

# **MODEL P348**

## **DUAL-CHANNEL BENCHTOP**

### **I/Q MODULATOR**



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## **Technical Manual**

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# **1 Introduction**

This is the user manual for the Highland model P348 I/Q Modulator.

The P348 is a small dual-channel analog box, where each channel accepts a sinewave carrier signal C and two DC-coupled baseband signals I and Q. Each independent channel will perform the function:

$$Y = I \times C_i + Q \times C_q$$

Where  $C_i$  is the in-phase carrier, and  $C_q$  is the quadrature-phase-shifted carrier. This permits two channels of vector modulation and rotation under control of an external four-channel arbitrary waveform generator.

Features of the P348 include:

- Two independent, isolated I/Q quadrature modulator channels
- Performs eddy current and proximity sensor simulation
- Precision linear modulation of RF carrier inputs
- Transformer isolated inputs/outputs
- Switchable input impedances
- Customizable for frequency, matching, and amplitudes

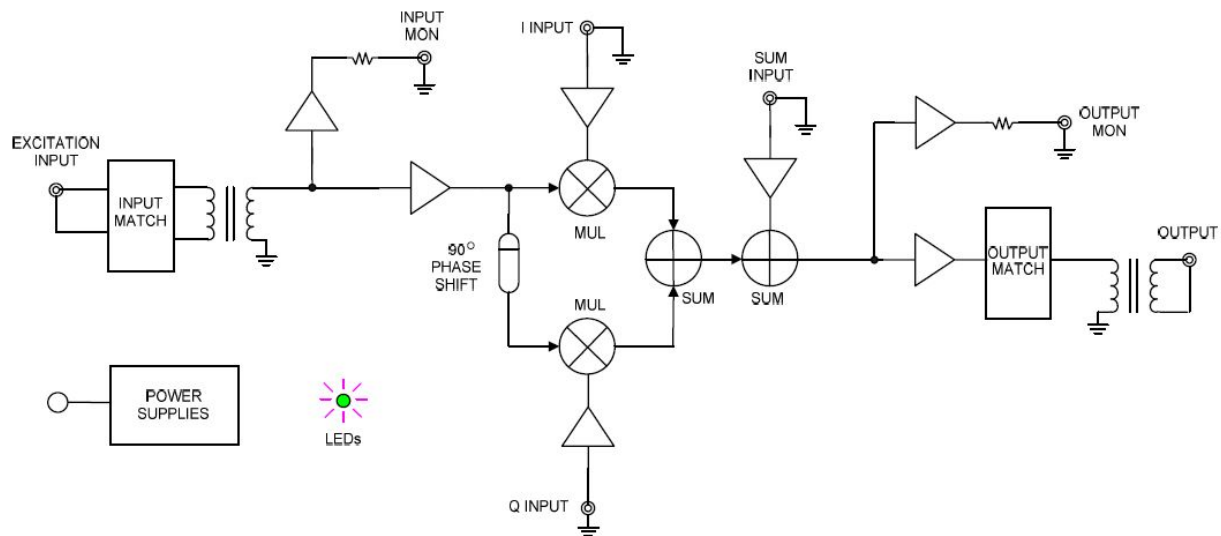
## 2 Specifications

FUNCTION	Two-channel I/Q Modulator
CARRIER FREQUENCY	Single frequency, 14.8 MHZ Other frequencies on request
CARRIER INPUT RANGE	28Vpp nominal, 34Vpp Max Switchable input impedance 50 $\Omega$ , 100 $\Omega$ , HiZ
I INPUTS	$\pm 5V$ , -3 dB at 1 MHz, 500 $\Omega$
Q INPUTS	$\pm 5V$ , -3 dB at 1 MHz, 500 $\Omega$
OUTPUTS	400 mV p-p full scale into 50 $\Omega$
SUM INPUTS	0.04 gain to loaded output for noise simulation 5K $\Omega$ input impedance
90° PHASE SHIFT ACURRACY	$\pm 3^\circ$ at specified carrier frequency
INPUT MONITOR	Provides attenuated (140:1) signal for monitoring of input, 50 $\Omega$
OUTPUT MONITOR	Provides attenuated (2:1) signal for monitoring of output, 50 $\Omega$
CONNECTORS	Isolated Triaxial with optional grounding for IN and OUT carrier wave SMB for monitors, I, Q and SUM
PACKAGING	7.0" (L) x 5.0" (W) x 2.25" (H) Aluminum enclosure
INDICATORS	Green power, two orange signal indicators
OPERATING TEMPERATURE	0 to 70°C
CALIBRATION INTERVAL	No internal calibrations
POWER	24 volts DC, 500mA max model J24, 24 VDC, 30 watt external adapter furnished 2.1 x 5.5 mm barrel connector, center pin positive

### 3 Overview

The P348 includes two independent transformer coupled channels, named A, B. Each channel has RF IN, I, Q and SUM as inputs, and one RF output.

