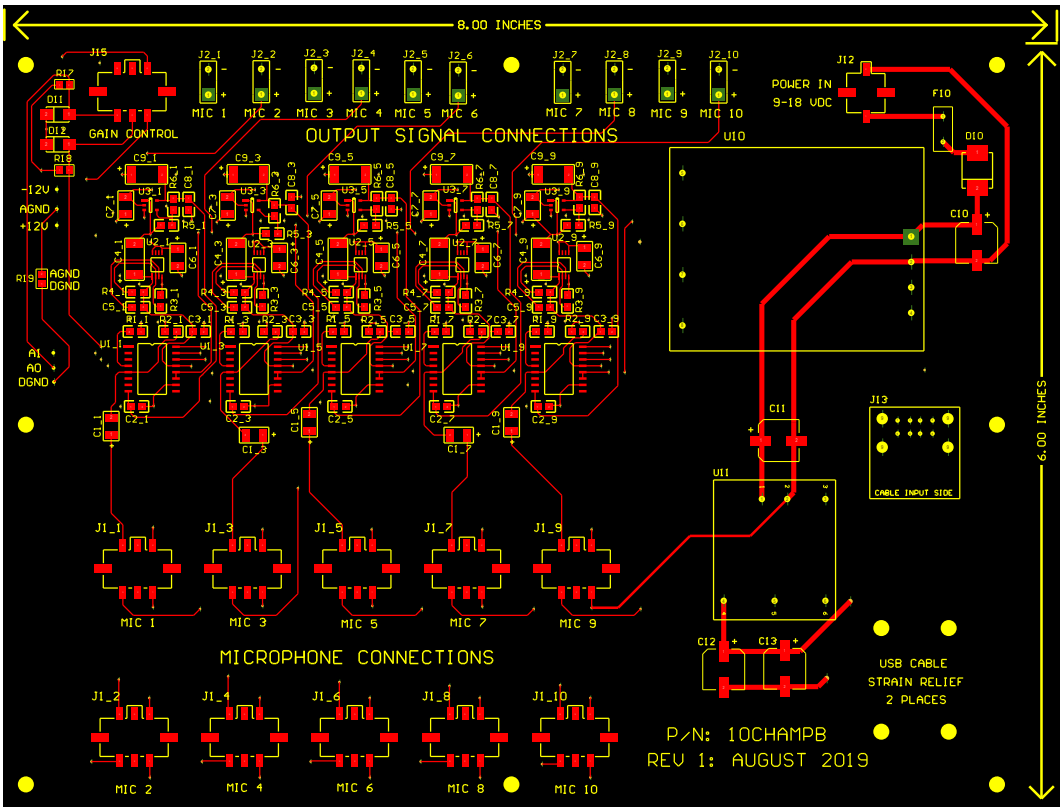

Fig. 2 Top-side view of the PHAD amplifier PCB

4. PHAD Amplifier Bill of Materials

The PHAD amplifier bill of materials is shown in Table 1.

Table 1 PHAD amplifier bill of materials

Comment	Description	Designator	Footprint	QTY/PCB
2.2 uF, 10 V	Capacitor, ceramic, 2.2 uF, 10 V, 10%, X7R, SMT, 1210	C1_1, C1_2, C1_3, C1_4, C1_5, C1_6, C1_7, C1_8, C1_9, C1_10	1210 CAP	10
0.1 uF	Capacitor, ceramic, 0.1 uF, 50 V, 10%, X7R, SMT, 0805	C2_1, C2_2, C2_3, C2_4, C2_5, C2_6, C2_7, C2_8, C2_9, C2_10, C3_1, C3_2, C3_3, C3_4, C3_5, C3_6, C3_7, C3_8, C3_9, C3_10	0805	20
10 uF, 25V	Capacitor, ceramic, 10 uF, 25 V, 10%, X7R, SMT, 2212	C4_1, C4_2, C4_3, C4_4, C4_5, C4_6, C4_7, C4_8, C4_9, C4_10, C9_1, C9_2, C9_3, C9_4, C9_5, C9_6, C9_7, C9_8, C9_9, C9_10, C14	2212 SMT	21

