

# CT220

## XtremeSense™ High Linearity, High-Resolution TMR Contactless Current Sensor in Miniature Form Factor

### Features

- AC or DC Contactless Current Sensing Range: Up to 1,000 A
  - Resolution: 5 mA
- Inherently High Isolation
- Magnetic Field (Current) Range:
  - $\pm 1.5$  mT
  - $\pm 5.0$  mT
  - $\pm 10.0$  mT
  - $\pm 15.0$  mT
- Stable Performance over Temperature
- Supply Current:  $\sim 1.2$  mA
- FLAG Pin to Indicate 90% and 10% of Full Field Range
  - Active LOW Digital Output (Push-pull)
- Supply Voltage: 2.7 V to 5.5 V
- Operating Temperature Ranges:
  - Industrial:  $-40^{\circ}\text{C}$  to  $+85^{\circ}\text{C}$
  - Extended Industrial:  $-40^{\circ}\text{C}$  to  $+125^{\circ}\text{C}$
- Package: 5-lead SOT23

### Applications

- Contactless Current Sensing Measurements
- Motor Control
- Solar Inverters
- Power Distribution Units (PDUs)
- UPS, SMPS and Telecom Power Supplies
- Smart Appliances
- IoT Smart Plugs/Energy Devices
- Battery Management Systems
- Battery Chargers
- PC and Servers

### Product Description

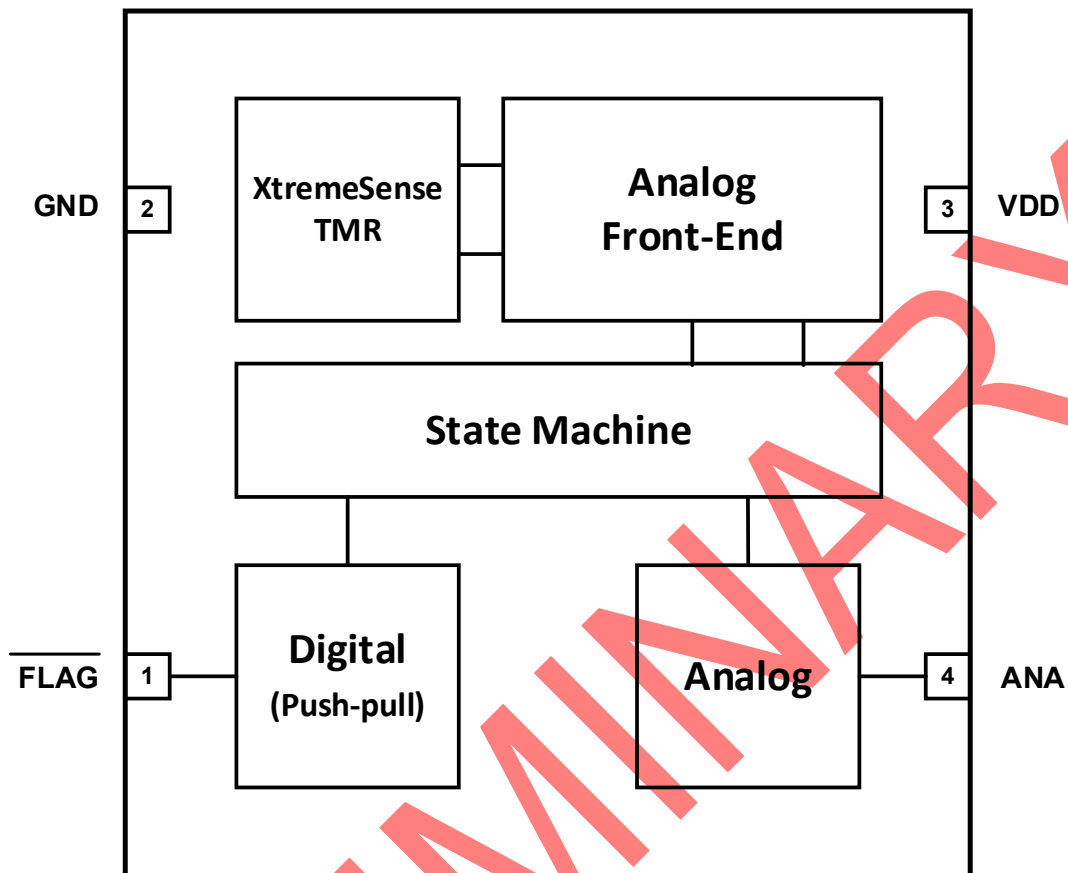
The CT220 is a high linearity and high-resolution contactless current sensor from Crocus Technology developed on its patented XtremeSense TMR technology with the capability of measuring up to 1,000 A. It measures the magnetic field of the current flowing through a busbar or printed circuit board (PCB) trace and converts it to an analog output voltage that represents the field and therefore current.

As a contactless current sensor, it has an inherently high isolation making it an ideal solution for applications where product safety compliance is a requirement due to high operating voltages combined with human interaction with the product. The CT220 achieves XtremeSense™ performance with a typical total out error of  $\pm 0.5\%$  while sensing field (current) as low as 5 mA. It supports a wide operating voltage range of 2.7 V to 5.5 V.

The CT220 is an ideal contactless current sensing solution for applications that need to have excellent isolation and accurate current measurements. There are four (4) variants of the CT220 that will sense the following magnetic fields:  $\pm 1.5$  mT,  $\pm 5.0$  mT,  $\pm 10.0$  mT and  $\pm 15.0$  mT. It also integrates a FLAG output that is active LOW and will indicate when the field is above 90% and below 10% the full field range.

It is available in an industry standard 5-lead SOT23 package.

