

# DENT Instruments

## RōCoil TCA-5™

### 5 Amp Transconductance Amplifier



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## Operator's Guide

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# Table of Contents

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<b>INTRODUCTION</b>	<b>4</b>
Product Description.....	4
Specifications.....	5
Safety Summary.....	6
<b>FIELD INSTALLATION</b>	<b>8</b>
Powering the TCA-5.....	9
Connecting RōCoil Current Sensors.....	11
Connecting Current Outputs .....	12
Output Impedance/Burden.....	12
<b>THEORY OF OPERATION</b>	<b>14</b>
Input Signal .....	14
Range Selection .....	15
Integration.....	16
Frequency Selection .....	16
Performance .....	16
<b>FREQUENTLY ASKED QUESTIONS</b>	<b>17</b>

# Introduction

## Product Description

The RōCoil TCA-5™ is a three channel integrating transconductance amplifier that translates the electrical output signal from a flexible RōCoil™ current sensor to a 5-amp AC current, emulating a traditional 5A secondary current sensing transformer. This combination enables the flexibility and ease of installation of the RōCoil to be extended to applications having power meters or panels that cannot process a RōCoil signal directly. The RōCoil TCA-5 is a DIN rail- or panel-mounted device requiring an external 48-volt power supply (available as an option). The RōCoil TCA-5 has four selectable current ranges: 500, 1k, 2.5k, and 5k amps and is accurate for both 50 and 60 Hz systems. The RōCoil TCA-5 has been factory calibrated for DENT RōCoil current sensors with an output of 131.0 mV per thousand amps at 60 Hz.

**NOTE:** The RōCoil TCA-5 has been tested for electromagnetic compatibility (EMC) as an assembly which includes a discrete filter between the 48 volt DC power supply and the TCA-5. Removal of this filter may result in spurious results or saturation of the high gain internal amplifier.

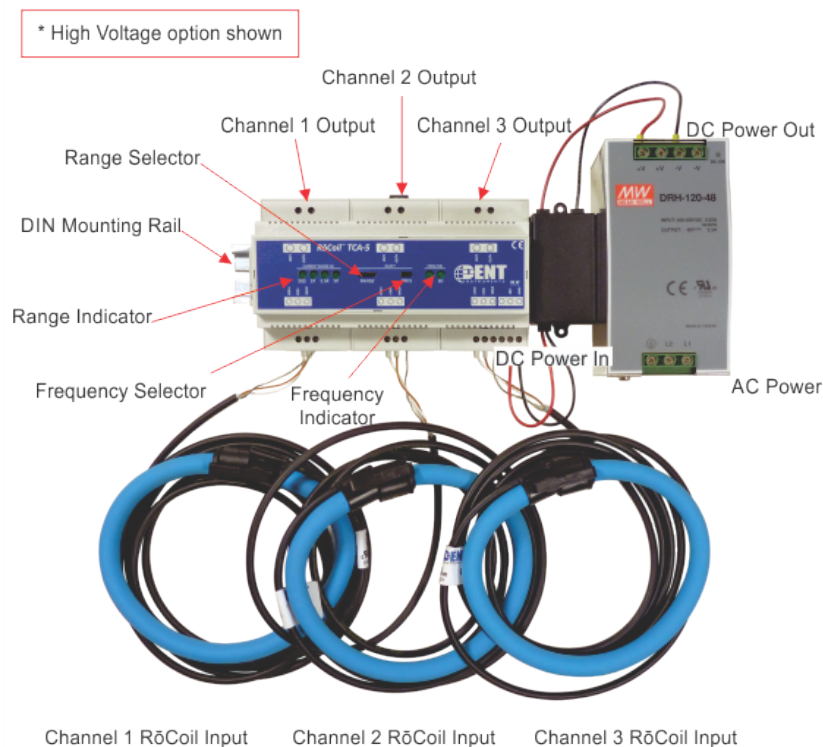


Figure 1-1: Anatomy of the 5-Amp RōCoil TCA

**KEY SPECIFICATIONS**

Input Measurement Voltage	0 – 655 mV (RMS)
RōCoil Current Range	0.5 – 5000 amps (80 dB Signal Range)
Output Current	0 – 5.00 amps (RMS)* ⚠
RōCoil Sensing Ranges	500, 1K, 2.5K, 5K Amps (User-selectable)
Maximum Burden	1.25 VA per channel
Maximum Output Impedance	50 m-ohms
Measurement Channels	3 (3-phase or single phase)
Frequency	50/60 Hz Select
Accuracy	1%**
Channel Cross Talk	< 60 dB