Comment	Description	Designator	Footprint	QTY/PCB
0.01 uF	Capacitor, ceramic, 0.01uF, 50 V, 10%, X7R, SMT, 0805	C5_1, C5_2, C5_3, C5_4, C5_5, C5_6, C5_7, C5_8, C5_9, C5_10, C8_1, C8_2, C8_3, C8_4, C8_5, C8_6, C8_7, C8_8, C8_9, C8_10, C15	0805	21
1 uF, 25V	Capacitor, ceramic, 1 uF, 25 V, 10%, X7R, SMT, 1210	C6_1, C6_2, C6_3, C6_4, C6_5, C6_6, C6_7, C6_8, C6_9, C6_10, C7_1, C7_2, C7_3, C7_4, C7_5, C7_6, C7_7, C7_8, C7_9, C7_10, C16	1210 CAP	21
100uF/35V	Capacitor, aluminum, low ESR, 100uF, 35V, 20%, SMT CAP SIZE F	C10	SMT CAP SIZE F	1
100uF/35V	DNP, Capacitor, aluminum, low ESR, 100uF, 35V, 20%, SMT CAP SIZE F	C11	SMT CAP SIZE F	DNP
220uF/10V	DNP, Capacitor, aluminum, low ESR, 220uF, 25V, 20%, SMT CAP SIZE F	C12, C13	SMT CAP SIZE F	DNP
LSM845	Schottky Diode, LSM845, SMT, DO214AB	D10	DO214AB	1
1N4148	Diode, 1N4148, SMT, SMA DIODE	D11, D12	SMA DIODE	2
PTC Resettable Fuse, 3A	Fuse, 60V, PTC Resettable, 1.5A hold@85C, Thru hole, radial, 0.2" lead spacing	F10	RAD-0.2	1
MICROPHONE CONNECTION	Connector, Vertical, 6 Pin Molex Microfit 3.0	J1_1, J1_2, J1_3, J1_4, J1_5, J1_6, J1_7, J1_8, J1_9, J1_10	MOLEX-6	10
OUTPUT SIGNAL	DNP, 2 PAD HEADER	J2_1, J2_2, J2_3, J2_4, J2_5, J2_6, J2_7, J2_8, J2_9, J2_10	I/O SIGNAL	DNP
POWER IN	Connector, Vertical, 2 Pin Molex Microfit 3.0	J12	MOLEX-2	1
Dual USB 2.0	DNP, Dual USB 2.0 Type A Horizontal	J13	USB Type A dual Wurth	DNP
GAIN CONTROL	Connector, Vertical, 6 Pin Molex Microfit 3.0	J15	MOLEX-6	1
47.5 K	Resistor, 47.5 K, 1%, 1/10 W, SMT, 0805	R1_1, R1_2, R1_3, R1_4, R1_5, R1_6, R1_7, R1_8, R1_9, R1_10, R2_1, R2_2, R2_3, R2_4, R2_5, R2_6, R2_7, R2_8, R2_9, R2_10, R17, R18	0805	22
140 K	Resistor, 140 K, 1%, 1/10 W, SMT, 0805	R3_1, R3_2, R3_3, R3_4, R3_5, R3_6, R3_7, R3_8, R3_9, R3_10, R5_1, R5_2, R5_3, R5_4, R5_5, R5_6, R5_7, R5_8, R5_9, R5_10	0805	20
1 M	Resistor, 1.00 M, 1%, 1/10 W, SMT, 0805	R4_1, R4_2, R4_3, R4_4, R4_5, R4_6, R4_7, R4_8, R4_9, R4_10, R6_1, R6_2, R6_3, R6_4, R6_5, R6_6, R6_7, R6_8, R6_9, R6_10	0805	20
75.0K	Resistor, 75.0 K, 1%, 1/10 W, SMT, 0805	R10	SMT 0805	1
51.1K	Resistor, 51.1 K, 1%, 1/10 W, SMT, 0805	R11, R13	SMT 0805	2

Comment	Description	Designator	Footprint	QTY/PCB
43.2K	Resistor, 43.2 K, 1%, 1/10 W, SMT, 0805	R12	SMT 0805	1
499 K	Resistor, 499 K, 1%, 1/10 W, SMT, 0805	R14	0805	1
162 K	Resistor, 162 K, 1%, 1/10 W, SMT, 0805	R15	0805	1
0 OHM JUMPER	Jumper, 0 ohm, 1/10 W, SMT, 0805	R19	SMT 0805	1
PGA204AU(16)	Programmable Gain Instrumentation Amplifier, PGA204AU(16), SMT, 16-SOIC	U1_1, U1_2, U1_3, U1_4, U1_5, U1_6, U1_7, U1_8, U1_9, U1_10	16-SOIC	10
LT1762EMS8	150 mA, Adjustable Positive Voltage Regulator, Low noise, LDO, Micropower, SMT, 8-MSOP	U2_1, U2_2, U2_3, U2_4, U2_5, U2_6, U2_7, U2_8, U2_9, U2_10, U12	MSOP8	11
LT1964ES5-BYP	200 mA, Adjustable Negative Voltage Regulator, Low noise, LDO, Micropower, SMT, TSOT-23	U3_1, U3_2, U3_3, U3_4, U3_5, U3_6, U3_7, U3_8, U3_9, U3_10	TSOT23-5	9
WPN20R12D12	DC/DC Converter, Isolated, 9-18 V Input Range, Dual +/- 12 V Output, 20W, Thru hole	U10	DUAL DC-DC MODULE	1
UEI15-050-Q12P-C	DNP,DC/DC Converter, Isolated, 9-36 V Input Range, +5V Output, 15W, Thru hole	U11	UEI15-Q12P DC-DC	DNP

5. Modifications to the PHAD Amplifier PCB for the Large Array

This section describes the modifications to the amplifier PCB prior to assembly in the amplifier enclosure for the PHAD large array. These modifications can be done before or after the PCB is populated. This modification provides ±12 V to the microphone preamplifier PCB.