The functional equivalent circuit of each channel is:

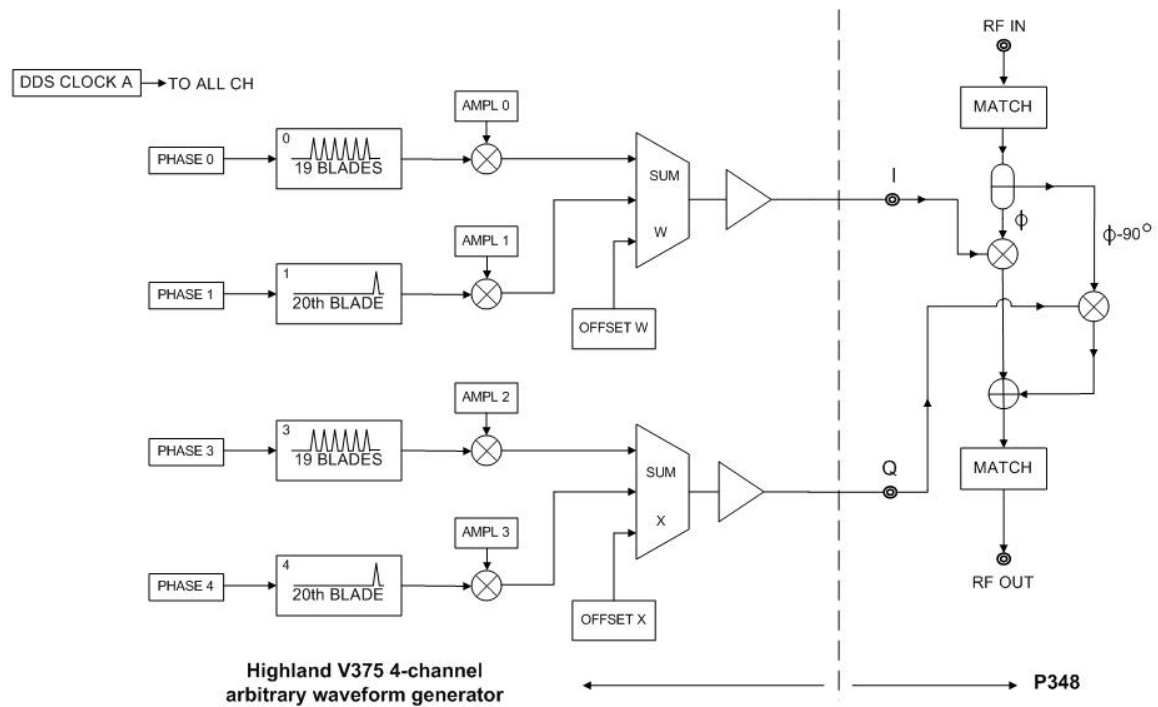


**Figure 1. P348 Equivalent Circuit**

The P348 includes a 90° phase-shift network that operates at the specified input carrier frequency.

We assume that a separate 4-channel arbitrary waveform generator will provide the I/Q baseband signals for the two independent simulator channels. The Highland [V375](#), [V346](#), [T346](#), and [P350](#) products are suitable.

As an example, the Highland V375 4-channel VME arbitrary waveform generator can be programmed to accurately simulate inductive proximity-type blade tip sensors.