**ENVIRONMENTAL**

Location	Indoor use only
Altitude	Up to 2000m
Operating Temperature	-20° C (-4° F) to 40° C (104° F)
Relative humidity	5% to 95% non-condensing

**POWER REQUIREMENTS**

TCA Supply Voltage	48 VDC +/- 10%, 30 Watts
TCA Supply Current	0.6 amps DC @ 48 VDC

**KEY SPECIFICATIONS****DIMENSIONS/MOUNTING**

Width Base Unit/Assembled	15.7 cm (6.2")/25.0 cm (9.8")
Height Base Unit/Assembled	9.0 cm (3.5")/12.6 cm (5.0")
Input Wire Connection	18 – 28 AWG
Output Wire Connection	12 – 18 AWG (length dependent)

**ACCESSORIES**

AC/DC Power Supply	Low Voltage: 120/240 VAC    40W High Voltage: 400/500 VAC    120W
Mounting Rail	TS35/7 DIN Rail


**Table 1-1: Specifications**

- \* The RōCoil TCA-5 is limited to 19 amps of peak instantaneous current. The 19 amp limit is reached at 6.7 amps (RMS) when measuring 3 phase loads but is reduced to 4.5 amps (RMS) when measuring three currents on the same phase. **NOTE:** Operating with an output channel over 5 amps RMS can cause the RōCoil TCA-5 to overheat and become damaged.
- \*\* All accuracies specified at 20° C (+/- 2° C) with RōCoil centered on conductor. Typical accuracy with RōCoil CTs < 1%.



**TIP:** Use a “true RMS” DVM to measure the voltage across the output terminals of the RōCoil TCA-5. A voltage above 250 mV RMS indicates that the signal may be clipped.

## Safety Summary

<p>This general safety information is to be used by both operator and servicing personnel. DENT Instruments, Inc. assumes no liability for user's failure to comply with these safety guidelines.</p>		<p>Conforms to UL STD 61010-1 Conforms to CAN/CSA STD C22.2 No. 61010</p>
<p><b>CAUTION: Service panel voltages may contain life-threatening voltages. QUALIFIED PERSONNEL MUST install CTs or power leads using methods consistent with NEC and local codes.</b></p>		



**WARNING!** Use of this device in a manner for which it is not intended may impair its means of protection.

### SYMBOLS ON EQUIPMENT



Denotes caution. See manual for a description of the meanings.

When connecting the RōCoil TCA-5™ to an AC load, follow these steps to prevent a shock hazard.

1. If possible, de-energize the circuit to be monitored.
2. Connect the CTs to the phases being monitored.
3. Use proper safety equipment (gloves, mask, and protective clothing) as required.



Measurement input terminals of the device shall be connected to Listed or Certified Rogowski coils, with 131mV/1000A output, rated for the voltage and category of the installation, and the CT is evaluated for Double/Reinforced Insulation.



Risk of electrical shock. Life-threatening voltages may be present. All work should be performed by a qualified electrician using proper safety equipment.



Dispose of properly.



### FCC COMPLIANCE

This device has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at user's own expense.