1) On the amplifier PCB, connect pin 2 on J1_ 1 through J1_8 together using hookup wire and then connect to +12 V pad on the PCB.

2) On the amplifier PCB, connect pin 5 on J1_1 through J1_8 together using hookup wire and then connect to –12 V pad on the PCB.

NOTE: The amplifier PCB is now ready for assembly in the amplifier enclosure for the PHAD large array.

6. PHAD Microphone Preamplifier Schematic

The PHAD microphone preamplifier schematic is shown in Fig. 3.

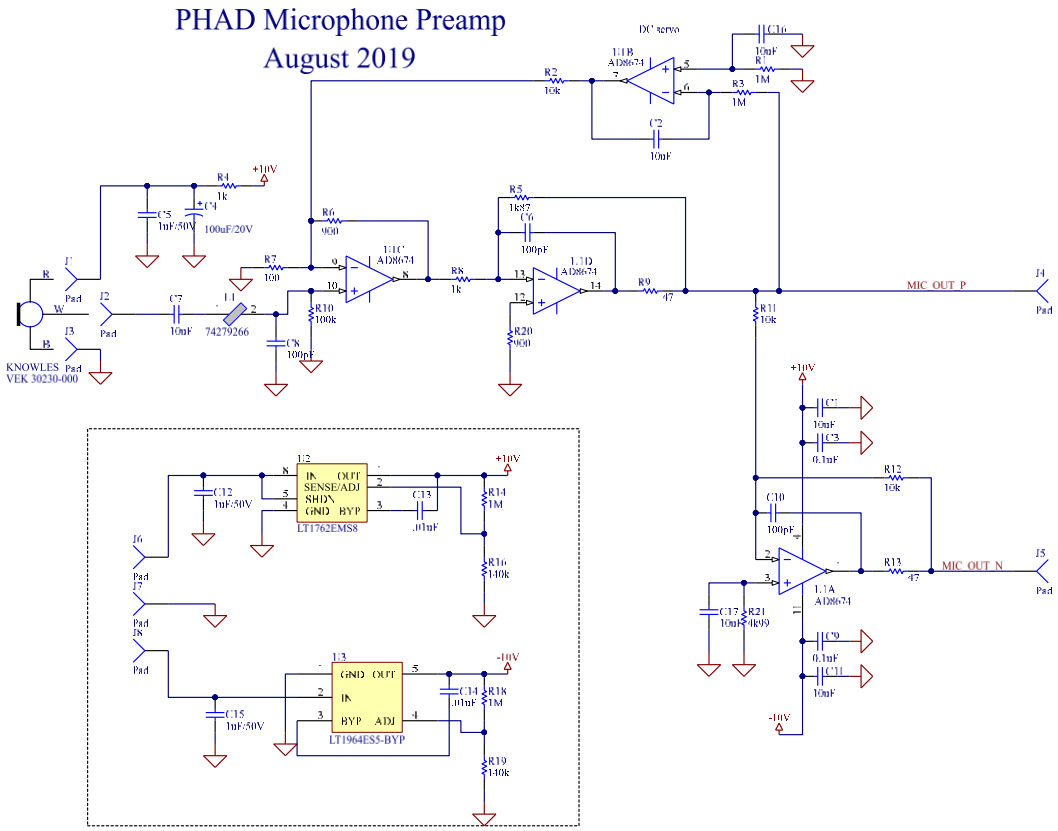

Fig. 3 PHAD microphone preamplifier schematic

7. PHAD Microphone Preamplifier PCB

For clarity, only the top-side view of the PHAD microphone preamplifier PCB (top copper layer and top silk layer) is shown in Fig. 4.

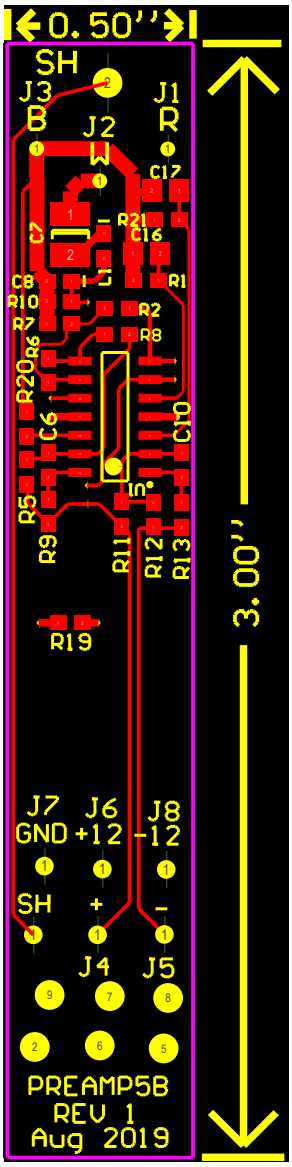

Fig. 4 Top-side view of the PHAD microphone preamplifier PCB

8. PHAD Microphone Preamplifier Bill of Materials

The PHAD microphone preamplifier bill of materials is shown in Table 2.