### V375 and P348

## 4 *Front and Rear Panel*

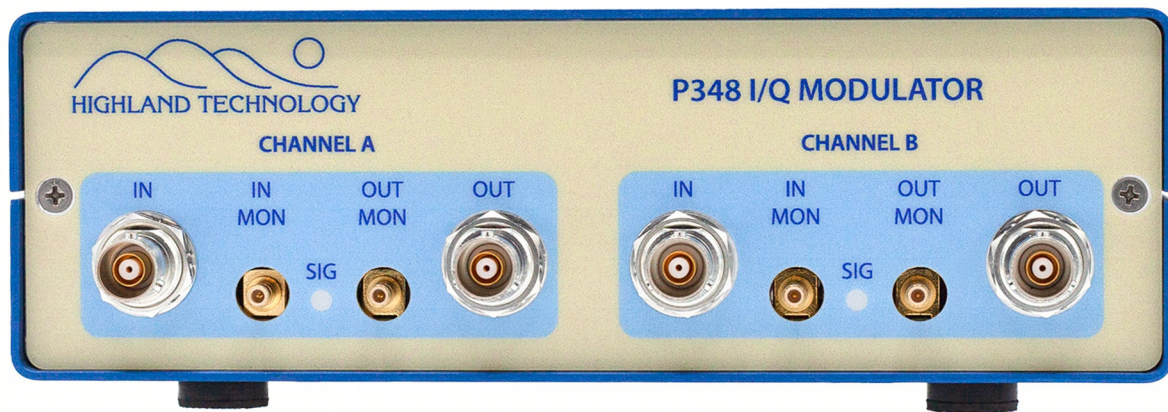


Figure 2: Front Panel

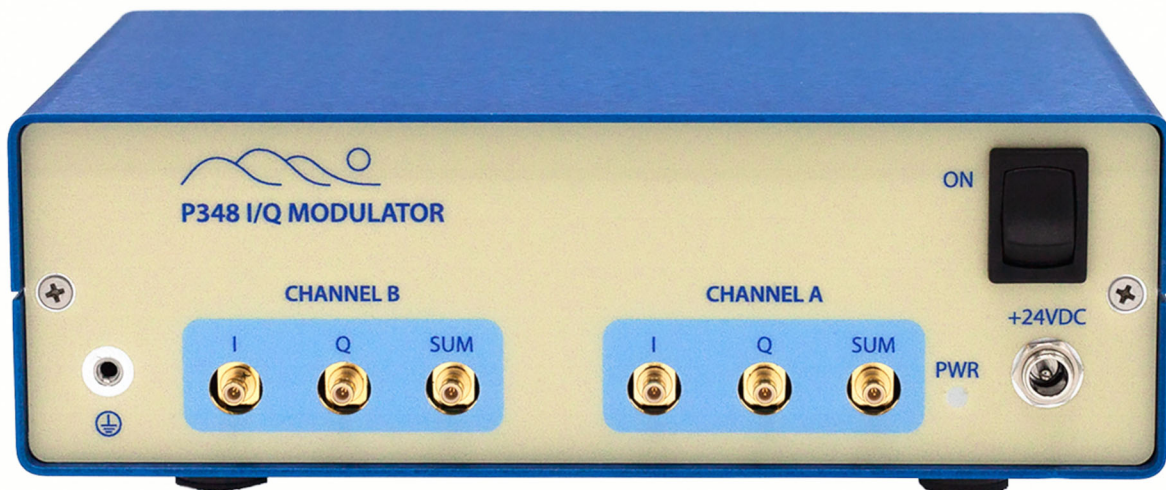


Figure 3: Rear Panel



## **4.1 LEDs**

There are 2 front-panel and 1 back-panel LED indicators.

The orange SIG LEDs turn on to indicate the presence of an input signal on each channel.

The green PWR LED turns on when power is connected and the power switch is set ON.

## **4.2 IN and OUT Connectors**

Each channel has a Triaxial input and output RF connector.

## **4.3 +24VDC Power Connector**

The P348 requires +24 volt DC power to its 2.1x5.5 mm DC barrel connector. The Highland model J24 supply is provided.

If users furnish their own 24 volt power, the model J27 cable is available, with a screw-thread barrel connector for a durable, vibration-proof connection. The other end of the J27 terminates with bare leads.