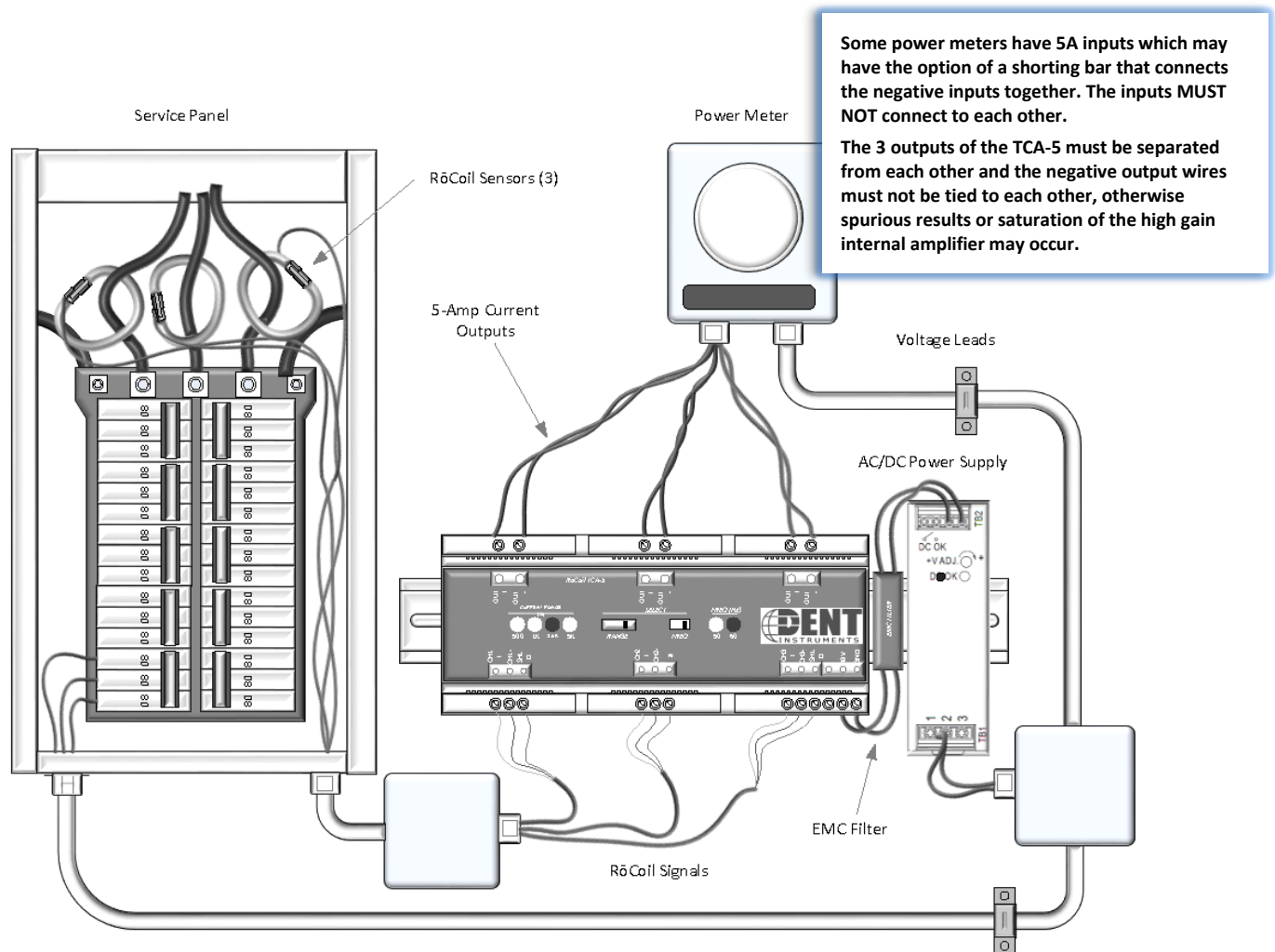
Operation is subject to the following two conditions: (1) This device may not cause harmful interference and (2) this device must accept any interference received, including interference that may cause undesired operation.

### MAINTENANCE

There is no required maintenance with the TCA-5. Abide by the following items:

Cleaning: No cleaning agents, including water, shall be used on the TCA-5.

# Field Installation



**Figure 2-1: Recommended Installation**

The RøCoil TCA-5 is intended to be mounted with the output terminal facing up. The RøCoil TCA-5 generates up to 20 watts of internal heat and relies on natural convection to cool itself. The unit must be mounted inside an electrical enclosure in order to meet UL requirements. The unit must not be mounted in a position that will interfere with the operating of the disconnect.