Table 2 PHAD microphone preamplifier bill of materials

Comment	Description	Designator	Footprint	Quantity/PCB
10 uF, 16 V	Capacitor, ceramic, 10 uF, 16 V, 10%, X5R, SMT, 0805	C1, C11, C16, C17	0805	4
10 uF, 25 V	Capacitor, ceramic, 10 uF, 25 V, 10%, X7R, SMT, 1210	C2, C7	1210	2
0.1 uF	Capacitor, ceramic, 0.1 uF, 50 V, 10%, X7R, SMT, 0603	C3, C9	0603	2
100 uF, 20 V	Capacitor, tantalum, 100 uF, 20 V, 10%, low ESR, SMT size D (2917)	C4	D	1
1 uF, 50 V	Capacitor, ceramic, 1 uF, 50 V, 10%, X7R, SMT, 0805	C5, C12, C15	0805	3
100 pF	Capacitor, ceramic, 100 pF, 50 V, 5%, NP0, SMT, 0603	C6, C8, C10	0603	3
0.01 uF	Capacitor, ceramic, 0.01uF, 50 V, 5%, NPO, SMT, 0603	C13, C14	0603	2
Pad	Wire connection to PCB	J1, J2, J3, J4, J5, J6, J7, J8	MIC_SOCKET	8
Ferrite bead	Ferrite bead, 1 Kohm@100 MHz, 200 mA, 600 mOhm, 1 signal line, SMT, 0603, Wurth #74279266	L1	0603	1
1 M	Resistor, 1.00 M, 1%, 1/10 W, SMT, 0603	R1, R3, R14, R18	ERA-0603	4
10 K	Resistor, 10.0 K, 1%, 1/10 W, SMT, 0603	R2, R11, R12	ERA-0603	3
1 K	Resistor, 1.00 K, 1%, 1/10 W, SMT, 0603	R4, R8	ERA-0603	2
1.87 K	Resistor, 1.87 K, 1%, 1/10 W, SMT, 0603	R5	ERA-0603	1
909	Resistor, 909, 1%, 1/10 W, SMT, 0603	R6, R20	ERA-0603	2
100	Resistor, 100, 1%, 1/10 W, SMT, 0603	R7	ERA-0603	1
47	Resistor, 47, 1%, 1/10 W, SMT, 0603	R9, R13	ERA-0603	2
100 K	Resistor, 100 K, 1%, 1/10 W, SMT, 0603	R10	ERA-0603	1
140 K	Resistor, 140 K, 1%, 1/10 W, SMT, 0603	R16, R19	ERA-0603	2
4.99 K	Resistor, 4.99 K, 1%, 1/10 W, SMT, 0603	R21	ERA-0603	1
AD8674ARZ	Operational amplifier, Quad, Precision, Low noise, SMT, 14-SOIC	U1	SOIC127P600-14N	1
LT1762EMS8	150 mA, Adjustable Positive Voltage Regulator, Low noise, LDO, Micropower, SMT, 8-MSOP	U2	TSSO3x5-G8/X.4	1
LT1964ES5-BYP	200 mA, Adjustable Negative Voltage Regulator, Low noise, LDO, Micropower, SMT, TSOT-23	U3	SO-G5/P.95	1

9. Notes for All Assemblies

Follow the manufacturer-provided assembly instructions for all connector assemblies. Specialty tools and fixtures may be needed for crimping of contacts and assembly of the connectors. The model number of any required tools and fixtures will be specified in the manufacturer-provided instructions.

10. PHAD Amplifier Gain Control Harness

This section describes the assembly of the gain control harness used to set the gain for the PHAD amplifier in the electronics box.

1) Using a 30-inch length of 22 AWG hookup wire (four different colors), solder one end of the wire to a four-position rotary gain control switch—Grayhill P/N 50D90-01-1-AJN or equivalent. Cover the solder connections with heat-shrink tubing.

2) Connect the other end of the wire to a 6-pin receptacle, Molex P/N 43025-0600, using female contacts 20-24 AWG, Molex P/N 43030-0009. Assemble according to the wiring table shown in Table 3.

Table 3 Gain control harness assembly

Switch contact no.	Molex 43025-0600 contact no.
1	1
2	2
3	3
Center	4

11. PHAD Amplifier Power Input Harness

This section describes the assembly of the +12 V DC power harness that connects the +12 V power bus inside the electronics box to the amplifier PCB.

1) Using 22 AWG hookup wire, 6 inches in length, solder one end of the wires to an isolated Bayonet Neill–Concelman (BNC) connector. Cover both solder connections with heat shrink tubing.