## CT220 Block Diagram

Figure 1. CT220 with Analog and  $\overline{\text{FLAG}}$  Outputs in SOT23-5 Package Block Diagram

## CT220 Pin Configurations

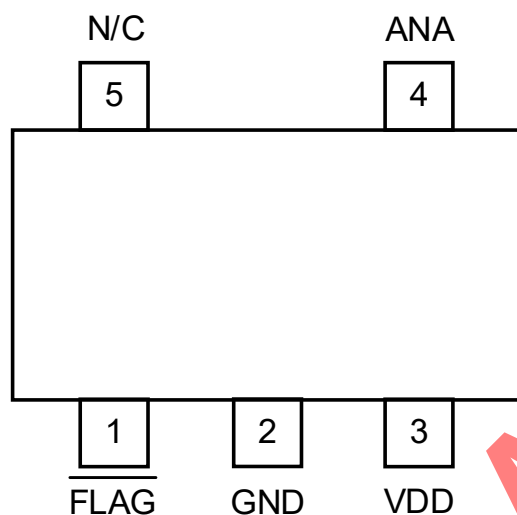


Figure 2. 5-Lead SOT23 Package, Top View

## Pin Definitions

Pin #	Pin Name	Pin Description
1	$\overline{\text{FLAG}}$	Outputs an active LOW flag signal to indicate when there the field (current) is above 90% or below 10% of the full field (current) range. It is a push-pull output.
2	GND	Ground.
3	VDD	Supply Voltage.
4	ANA	Analog output voltage that represents the measured current.
5	N/C	No Connect.

## CT220 Axis of Sensitivity Diagrams

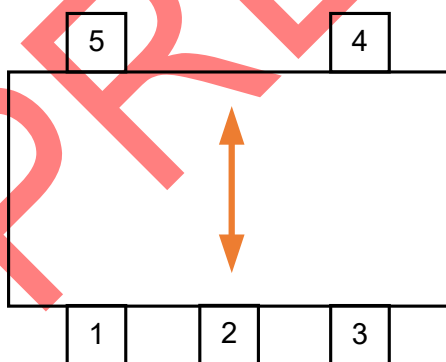


Figure 3. CT220: Axis of Sensitivity for Bipolar Magnetic Field with SOT23-5.

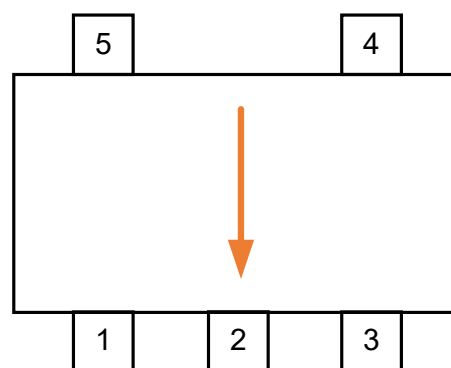


Figure 4. CT220: Axis of Sensitivity for Unipolar Magnetic Field with SOT23-5.

## Absolute Maximum Ratings

Stresses exceeding the absolute maximum ratings may damage the CT220 and may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only.

Symbol	Parameter		Min.	Max.	Unit
V <sub>DD</sub>	Supply Voltage strength		-0.3	6.0	V
V <sub>FLAG#_PP</sub>	Push-pull Output (Active LOW)		-0.3	V <sub>DD</sub> + 0.3	V
V <sub>I/O</sub>	Input/Output Pins Maximum Voltage		-0.3	V <sub>DD</sub> + 0.3	V
I <sub>IN</sub> / I <sub>OUT</sub>	Input and Output Current			±10.0	mA
ESD	Electrostatic Discharge Protection Level	Human Body Model (HBM) per JESD22-A114	±2.0		kV
T <sub>J</sub>	Junction Temperature		-40	+150	°C
T <sub>STG</sub>	Storage Temperature		-65	+150	°C
T <sub>L</sub>	Lead Soldering Temperature, 10 Seconds			+260	°C

## Recommended Operating Conditions

The Recommended Operating Conditions table defines the conditions for actual operation of the CT220. Recommended operating conditions are specified to ensure optimal performance to the specifications. Crocus Technology does not recommend exceeding them or designing to absolute maximum ratings.

Symbol	Parameter		Min.	Typ.	Max.	Unit
V <sub>DD</sub>	Supply Voltage Range		2.7	5.0	5.5	V
V <sub>OUT</sub>	Output Voltage Range		0		V <sub>DD</sub>	V
I <sub>OUT</sub>	Output Current				±3.0	mA
T <sub>A</sub>	Operating Ambient Temperature	Industrial	-40	+25	+85	°C
		Extended Industrial	-40	+25	+125	

## Electrical Specifications

### General Parameters

Unless otherwise specified:  $V_{DD} = 2.7 \text{ V}$  to  $5.5 \text{ V}$ ,  $C_{BYP} = 1.0 \mu\text{F}$  and  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are  $V_{DD} = 5.0 \text{ V}$  and  $T_A = +25^\circ\text{C}$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
$I_{DD(AVG)}$	Average Supply Current	$t \geq 10 \text{ s}$		1.2		mA
$f_s$	Sampling Frequency			200		kHz
$t_{IDLE}$	Idle Mode Time	$f_s = 200 \text{ kHz}$		5.0		$\mu\text{s}$
<b>Analog Output (ANA)</b>						
$I_{DRV(MAX)}$	Maximum Drive Capability	$\Delta V_{OUT} \leq 10 \text{ mV}$	-10		+10	$\mu\text{A}$
$V_{ANA}$	Analog Output Voltage Range		$0.05 \times V_{DD}$		$0.95 \times V_{DD}$	V
$V_{OQ}$	Voltage Output Quiescent		48.5	50.0	51.5	% $V_{DD}$
$t_{RISE}$	Rise Time <sup>(1)</sup>	$B_{ANA} = B_{ANA(MAX)}$ , $t_{VANA\_90\%} - t_{VANA\_10\%}$		15.5		$\mu\text{s}$
$t_{DELAY}$	Propagation Delay <sup>(1)</sup>	$B_{ANA} = B_{ANA(MAX)}$ , $t_{BANA} - t_{VANA}$ @ 20% of output value		4.6		$\mu\text{s}$
$t_{RESP}$	Response Time <sup>(1)</sup>	$B_{ANA} = B_{ANA(MAX)}$ , $t_{BANA} - t_{VANA}$ @ 90% of output value		20.0		$\mu\text{s}$
$e_{ND}$	Input Referred Noise Density <sup>(1)</sup>	$f_{BW} = 10 \text{ Hz}$ , $V_{DD} = 5.0 \text{ V}$		0.15		$\mu\text{T}_{RMS}/\sqrt{\text{Hz}}$
$C_L$	Output Capacitive Load				10	pF
<b>FLAG Push-pull Output (FLAG)</b>						
$V_{FLAG\_OL}$	$\overline{\text{FLAG}}$ Voltage LOW	Unipolar & Bipolar Fields		$0.9 \times V_{DD}$		V
		Bipolar Field		$0.1 \times V_{DD}$		
$V_{FLAG\_OH}$	$\overline{\text{FLAG}}$ Voltage HIGH	Unipolar & Bipolar Fields		$0.86 \times V_{DD}$		V
		Bipolar Field		$0.14 \times V_{DD}$		
$I_{FLAG\#}$	Current for FLAG			$\pm 2$		mA
<b>Timings</b>						
$t_{ON}$	Power-On Time	$V_{DD} \geq 2.7 \text{ V}$		50	75	$\mu\text{s}$
$t_{ACTIVE}$	Active Mode Time			2.5		$\mu\text{s}$
<b>Protection</b>						
$V_{UVLO}$	Under-Voltage Lockout	Rising $V_{DD}$		2.3	2.5	V
		Falling $V_{DD}$	2.0	2.2		V
$V_{UV\_HYS}$	UVLO Hysteresis			100		mV