Three RøCoil current sensors will typically be installed inside the service panel at the feeder or around the branch circuit of interest. Best practice is to separate the AC voltage (used to power the TCA-5 and power meter) from the RøCoil signal conductors by running them in separate conduits (as shown in Figure 2-1). The RøCoil signal shield wires should be terminated at the RøCoil TCA-5 end only.



## Powering the TCA-5

The TCA-5 operates from 48 volts DC +/- 10% and has a full power consumption of 30 watts. The DC connections are made in the lower right hand corner of the unit (inset image). The DC connection is polarity sensitive and will only power up if applied with the correct polarity. Backwards polarity will not damage the unit but it will not turn on.

DENT Instruments offers two DIN rail-mounted AC/DC power supplies for line powering: High voltage (400 – 500 VAC) and Low voltage (120 – 240 VAC). The High Voltage model is suggested for 480V three phase power systems across line-to-line and the Low Voltage model is suggested for single phase residential and 208V 3-phase systems. In both cases the AC/DC power supply input is connected between two phases of incoming voltage. DENT Instruments recommends powering the AC/DC power supply through a dedicated breaker to avoid the use of “tap rules” whenever space allows (as shown in Figure 2-1). If the TCA-5 is powered from an auxiliary control transformer rather than directly from line power ensure that the transformer has 30 VA of available capacity.

**NOTE:** The UL listing is valid only if power supplies approved for DENT Instruments products are used.



Figure 2-2: DC Connections

Where enclosures are required to protect the RōCoil TCA-5 from exposure to the local environment the following graph (courtesy of Hoffman Enclosures) provides an indication of the smallest allowable enclosure size. The internal enclosure temperature cannot be allowed to exceed 40° C (104° F) if full current is demanded from the RōCoil TCA-5. An enclosure having a surface area of 3 square feet or larger is recommended for a typical design case: 20° C temperature rise, 20-watt internal load, 6.7-watt/square foot.

The RōCoil TCA-5 can be mounted as a panel unit using the slide-out tabs on the back or mounted on a 35 mm-width DIN rail.