2) Connect the other ends of the wires to a 2-pin receptacle, Molex P/N 43025-0200 using female contacts 20-24 AWG, Molex P/N 43030-0009. Assemble according to the wiring table shown in Table 4.

Table 4 Power input harness assembly

BNC connector	Wire color	Molex 43025-0200
Contact	…	Contact no.
Center (+Vin)	Red	1
Tab (–Vin)	Black	2

12. PHAD Microphone Preamplifier Wiring and Assembly Instructions

This section describes the assembly and testing of the microphone preamplifier assembly for use in the PHAD large array.

1) Attach a 6-pin connector jack, Hirose P/N LF07WBJ-6P, to the preamplifier using a 1–3-inch cable, Belden P/N 9535 (5 conductor shielded cable, 24 AWG) according to the wiring table shown in Table 5.

Table 5 Microphone preamplifier wiring and assembly

Hirose LF07WBJ-6P contact no.	Belden 9535 wire color	Preamplifier connection pad designator
1	Red	J6 (+12V)
2	Green	J7 (GND)
3	Brown	J8 (–12 V)
4	Black	J5 (–)
5	White	J4 (+)
6	Shield drain wire (connector body)	SH

2) Attach microphone, Knowles P/N VEK-H-30320-000, to the preamplifier using the 8-inch factory-supplied microphone leads according to the wiring table shown in Table 6. Trim the leads only if required to make the wiring neater.

Table 6 Knowles P/N VEK-H-30320-000 microphone preamplifier wiring table

Microphone leads wire color	Preamplifier connection pad designator
Red (Vmic,+10V)	J1 (R)
Black (GND)	J3 (B)
White (SIGNAL)	J2 (W)
Shield	SH

3) Apply conformal coating to both sides of the preamplifier PCB according to instructions and let it cure completely before going on to the next step (Fig. 5).

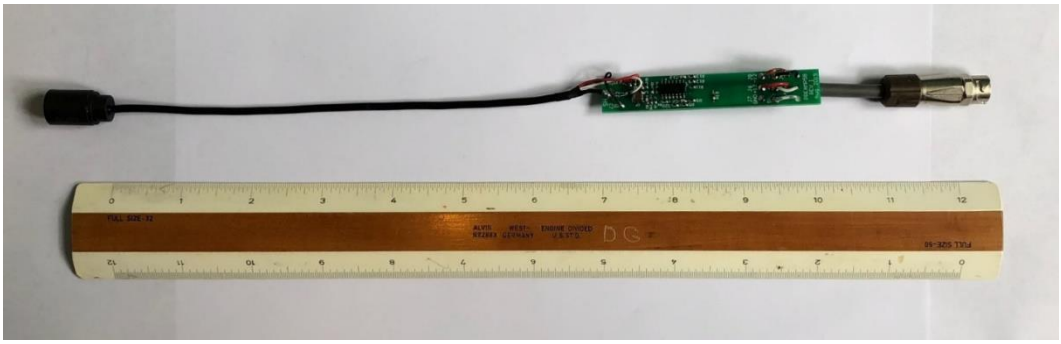

Fig. 5 Microphone preamplifier assembly after Steps 1–3

4) Cover the preamplifier PCB with heat-shrink tubing 4 inches long × 0.75 inches starting diameter. Shrink tubing using a heat gun.

5) Test all microphone assemblies using a harness built from a mating connector plug, Hirose P/N LF07WBP-6S, according to the wiring table shown in Table 7. Use 24-inch-length 24 AWG hookup wire. Use benchtop DC power supplies, an oscilloscope, and a B&K Calibrator Model 4226 set to Calibration Function, pressure response, 94 dB SPL @31.5 Hz. After all microphones have been tested, match the microphones into groups of eight with the most similar calibration voltages (sensitivities) grouped together. Approximately 10% extra assemblies should be built to allow for some that do not match well.

Table 7 Hirose P/N LF07WBP-6S harness assembly

Hirose LF07WBP-6S contact no.	Wire color	Connect to
1	Red	+12 V DC
2	Green	Ground
3	Brown	–12 V DC
4	N/A	No connect
5	White	Signal
6	N/A	No connect

6) Mount microphone assembly in metal stub and coupler.

   a. Install microphone assembly into microphone stub and coupler so that the top edge of the microphone extends 1/4 inches beyond the non-

coupler end of the stub. Install three set screws to hold the microphone in place.

b. Apply room-temperature vulcanizing (RTV) silicone to seal the gap between the microphone housing and the stub, being careful not to get any silicone on the top of the microphone. Wipe off any excess and make sure the gap is completely sealed. Wait for RTV/silicone to fully cure according to product instructions (Fig. 6).

Fig. 6 Microphone preamplifier assembly without heat shrink tubing on stub

c. Place a piece of heat-shrink tubing 1 inch long × 1 inch starting diameter over the end of the stub so that the screws are fully covered but the tubing does not extend beyond the end of the stub. Shrink tubing using a heat gun.

NOTE: The microphone preamplifier assembly is now ready for integration into the PHAD large array.