## 5 Operation

### 5.1 Phase Convention

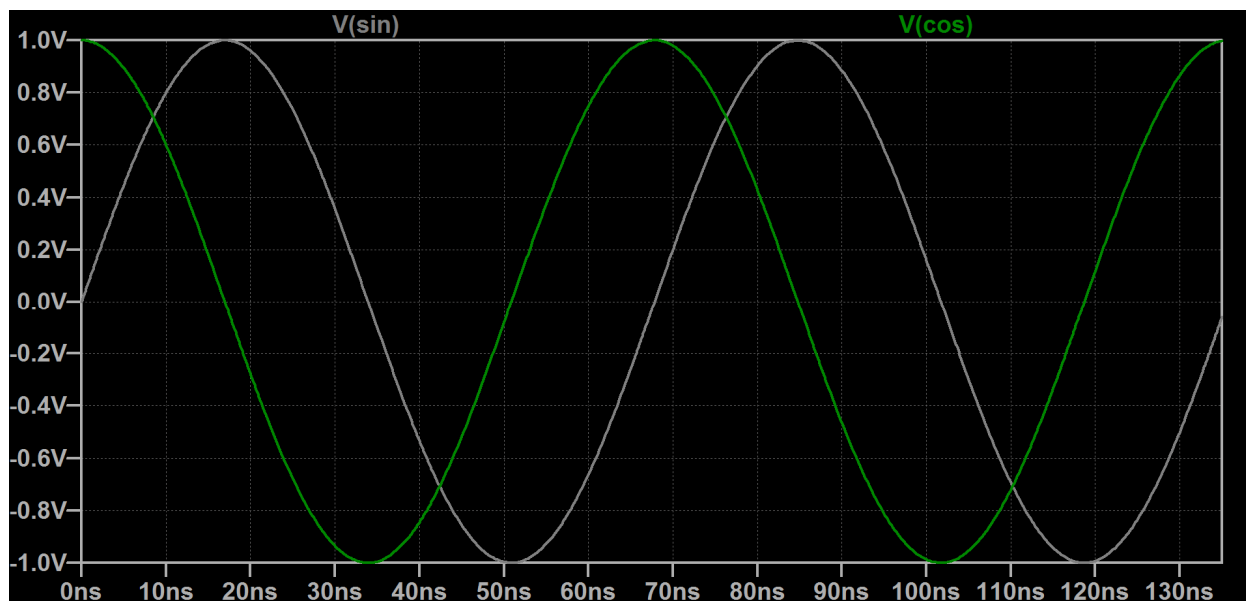


Figure 4. Phase Convention

The P348 uses by convention the cosine wave as in-phase component and the sine wave as the quadrature-phase component.

$C_i = V(\sin)$       grey waveform in-phase carrier waveform

$C_q = V(\cos)$       green waveform, +90 degree quadrature-phase carrier waveform

### 5.2 I Inputs: In-Phase Amplitude Modulation

The I input of each channel multiplies  $C_i$ , the channel in-phase carrier waveform.

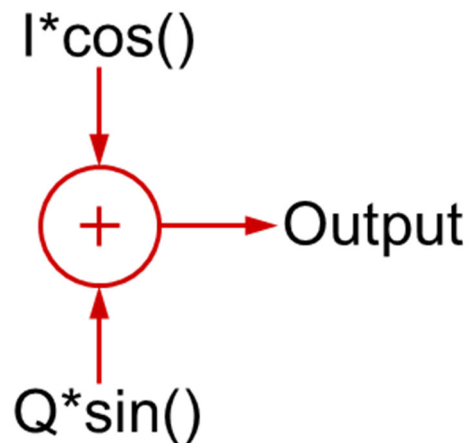
I	Phase Shift (°)	Output
+5V	0	$C_i$
-5V	180	$-C_i$
0v	-	0

### 5.3 Q Input: Quadrature Amplitude Modulation

The Q signal input signal multiplies Cq, the channel quadrature carrier signal.

Q	Phase Shift (°)	Output
+5V	90	Cq
-5V	270	-Cq
0V	-	0

### 5.4 I/Q Operation Vector Rotation Examples



I in	Q in	Phase Shift (°)	MON OUT	OUT
5V	0	0	200mVpp	400mVpp
0	5V	90	200mVpp	400mVpp
5V	5V	45	282mVpp	565mVpp
-5V	0	180	200mVpp	400mVpp
0	-5V	270	200mVpp	400mVpp

The above assumes 28 volts p-p RF input, and outputs loaded with 50 ohms.

## 5.5 Termination Switches

Each channel has two internal slide switches, which allow its RF input to be terminated in 50 ohms, 100 ohms, or HiZ. Each switch enables a 100 ohm termination.

The as-shipped state is 50 ohms, with both switches positioned to the left as shown below. This is suitable for terminating a 50 ohm coaxial cable.

Alternatively, one switch positioned to the left is 100 ohms, suitable to terminate a typical twisted pair.

Both switches positioned to the right is HiZ.