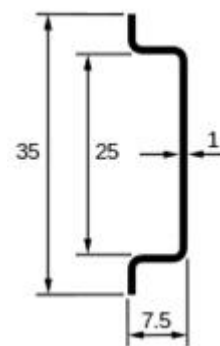


Figure 2-3: Top hat EN 50022 Rail

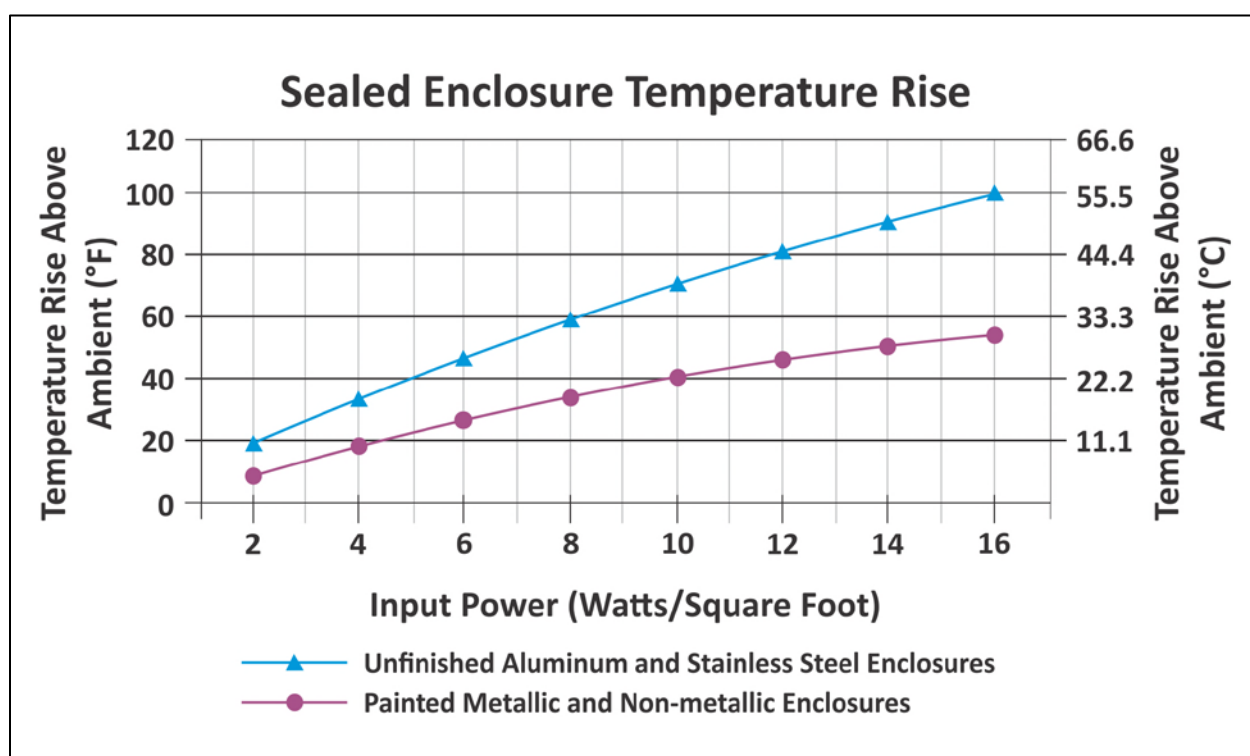


Figure 2-4: Sealed Enclosure Temperature Graph

## Connecting RōCoil Current Sensors

- 1) Open the CT by squeezing the connector latch and pulling it apart.
- 2) Connect the CT around the conductor to be measured. Make sure no other conductors are within the loop formed by the CT. Orient the CT so that the arrow on the CT connector points in the direction of conventional current flow (toward the load).

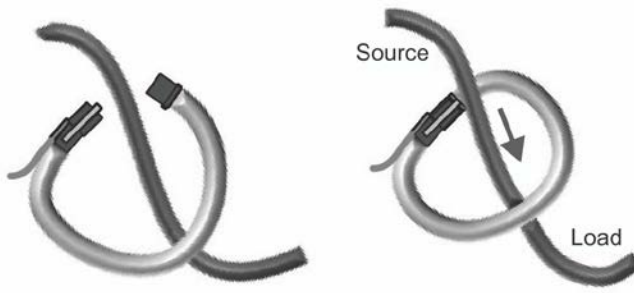


Figure 2-5: RōCoil Connectors

- 3) Push the connector back together with the conductor within the loop of the CT.
- 4) Mark and route the RōCoil signal wires to the RōCoil TCA-5.



Figure 2-6: Signal Wire

- 5) Identify and terminate the signal wires for connection to the RōCoil TCA-5.

CT + LEAD	CT - LEAD	SHIELD
White	Brown	Bare

Table 2-1: Connection Color Code

## Connecting Current Outputs

The output connector polarity is marked on top of the enclosure. Output connections should be tightened to 0.8 Nm (7 in-lbs) to ensure a low termination impedance. Avoid routing the output wires in close proximity with the signal input wires to avoid introducing feedback. Both the input and output circuitry are tolerant of plugging and unplugging under load without damaging the TCA.

Some power meters have 5A inputs which may have the option of a shorting bar that connects the negative inputs together. The inputs **MUST NOT** connect to each other.

The 3 outputs of the TCA-5 must be separated from each other and the negative output wires must not be tied to each other, otherwise spurious results or saturation of the high gain internal amplifier may occur.



### OUTPUT IMPEDANCE/BURDEN

The RōCoil TCA-5 is a bipolar push/pull current source that operates internally from a +/- 1.0 volt DC power supply. The design senses the output current using a precision resistor and drives a pair of MOSFETS through a feedback loop to control the current. Linearity and precision is maintained as long as the requested current can be delivered within the voltage compliance of the DC supply. The fraction of voltage drop allowed by the output circuitry (i.e., the voltage loss due to current flowing through the sum of the wire resistance and meter burden) is 250 mV. This condition is satisfied at 5.0 amps RMS with a crest factor of 1.414 for an output impedance of 50 m-ohms. Another way to express this limit is a burden of 1.25 VA.