(1) Guaranteed by design and characterization; not tested in production.

## Typical Timing & Electrical Characteristics

$V_{DD} = 5.0\text{ V}$ ,  $T_A = +25^\circ\text{C}$  and  $C_{BYP} = 1.0\text{ }\mu\text{F}$  (unless otherwise specified).

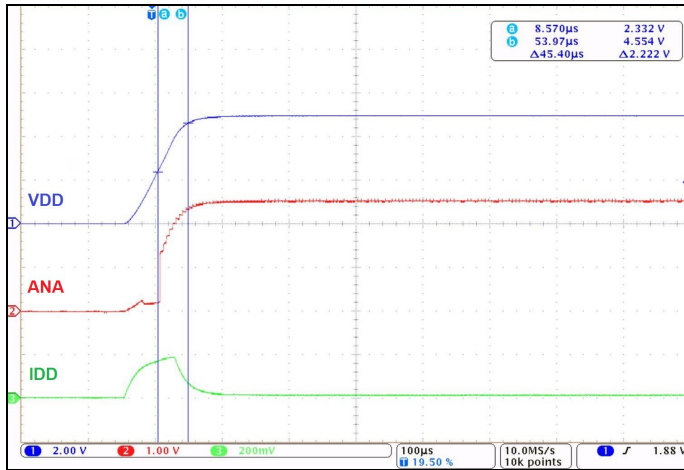


Figure 5. Power-On Time for CT220

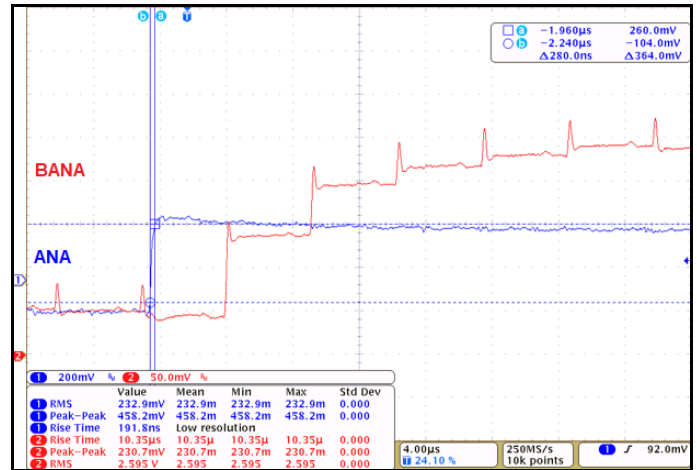


Figure 6. Rise Time for CT220

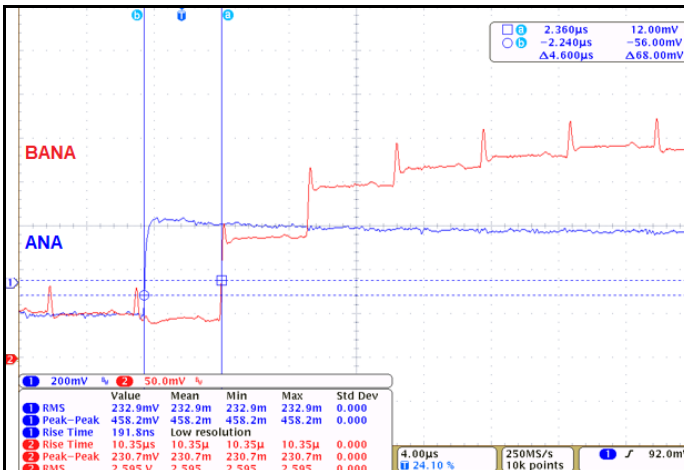


Figure 7. Propagation Delay Time for CT220

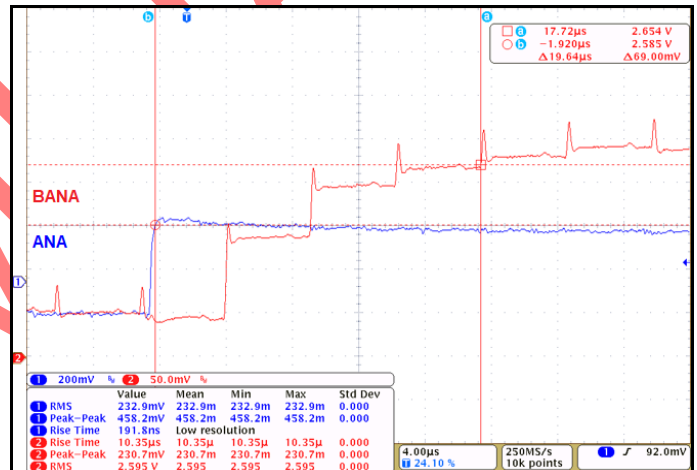


Figure 8. Response Time for CT220

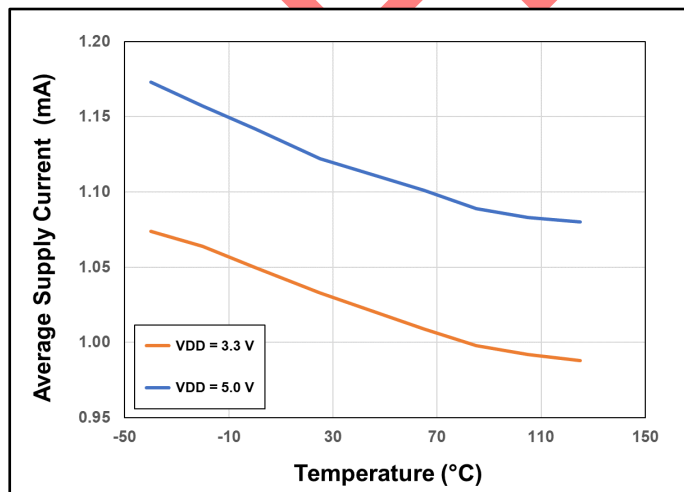


Figure 9. CT220 Average Supply Current vs. Temperature vs. Supply Voltage

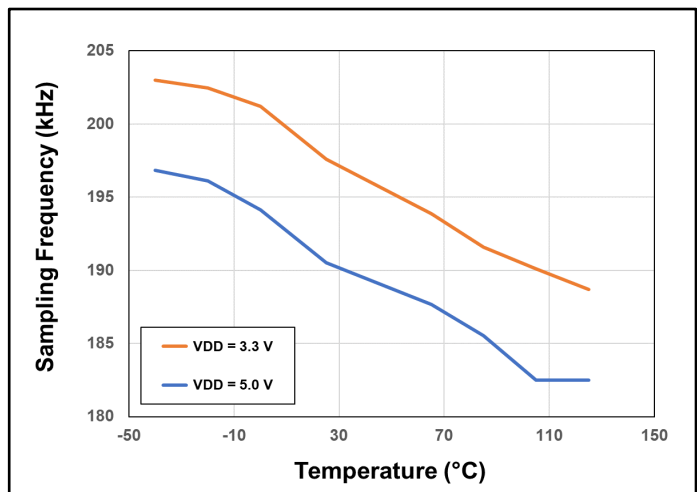


Figure 10. CT220 Sampling Frequency vs. Temperature vs. Supply Voltage

## Electrical Specifications

### CT220BMx ( $\pm 1.5$ mT)

Unless otherwise specified:  $V_{DD} = 2.7$  V to 5.5 V,  $C_{BYP} = 1.0$   $\mu$ F and  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are  $V_{DD} = 5.0$  V and  $T_A = +25^\circ\text{C}$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Analog Output						
G <sub>BP</sub>	Gain for Bipolar Magnetic Field			300		mV/V/mT
G <sub>UP</sub>	Gain for Unipolar Magnetic Field			-300		mV/V/mT
B <sub>ANA</sub>	Operating Magnetic Field		-1.5		+1.5	mT
Resolution						
RES	Resolution	I <sub>BUSBAR</sub> = ±3.5 A <sup>(1)</sup>		5.0		mA
Total Output Error Performance						
E <sub>TOT_BMC</sub>	Total Output Error for CT220BMC <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.0	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±2.0	
E <sub>TOT_BMV</sub>	Total Output Error for CT220BMV <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.5	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±4.0	
Total Output Error Components						
e <sub>LIN</sub>	Non-Linearity	B <sub>ANA</sub> = ±1.5 mT T <sub>A</sub> = -40°C to +125°C		±0.15		% FS
TCS <sub>BMC</sub>	Temperature Coefficient of Sensitivity for CT220BMC <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-70		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-150	-250	
TCS <sub>BMV</sub>	Temperature Coefficient of Sensitivity for CT220BMV <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-100		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-200	-400	