13. PHAD Large Array Cable Assembly Instructions

This section describes the assembly and testing of the array cables used to connect the microphone preamplifier assembly to the main electronics box used in the PHAD large array. All cables are wired the same, but the length varies for each as called out in Table 8. The lengths as built provide approximately 3 feet of extra length to allow for a service loop in the microphone box and the PHAD main electronics unit.

Table 8 Microphone cable lengths

Cable for microphone no.	Cable length (feet)
1	6
2	7
3	8
4	9
5	11
6	13
7	16
8	20

1) Attach a 6-pin plug, Hirose P/N LF07WBP-6S, to both ends of cable, Belden P/N 9535 (5 conductor shielded cable, 24 AWG), according to the wiring table shown in Table 9. (The length of each cable is listed in Table 8.)

Table 9 Hirose P/N LF07WBP-6S cable wiring assembly

Hirose LF07WBJ-6S contact no.	Belden 9535 wire color
1	Red
2	Green
3	Brown
4	Black
5	White
6	Shield drain wire (Connector body)

2) Test each cable for continuity and for potential shorts between contacts.

3) Label each cable at both ends with the cable length for easy identification.

NOTE: The cable assembly is now ready for integration into the PHAD large array.

14. PHAD Large Array Cable to Amplifier Bulkhead Harness

This section describes the assembly and testing of the harness that connects the PHAD large array cables to the amplifier PCB.

1) Attach a 6-pin bulkhead receptacle, Hirose P/N LF07WBR-6P, to cable, 6 inch length, Belden P/N 9535 (5 conductor shielded cable, 24 AWG).

2) Attach a 6-pin receptacle, Molex P/N 43025-0600, to the other end of the cable using female contacts 20-24 AWG, Molex P/N 43030-0009. Assemble the harness according to the wiring table shown in Table 10.

Table 10 Hirose P/N LF07WBR-6P cable wiring assembly

Hirose LF07WBR-6P contact no.	Belden 9535 wire color	Molex 43025-0600 contact no.
1	Red	2
2	Green	4
3	Brown	5
4	Black	No connect
5	White	6
6	Shield drain wire (connector body)	1

3) Test the harness for continuity and for potential shorts between contacts.

NOTE: The harness is now ready for assembly in the PHAD large array amplifier enclosure.

15. Microphone Cable Assembly for the PHAD Small Array

This section describes the assembly and testing of the microphone/cable assembly that connects the microphones mounted on the top plate of the small array and the variable gain amplifier PCB located inside the electronics box.

1) Attach microphone, Knowles P/N VEK-H-30320-000, to cable, 36-inch length, Alpha P/N 3222 (3 conductor shielded cable, 22 AWG). Do not trim the factory-supplied 8-inch microphone leads. Cover each splice with heat-shrink tubing and shrink using a heat gun, being careful not to melt the PVC insulation on the wires. Place heat-shrink tubing over the insulation and conductors of the cable to provide strain relief (Fig. 7).

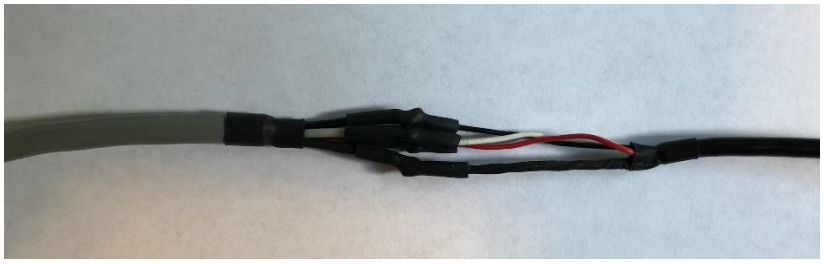

Fig. 7 Close-up of strain relief (left) and splices (right)

2) Attach the other end of the cable to a 6-pin receptacle, Molex P/N 43025-0600, using female contacts 20-24 AWG, Molex P/N 43030-0009. Place heat-shrink tubing over the insulation and conductors of the cable to provide strain relief.

3) The overall length of the microphone cable assembly is about 44 inches using a 36-inch length of Alpha P/N 3222 cable. Assemble according to the wiring table shown in Table 11.

Table 11 Alpha P/N 3222 cable wiring assembly

Microphone leads wire color	Alpha 3222 wire color	Molex 43025-0600 contact no.
Shield	Shield	1
Red (Vmic,+10 V)	Red	3
Black (GND)	Black	4
White (Signal)	White	6

4) Test all microphone cable assemblies using a harness built from a mating connector, Molex P/N 43045-0620, according to the wiring table shown in Table 11. The shield connection is not required for the test harness. Use 24-inch-length 24 AWG hookup wire. Use benchtop DC power supplies, an oscilloscope, and a B&K Calibrator Model 4226 set to Calibration Function, pressure response, 94 dB SPL @31.5 Hz. After all microphones have been tested, match the microphones into groups of eight with the most similar calibration voltages (sensitivities) grouped together. Approximately 10% extra assemblies should be built to allow for some that do not match well.