The 50 m-ohm output impedance plays a critical role in the selection of output wire size and the allowable distance between the power meter and the RōCoil TCA-5. The table below has been generated assuming that the meter burden is 5 m-ohms, leaving 45 m-ohms for the wire. Note that the meter distance is half the wire length.

WIRE AWG	MOHMS PER FOOT	MAX METER DISTANCE (FT)
12	1.588	14.35
14	2.525	8.9
16	4.016	5.6
17	5.064	4.4
18	6.385	3.5
20	10.15	2.4

**Table 2-2: Allowable Distance**



**TIP:** Twisting the output cables together to reduce the effects of electromagnetic interference shortens the physical length of the cable by approximately 20%.

Table 2-2 sets the practical **maximum** length between the meter and the RōCoil TCA-5. Extremely short cable connections with large wire should also be avoided. Because the amplifier operates from a fixed DC supply voltage the power delivered by the amplifier is the same for a given current regardless of the output impedance. The output impedance impacts *where* the heat is generated. If the RōCoil TCA-5 is delivering 5 amps and the output impedance is near zero, then the full 1.875 watt burden is placed on the internal MOSFETS. The design can tolerate this condition but the temperature of the amplifier will increase considerably, reducing the accuracy of the system.



**TIP:** Use a “true RMS” DVM to measure the voltage across the output terminals of the RōCoil TCA-5. A voltage above 250 mV RMS indicates that the signal may be clipped.

# Theory of Operation

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## Input Signal

DENT RōCoil current sensors produce a signal voltage in accordance with

$$V = \frac{-AN\mu_o \frac{dI}{dt}}{L}$$

Where  $I$  is the current flowing in the measurement conductor and  $A$ ,  $N$ ,  $\mu_o$ , and  $L$  are determined by the physical construction of the RōCoil.

DENT RōCoils are manufactured to produce  $2.183 \frac{\mu V \cdot Hz}{Amp}$  which is more commonly expressed as 131.0 mV/kA @ 60 Hz and 109.2 mV/kA @ 50 Hz.

The RōCoil TCA-5 is factory calibrated for use with DENT RōCoils. The use of other Rogowski brands will introduce a scaling error. The RōCoil TCA-5 is extremely sensitive and accurately translates conductor currents between 500 mA and 5000 amps into meter currents between 500  $\mu A$  and 5.0 amps.

The operation of the RōCoil TCA-5 is best expressed using vector notation and is illustrated as a vector diagram in Figure 3-1, next page. The voltage generated by the RōCoil sensor leads the current flowing in the measurement conductor by almost 90 degrees (angle exaggerated for clarity), labeled (1). The positive X axis (0 degrees) is the current vector of the conductor being measured.