TCO	Temperature Coefficient of Offset Voltage <sup>(3)</sup>	T <sub>A</sub> = -40°C to +125°C, V <sub>DD</sub> = 5.0 V		100		ppm/°C
Noise						
e <sub>N</sub>	Input Referred Noise <sup>(1)</sup>	f <sub>BW</sub> = 1 Hz to 30 kHz, V <sub>DD</sub> = 5.0 V		3.5		μT <sub>RMS</sub>

(1) Measurement result from EVB222 (top trace on PCB), CT220 evaluation board.

(2) Reference the CT220 Calibration Guide on page 14.

(3) Guaranteed by design and characterization; not tested in production.

CT220FMx ( $\pm 5.0$  mT)

Unless otherwise specified:  $V_{DD} = 2.7$  V to 5.5 V,  $C_{BYP} = 1.0$   $\mu$ F and  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are  $V_{DD} = 5.0$  V and  $T_A = +25^\circ\text{C}$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Analog Output						
G <sub>BP</sub>	Gain for Bipolar Magnetic Field			90		mV/V/mT
G <sub>UP</sub>	Gain for Unipolar Magnetic Field			-90		mV/V/mT
B <sub>ANA</sub>	Operating Magnetic Field		-5		+5	mT
Resolution						
RES	Resolution	I <sub>TRACE</sub> = ±3.5 A <sup>(1)</sup>		5		mA
Total Output Error Performance						
E <sub>TOT_FMC</sub>	Total Output Error for CT220FMC <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.0	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±2.0	
E <sub>TOT_FMV</sub>	Total Output Error for CT220FMV <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.5	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±4.0	
Total Output Error Components						
e <sub>LIN</sub>	Non-Linearity	B <sub>ANA</sub> = ±5.0 mT T <sub>A</sub> = -40°C to +125°C		±0.15		% FS
TCS <sub>FMC</sub>	Temperature Coefficient of Sensitivity for CT220FMC <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-70		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-150	-250	
TCS <sub>FMV</sub>	Temperature Coefficient of Sensitivity for CT220FMV <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-100		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-200	-400	
TCO	Temperature Coefficient of Offset Voltage <sup>(3)</sup>	T <sub>A</sub> = -40°C to +125°C, V <sub>DD</sub> = 5.0 V		100		ppm/°C
Noise						
e <sub>N</sub>	Input Referred Noise <sup>(3)</sup>	f <sub>BW</sub> = 1 Hz to 30 kHz, V <sub>DD</sub> = 5.0 V		4.0		μT <sub>RMS</sub>

(1) Measurement result from EVB222 (top trace on PCB), CT220 evaluation board.