5) Mount the microphone cable assemblies to the microphone array plate by laying the array plate face down on a flat surface with 1/4-inch spacers at each corner so the plate is 1/4 inch above the flat surface. Insert a microphone through each hole on the plate and position it so the tip of the microphone rests on the flat surface. Apply RTV/silicone between the microphone and array plate to seal the gap. Wait for RTV/silicone to fully cure according to product instructions.

6) Flip the array plate so that the tips of the microphones are facing up. Use spacers to ensure the plate is not resting on the cables. Apply RTV/silicone between the microphone and array plate to seal the gap, being careful not to get any RTV on the top of the microphone. Wipe off any excess and make sure the gap is completely sealed. Wait for RTV/silicone to fully cure according to product instructions.

7) Label the microphone cables 1 through 8, with 1 being the closest microphone to the centerline of the plate on the right side. Number the rest sequentially in a counterclockwise pattern moving farther out from the center of the array plate.

16. PHAD Amplifier Assembly Procedure

This section describes the procedure for final assembly of the PHAD amplifier PCB in the amplifier enclosure. The amplifier enclosure has been fabricated according to the mechanical drawings for the enclosure.

The amplifier assembly procedure is the same for both large and small arrays, but the PCBs are different for each as previously addressed. The lid and final assembly into the PHAD electronics box is different for the large and small array. This will be addressed later in the assembly procedure for the PHAD electronics box.

1) Populate amplifier PCB with components according to the Bill of Materials in Table 1. Do not populate Channels 9 or 10 as they are extra channels not used for PHAD.
2) Solder wires, 24-inch-length black and red twisted pair 20 AWG, to each of the output signal connection headers marked “J2_1” through “J2_8” on the amplifier PCB.
3) Install eight 1/4-inch-diameter rubber grommets in side wall of enclosure.
4) Install amplifier “Power Input Harness” BNC connector in enclosure.
5) Mount #4-40 × 1/2-inch-length standoffs to bottom side of amplifier PCB.
6) Mount amplifier PCB inside enclosure.
7) Run one twisted pair through each 1/4-inch grommet.
8) Connect “Power Input Harness” Molex connector to J12 on PCB.
9) Connect “Gain Control Harness” Molex connector to J15 on the PCB and route switch through the hole on the enclosure.
10) Put tie wraps around switch wires at inside and outside walls of enclosure to keep “Gain Control Harness” wires from moving.

NOTE: The amplifier is now ready for assembly in the PHAD small array main electronics unit. For the PHAD large array amplifier, continue with the following additional steps.

11) Install the eight “PHAD Large Array Cable to Amplifier Bulkhead Harnesses” in the amplifier enclosure lid fabricated for the large array. The lid is split into two pieces with one-half slotted to allow for installation of the bulkhead harnesses.

12) Connect the Molex-6 connector on the harness to the "Microphone Connections" marked J1_1 through J1_8 on the amplifier PCB with the leftmost harness as J1_1.

13) Place the lid so that the bulkhead connectors are near the middle of the enclosure, but do not attach the lid at this time. The inside of the amplifier enclosure will need to be accessed during final assembly so that the amplifier can be mounted to the equipment plate of the PHAD main electronics unit.

17. PHAD Main Electronics Unit Assembly Instructions

This section describes the final assembly procedure for the PHAD main electronics unit. At this point, all PCBs, cables, harnesses, and subassemblies have been fabricated and tested. Most of the procedure is the same for both the large and small arrays with differences being noted during the individual steps.

1) Attach three isolated BNC connectors to the equipment plate with BNC side facing up. On the terminal side, connect center conductors together and connect to red wire of DC power input harness (3-pin military [MIL] connector that mates with the power conditioner cable and goes to red/black pigtails inside the main electronics unit). Connect ground tabs together and connect to black wire of DC power input harness.

2) Attach the amplifier and the CompactRIO controller to the equipment plate using #8 screws and nylon locknuts. Use four 1/4-inch-length spacers between the amplifier enclosure and equipment plate. For the large array only, install the lid on the amplifier enclosure using eight #8 × 3/8-inch-length sheet-metal screws.

3) Connect the twisted pairs from the amplifier to the CompactRIO A/D modules with the red wire going to the "+" terminal and black wire going to the "–" terminal. The A/D module closest to the ports on the controller is A/D Channels 1–4.

4) Install the equipment plate in the main electronics unit using four hex bolts, which go through the equipment plate, then through the unthreaded short standoff, then through a sealing washer with the rubber side on the bottom. The hex bolts then go through holes in the bottom of the main electronics unit and screw into the threaded long standoff.

5) Attach the leveling plate with the single hole nearest the front face of the electronics box.

6) Attach the leveling legs. Replace the thin nut with a thick nut so there is one nut on each side of the leveling plate.