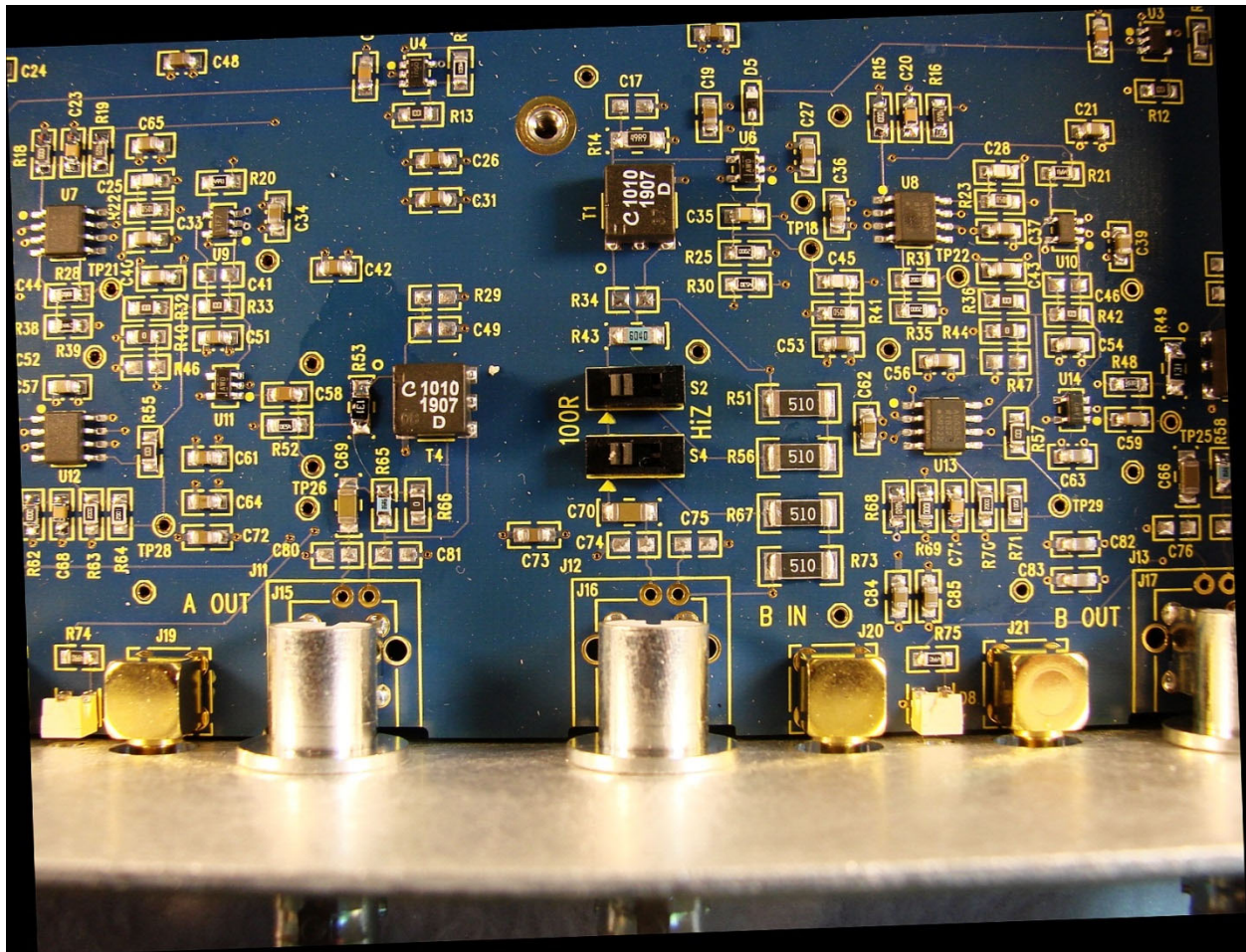


Figure 5: Input Termination Switches

## **6 Versions**

P348-1      dual-channel benchtop I/Q modulator

## **7 Customization**

The P348 can be customized for carrier frequency, I and Q full-scale inputs, input matching, output matching, and gains. Input and output connectors can be isolated or grounded BNCs. SMBs can be SMAs.

## **8 Revision History**

Revision B      September 2019  
Initial release

## **9 Accessories**

J24-1	24 volt 1.2 amp power supply (furnished with purchase)
J27-1	2.1 x 5.5 mm barrel to pigtail power cable
J42-1	3' SMB to SMA cable
J47-1	BNC female to triax male adapter
J53-1	3' SMB to BNC cable
J53-2	6" SMB to BNC cable
P10-1	19" rack mount shelf (two p-boxes per rack)
P51-1	Mounting flange