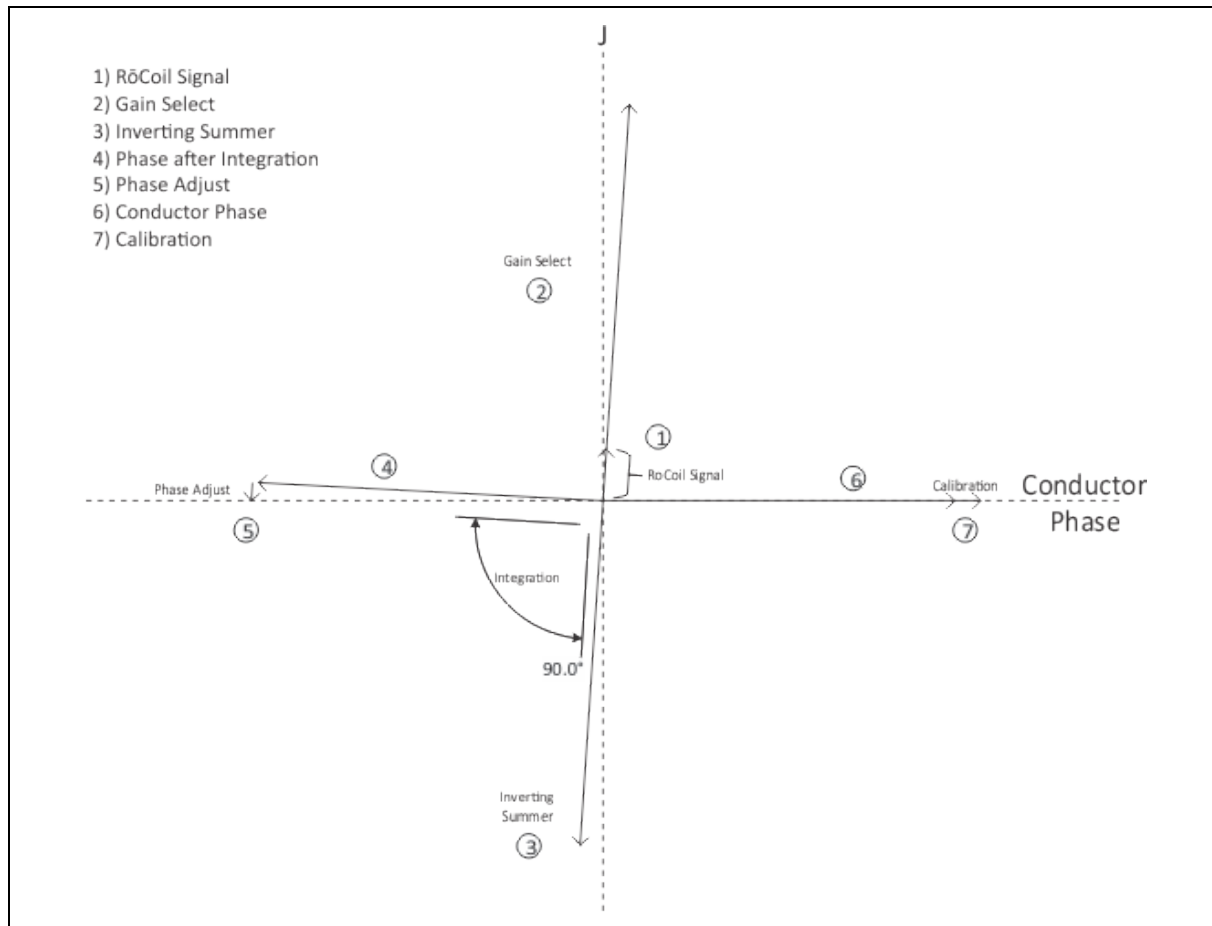


Figure 3-1: RōCoil TCA™ Vector Diagram

## Range Selection

The RōCoil TCA-5 range selection slider switch selects the primary gain of the amplifier. Internal feedback with gains of 1, 2, 5 and 10 are selected using laser trimmed precision resistors within an inverting precision operational amp circuit (shown as vectors 2 and 3 in Figure 3-1). The Current Range Selector is normally set to the nearest value over the size of the breaker feeding the load being measured. For example, the 1000 amp setting would be used with an 800 amp service breaker. If the size of the load is known to be much smaller than the service capacity, better accuracy can be obtained by selecting the range closest to the actual usage.

If the actual current is higher than the selected range the RōCoil TCA-5 waveform will be clipped and will not give an accurate reading. The effect of clipping the waveform is illustrated in Figure 3-2.

Severely clipped waveforms resemble a square wave. Ensure that the selected current range of the meter is above the current flowing in the measurement circuit to avoid this condition.