(2) Reference the CT220 Calibration Guide on page 14.

(3) Guaranteed by design and characterization; not tested in production.



**CT220PMx ( $\pm 10.0$  mT)**

Unless otherwise specified:  $V_{DD} = 2.7$  V to 5.5 V,  $C_{BYP} = 1.0$   $\mu$ F and  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are  $V_{DD} = 5.0$  V and  $T_A = +25^\circ\text{C}$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Analog Output						
G <sub>BP</sub>	Gain for Bipolar Magnetic Field			45		mV/V/mT
G <sub>UP</sub>	Gain for Unipolar Magnetic Field			-45		mV/V/mT
B <sub>ANA</sub>	Operating Magnetic Field		-10		+10	mT
Resolution						
RES	Resolution	I <sub>TRACE</sub> =TBD A <sup>(1)</sup>		TBD		mA
Total Output Error Performance						
E <sub>TOT_PMC</sub>	Total Output Error for CT220PMC <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.0	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±2.0	
E <sub>TOT_PMV</sub>	Total Output Error for CT220PMV <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.5	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±4.0	
Total Output Error Components						
e <sub>LIN</sub>	Non-Linearity	B <sub>ANA</sub> = ±10.0 mT T <sub>A</sub> = -40°C to +125°C		±0.20		% FS
TCS <sub>PMC</sub>	Temperature Coefficient of Sensitivity for CT220PMC <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-70		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-150	-250	
TCS <sub>PMV</sub>	Temperature Coefficient of Sensitivity for CT220PMV <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-100		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-200	-400	
TCO	Temperature Coefficient of Offset Voltage <sup>(3)</sup>	T <sub>A</sub> = -40°C to +125°C, V <sub>DD</sub> = 5.0 V		100		ppm/°C
Noise						
e <sub>N</sub>	Input Referred Noise <sup>(3)</sup>	f <sub>BW</sub> = 1 Hz to 30 kHz, V <sub>DD</sub> = 5.0 V		TBD		μT <sub>RMS</sub>

(1) Measurement result from EVB222 (top trace on PCB), CT220 evaluation board.

(2) Reference the CT220 Calibration Guide on page 14.

(3) Guaranteed by design and characterization; not tested in production.

**CT220RMx ( $\pm 15.0$  mT)**

Unless otherwise specified:  $V_{DD} = 2.7$  V to 5.5 V,  $C_{BYP} = 1.0$   $\mu$ F and  $T_A = -40^\circ\text{C}$  to  $+125^\circ\text{C}$ . Typical values are  $V_{DD} = 5.0$  V and  $T_A = +25^\circ\text{C}$ .

Symbol	Parameter	Conditions	Min.	Typ.	Max.	Unit
Analog Output						
G <sub>BP</sub>	Gain for Bipolar Magnetic Field			30.0		mV/V/mT
G <sub>UP</sub>	Gain for Unipolar Magnetic Field			-30.0		mV/V/mT
B <sub>ANA</sub>	Operating Magnetic Field		-15		+15	mT
Resolution						
RES	Resolution	I <sub>TRACE</sub> = TBD A <sup>(1)</sup>		TBD		mA
Total Output Error Performance						
E <sub>TOT_RMC</sub>	Total Output Error for CT220RMC <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.0	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±2.0	
E <sub>TOT_RMV</sub>	Total Output Error for CT220RMV <sup>(2)</sup>	T <sub>A</sub> = 0°C to +125°C		±0.5	±1.5	% FS
		T <sub>A</sub> = -40°C to +125°C		±0.5	±4.0	
Total Output Error Components						
e <sub>LIN</sub>	Non-Linearity	B <sub>ANA</sub> = ±15.0 mT T <sub>A</sub> = -40°C to +125°C		±0.30		% FS
TCS <sub>RMC</sub>	Temperature Coefficient of Sensitivity for CT220RMC <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-70		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-150	-250	
TCS <sub>RMV</sub>	Temperature Coefficient of Sensitivity for CT220RMV <sup>(3)</sup>	T <sub>A</sub> = 0°C to +125°C		-100		ppm/°C
		T <sub>A</sub> = -40°C to +125°C		-200	-400	
TCO	Temperature Coefficient of Offset Voltage <sup>(3)</sup>	T <sub>A</sub> = -40°C to +125°C, V <sub>DD</sub> = 5.0 V		100		ppm/°C
Noise						
e <sub>N</sub>	Input Referred Noise <sup>(3)</sup>	f <sub>BW</sub> = 1 Hz to 30 kHz, V <sub>DD</sub> = 5.0 V		TBD		μT <sub>RMS</sub>

(1) Measurement result from EVB222 (top trace on PCB), CT220 evaluation board.

(2) Reference the CT220 Calibration Guide on page 14.

(3) Guaranteed by design and characterization; not tested in production.