NOTE: Steps 7–10 apply to both the large and small array except the connectors are mounted to the side wall of the large array main electronics unit rather than the bottom as described here for the small array main electronics unit.

7) Install a panel mount RJ-45 receptacle on the bottom of the main electronics unit with the exterior tab facing toward the front face of the electronics box. Make sure the sealing gasket is installed between the receptacle flange and the main electronics unit. Install a connector cap.

8) Grease the O-ring and install the DC power input connector (3-pin MIL connector) on the bottom of the main electronics unit.

9) Install the amplifier gain control switch and gain control knob on the bottom of the main electronics unit.

10) Grease the O-ring and install the GPS connector (SMA feedthrough F/F) on the bottom of the main electronics unit.

11) Connect a BNC patch cable between the equipment plate mounted BNC and the "Power Input Harness" BNC connector mounted to the amplifier enclosure.

12) Connect an isolated BNC connector with red/black wire pigtails between the equipment plate mounted BNC and the "Power Connector" of the CompactRIO controller.

13) Connect an SMA (M/M) patch cable between the main electronics unit mounted GPS connector and the CompactRIO "GPS Input".

14) Install a CAT-6 Ethernet patch cable between the main electronics unit mounted RJ-45 receptacle and the CompactRIO "Ethernet Port".

15) For the large array only, install weather stripping to the bottom side of the main electronics unit lid and then install the lid using the supplied bolts.

NOTE: The large array is ready for shipment or installation. The lid will need to be removed during installation to make the final connections between the large array microphone cables and the bulkhead connectors on the amplifier enclosure.

NOTE: The remaining steps apply to the small array only. It is highly recommended that a second person helps with Steps 16–20 to avoid personnel injury or damage to the array.

16) Install weather stripping to the wire side of the microphone array plate.

17) While propping up the microphone array plate, run the microphone cables through the 1¼-inch hole in the lid of the amplifier enclosure. Connect the Molex-6 connectors to the corresponding "Microphone Connections" J1_1 through J1_8 on the amplifier PCB.

18) Place tie wraps on both sides of the amplifier enclosure lid to keep the microphone cables from moving inside the enclosure once the lid is secured.

19) Secure the amplifier enclosure lid using four #8 × 3/8-inch-length sheet-metal screws.

20) Place the microphone array plate on the main electronics unit such that the "North" marking on the array plate points toward the rear of the main electronics unit. The rear side of the main electronics unit should have two leveling feet along that side.

21) Secure the microphone array plate to the main electronics unit by first clamping the four corners using 3/4-inch-length standoffs and 2-inch-length bolts. Tighten securely.

22) Install 1-inch-length bolts with sealing washers to remaining holes on all sides.

23) Replace the corner bolts with 1-inch bolts and sealing washers. Tighten all bolts.

NOTE: The small array is now ready for testing and installation. If the small array is going to be transported or stored, the following steps should be taken to prevent damage to the microphones.

24) Remove the four corner bolts. Place a 3/4-inch-length standoff used in Step 21 over each corner hole and then place the protective metal cover on top of the standoffs. Secure cover with the 2-inch-length bolts that were used in Step 21.

25) Once the small array is transported to the installation location, remove the four corner bolts and the protective cover. Set the cover plate, 2-inch bolts, and 3/4-inch standoffs aside for future transportation or storage of the small array. Install the 1-inch-length bolts with sealing washers from Step 23 into the four corners and tighten. The PHAD small array is now ready for installation.

18. Molex Connector Contact Arrangement

Top view (wire side) of the Molex connector contact arrangement is shown in Fig. 8.

43025-0200

Tab	**2**	**1**

43025-0600

Tab	**4**	**1**
	5	**2**
	6	**3**

Fig. 8 Top view (wire side) of the Molex connector contact arrangement

19. Hirose Connector Contact Arrangement

View of the Hirose connector contact arrangement is shown from the plug connector mating end or receptacle/jack solder pot side (Fig. 9). Note: The ▼ symbol indicates the polarizing key position.

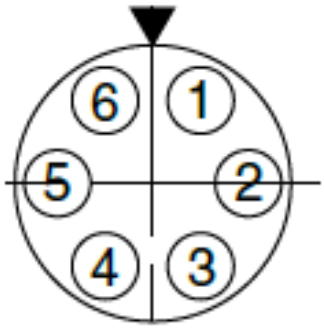

Fig. 9 Hirose connector contact arrangement

List of Symbols, Abbreviations, and Acronyms

A/D	analog to digital
ARL	Army Research Laboratory
BNC	Bayonet Neill–Concelman
CCDC	US Army Combat Capabilities Development Command
DC	direct current
F/F	female to female
GPS	Global Positioning System
IP	Internet Protocol
M/M	male to male
MIL	military
N/A	not applicable
PCB	printed circuit board
PHAD	Persistent Harmonic Acoustic Detector
P/N	part number
PVC	polyvinyl chloride
RTV	room-temperature vulcanizing
SMA	Subminiature Type-A
V	volts

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