**NOTE:** The RōCoil TCA-5 will not be damaged if the output is over-ranged and is clipping.

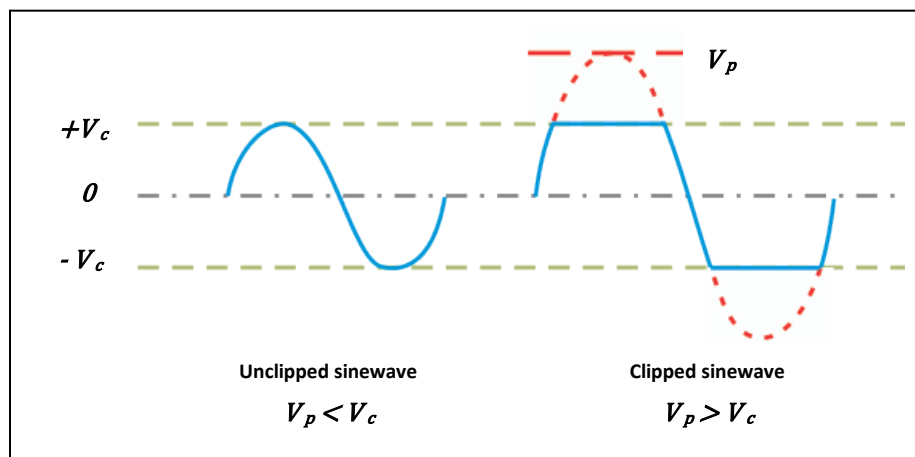


Figure 3-2: RōCoil Clipped Waveform



**TIP:** Use a “true RMS” DVM to measure the voltage across the output terminals of the RōCoil TCA-5. A voltage above 250 mV RMS indicates that the signal may be clipped.

## Integration

The RōCoil TCA-5 employs an internal precision analog integrator to compensate for the phase angle produced by the RōCoil current sensor (vector 4). For this reason the TCA cannot be used with a 333mV split core current transducer unless the phase information is not needed.

## Frequency Selection

The RōCoil TCA-5 has been specifically designed and calibrated to work with 50 and 60 Hz circuits. The 50/60 Hz slider selects one of two small angle correction vectors and inverting vectors (5 and 6) bringing the amplifier phase within 0.1 degree of the reference conductor phase. If the incorrect frequency is selected a phase error of 0.6 degrees will result. The sensitivity of the phase to frequency is approximately .06 degrees per Hz. The RōCoil TCA can be used on portable generators where frequency is not well regulated. Consult DENT Instruments for use of the RōCoil TCA-5 on 400 Hz circuits.

## Performance

The RōCoil TCA-5 can be supplied with RōCoil flexible current transformers (purchased separately). The combined errors of the TCA used in conjunction with supplied CTs is typically better than 1%.

CURRENT RANGE SETTING	MIN CURRENT @ 1% ERROR	MAX CURRENT
500 A	5 A	500 A
1000 A	10 A	1000 A
2500 A	25 A	2500 A
5000 A	50 A	5000 A

Table 3-1: Min/Max Current Range



## FAQs

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### Frequently Asked Questions

- How can I tell if the amplifier is clipping?

The voltage across the output terminals is above 250mV RMS. Correct this by using a larger wire gauge or moving the TCA-5 closer to the meter.

- Does output clipping damage the unit?

Clipping the output signal does not harm the TCA-5 as long as the output current remains less than 5 amps, as in the case when the output impedance is greater than 50m-ohms or the output wires are disconnected.

- Why does the TCA-5 run so hot?

Each channel dissipates approximately 5 watts of heat at full power.

- Why is the TCA-5 limited to 4.5 Amps RMS on 3 single-phase loads?

The TCA-5 has a peak internal current of 19 amps.

- Is there any configuration that can cause the TCA-5 to fail?

The TCA-5 will attempt to deliver more than 5 amps if the current being measured is larger than the selected range. For example: placing the RōCoil current sensor around a conductor with 900 amps flowing through it. The TCA-5 will deliver 9 amps of current into the output even though the 500 amp range is selected on the front panel. If the output burden is low enough, the TCA will deliver the requested current and burn out the channel if this condition persists. Note that this scenario is limited to single phase measurements. A balanced three phase system will share the current between channels preventing any one channel from overheating.

- Is there a 24-volt version?

Not at this time.

- Is there a single phase version?

The TCA-5 can be used on single-phase circuits, however there is currently no "1 channel model."

- Can the TCA-5 be used with 333mV current sensors?

The TCA-5 includes a 90 degree phase shifter. It can only be used with 333mV sensors to report current, NOT POWER.

- I had the 50Hz selector on by mistake. Is my collected data any good?

Yes, the phase angle will be reported 0.6 degrees higher than actual, which is also about 0.6% low for a PF of 0.866.