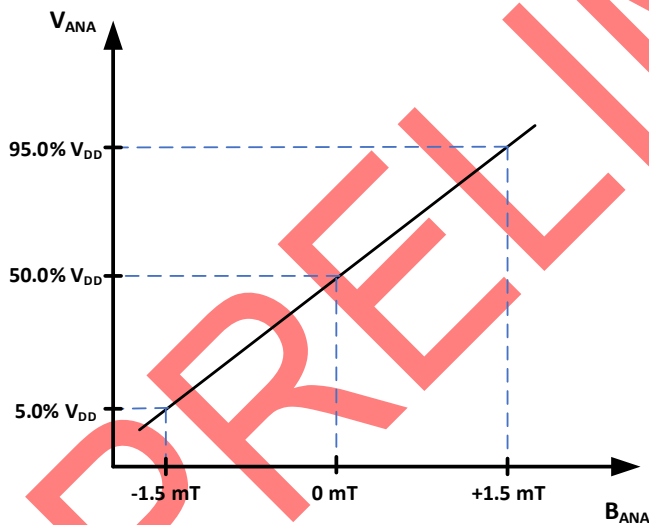
## Circuit Description

### Overview

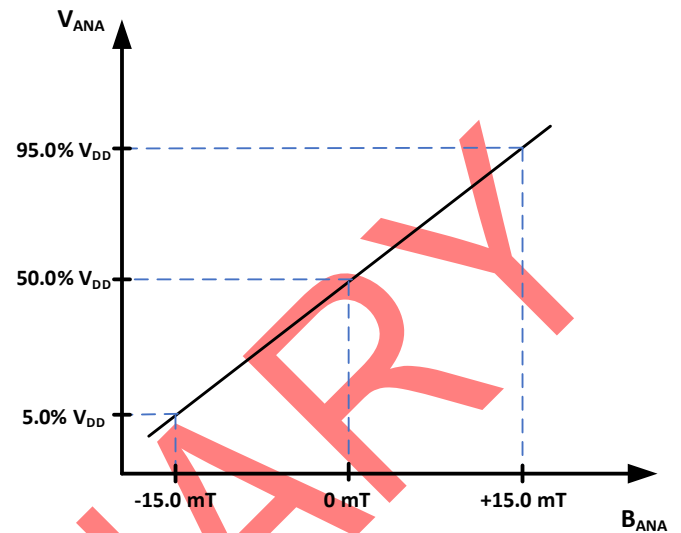
The CT220 is a high resolution and low noise contactless current sensor and a  $\overline{\text{FLAG}}$  output that operates from 2.7 V to 5.5 V assembled in a custom DFN package. The chip measures the magnetic field of the current through the package and converts it to an analog signal that is equivalent to the current flowing through the printed circuit board (PCB) trace. The  $\overline{\text{FLAG}}$  output indicates whether there is an over-current condition seen by CT220 during operation and will alert the host system.

### Analog Output Measurement

The CT220 provides a continuous (sample & hold) linear analog output voltage which represents the measured magnetic field of the current. The output voltage range of ANA is 5.0% of  $V_{DD}$  to 95.0% of  $V_{DD}$  which represents the operating magnetic field from the typical low-end values (-1.5 mT to -15.0 mT) to the maximum field values (+1.5 mT to +15.0 mT) respectively. The output sampling frequency is 200 kHz. A resistor-capacitor (R-C) filter may be implemented on the ANA pin to further lower the noise. Figure 11 illustrates the output voltage range of the ANA pin as a function of the measured field of  $\pm 1.5$  mT while Figure 12 shows the  $V_{ANA}$  vs. measured field of  $\pm 15.0$  mT.



**Figure 11. Linear Output Voltage Range vs. Measured Field for  $G = 300$  mV/V/mT and current range of  $\pm 1.5$  mT.**



**Figure 12. Linear Output Voltage Range vs. Measured Field for  $G = 30$  mV/V/mT and current range of  $\pm 15.0$  mT.**

### 90% & 10% Field (Current) Detection Flag

The Field Detection circuitry detects when the measured magnetic field is greater than 90% or less than 10% of the full field range. As a result, it translates to greater than 90% of the  $V_{DD}$  and 10% of the  $V_{DD}$  on the ANA pin. This will generate a flag signal via the  $\overline{\text{FLAG}}$  pin to the host system's microcontroller as an active LOW signal. Once the  $V_{ANA}$  falls below 86% or rises above 14% of the  $V_{DD}$  then the  $\overline{\text{FLAG}}$  signal will go HIGH.

### Rise Time ( $t_{RISE}$ )

The CT220's rise time,  $t_{RISE}$ , is the time interval of when it reaches 10% and 90% of the full-scale output voltage. The  $t_{RISE}$  of the CT220 is 15.5  $\mu$ s.

### Propagation Delay ( $t_{DELAY}$ )

The propagation delay,  $t_{DELAY}$ , is the time measured between the  $B_{ANA}$  reaches 20% of its final value and the CT220 attains 20% of its full-scale output voltage. It's propagation delay is 4.6  $\mu$ s.

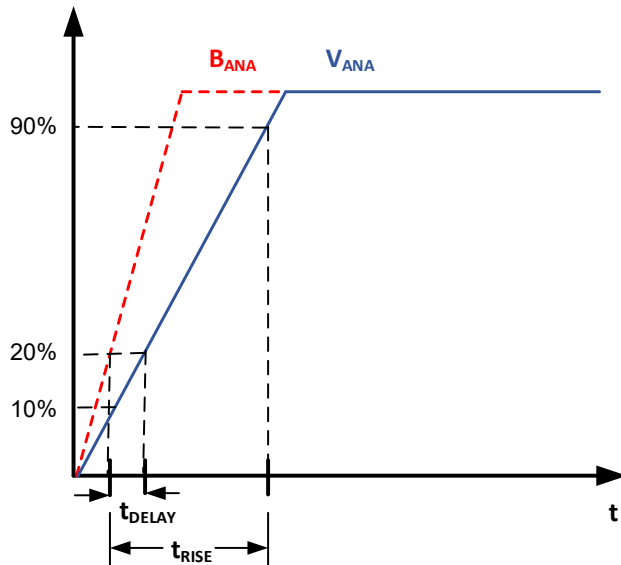


Figure 13. CT220 Propagation Delay and Rise Time Curve

### Response Time ( $t_{RESP}$ )

The response time,  $t_{RESP}$ , is the difference in time from when the  $B_{ANA}$  reaches 90% of its final value and  $V_{ANA}$  attains 90% of its final value. The CT220's response time is typically 20.0  $\mu s$ .

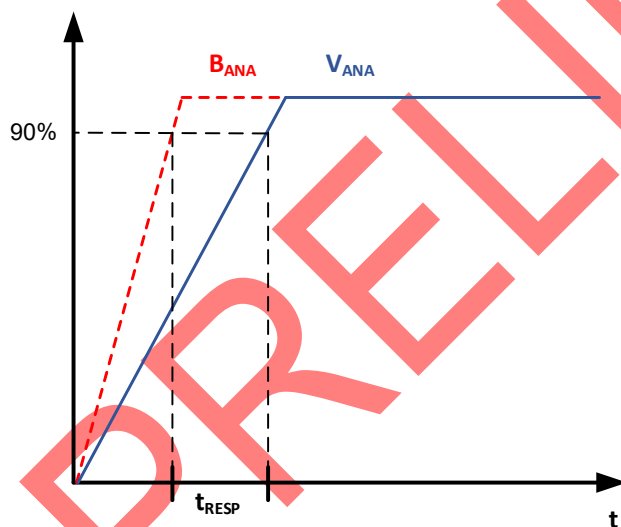


Figure 14. CT220 Response Time Curve

### Power-On Time ( $t_{ON}$ )

The Power-On Time ( $t_{ON}$ ) of 50  $\mu s$  is the amount of time required by the CT220 to start up, power-on and acquire the first sample. The chip is fully powered up and operational from the moment the supply voltage passes

the rising UVLO point (2.3 V). This time includes the ramp up time and the settling time (within 10% of steady-state voltage when current is flowing through the package) after the power supply have reach the minimum  $V_{DD}$ .

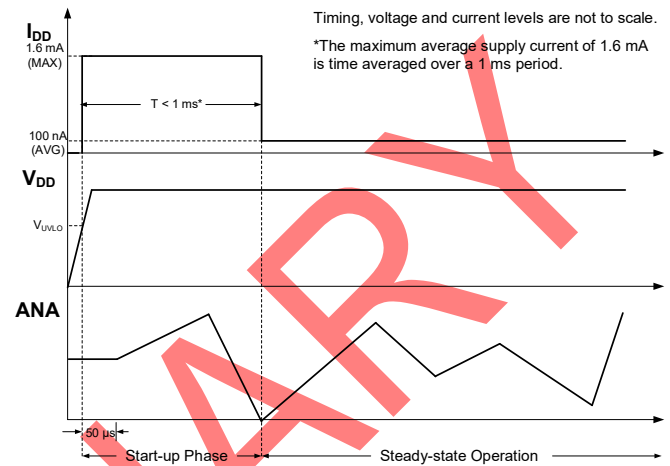


Figure 15. CT220 Power-On Timing Diagram

### Under-Voltage Lockout (UVLO)

The Under-Voltage Lock-out protection circuitry of the CT220 is activated when the supply voltage ( $V_{DD}$ ) falls below 2.1 V. The CT220 remains in a low quiescent state and the ANA output is not valid until  $V_{DD}$  rises above the UVLO threshold (2.3 V).

### Low Resolution and Low Noise

For the unipolar field (DC current), the resolution is TBD  $\mu T$  (5 mA) while the input referred noise in TBD  $\mu T_{RMS}$  (7  $mA_{RMS}$ ) however there is no contradiction in the CT220's capability to sense this level of current because the 5 mA was measured with a digital multi-meter (DMM) with limited bandwidth whereas the noise is over a wider bandwidth (up to 30 kHz).

## CT220 Calibration Guide

### Introduction

All current sensors, no matter how expensive they are, or what materials they use, or even if they were factory calibrated, are susceptible to deviations from their Ideal Transfer Line.

To extract the absolute best performance from any current sensing system, calibration is required.

### Ideal Transfer Line

Ideally, the sensor output follows a straight line, has a fixed slope, and crosses a fix offset point. This allows the user to apply a straightforward linear equation to extract the “physical” value being measured. In the case of a current sensor:

$$\text{Current} = \frac{\text{Voltage} - b}{a}$$

where a: slope and b: offset of the ideal curve. In a perfect sensor, both a and b coefficients can be simply looked up on the datasheet.

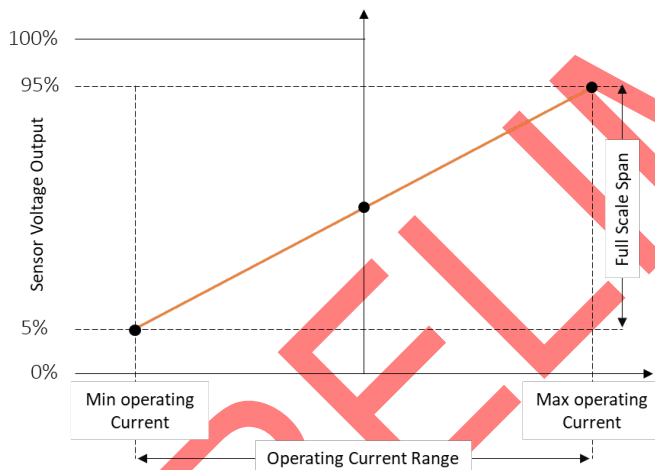


Figure 16. Ideal Transfer Line

Any deviation from this Ideal Line are considered sensor errors. More specifically Accuracy Errors as they related in the case of Crocus Technology's sensors to Gain and Offset errors.

### Offset Error

Based on the Ideal Transfer Line, when no current is applied, the voltage output of the sensor should be equal to 50% of  $V_{DD}$ . On the datasheet, the user can find the spread (i.e. min-max) values of offsets of Crocus Technology's products.

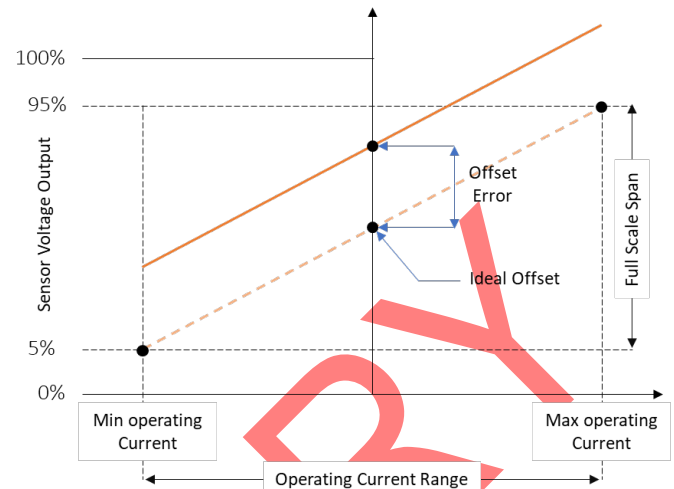


Figure 17. Exaggerated Offset Error

### Gain Error

The Ideal Transfer Line shows a line that reaches 95% of  $V_{DD}$  at the maximum operating current and 5% of  $V_{DD}$  at the minimum. The datasheet also shows the spread of the gain found on the sensors.

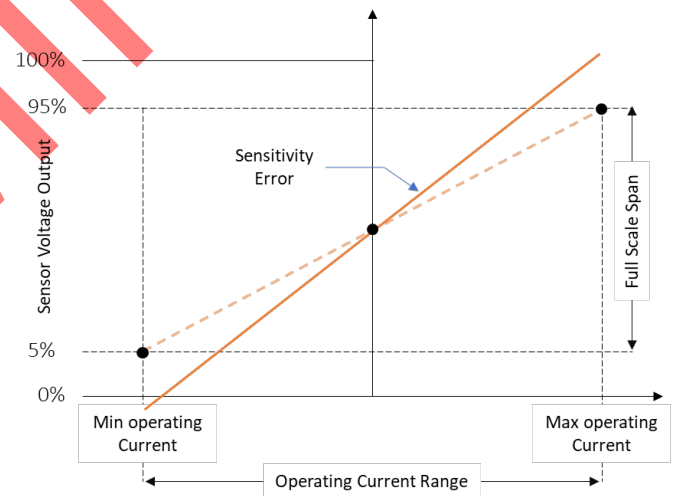


Figure 18. Exaggerated Gain Error

### Calibration

Different methods can be applied for offset and/or gain correction. The complexity of these methods lead to different calibration results. The higher the complexity the better the error correction is.

### Simple Offset Correction

Offset calibration is achieved simply by storing the voltage output of the sensor at zero flowing current.

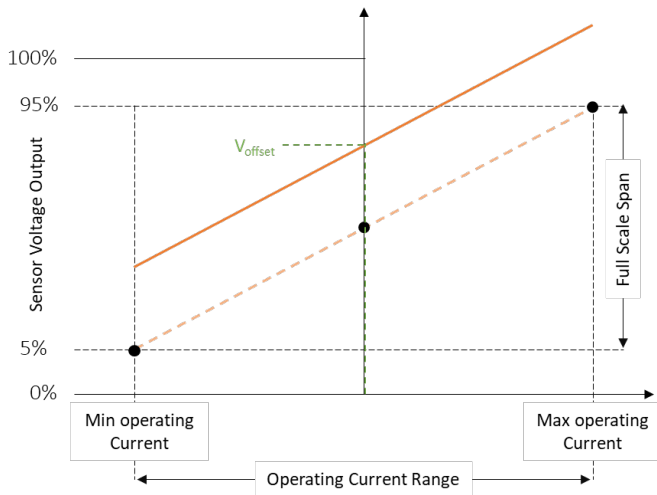


Figure 19. Simple Offset Calibration

This stored value  $V_{OFFSET}$  becomes the coefficient “b” in the linear transfer function:

$$Current = \frac{Voltage - b}{a}$$

### Simple Gain Correction

Basic Gain calibration can be achieved by applying a known current value ( $A_1$ ) and measure the sensor output voltage value ( $V_1$ )

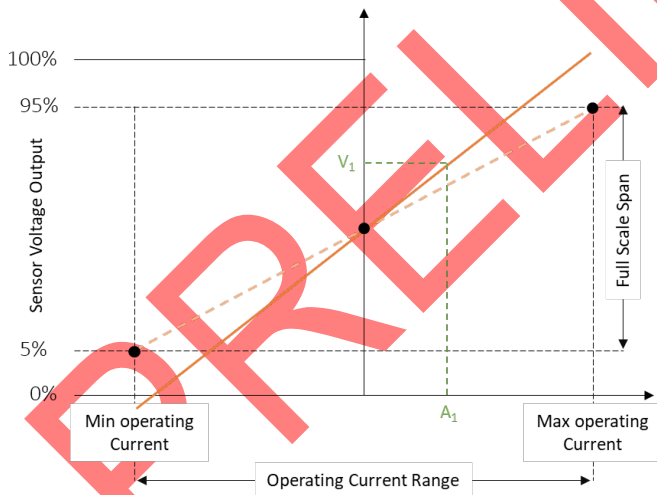


Figure 20. Simple Gain Calibration

The following equation is used to calculate the slope coefficient “a”:

$$a = \frac{V_1 - V_{OFFSET}}{A_1}$$

### Recommended Offset and Gain Correction

For bi-directional current applications, the steps below are recommended for users trying to perform the best error correction of gain and offset.

1. Apply a known current value ( $A_1$ ) and measure voltage output ( $V_1$ )
2. Apply a “second current value” ( $A_2$ ) and measure the voltage output ( $V_2$ )
3. Calculate the slope using the following equation

It is recommended that the applied currents  $A_1$  and  $A_2$  are the absolute maximum and minimum operating current the sensor will see during its normal operations.

Also,  $A_1 = -A_2$  for bi-directional current sensing.

$$a = \frac{V_1 - V_2}{A_1 - A_2} \quad b = \frac{V_1 + V_2}{2}$$

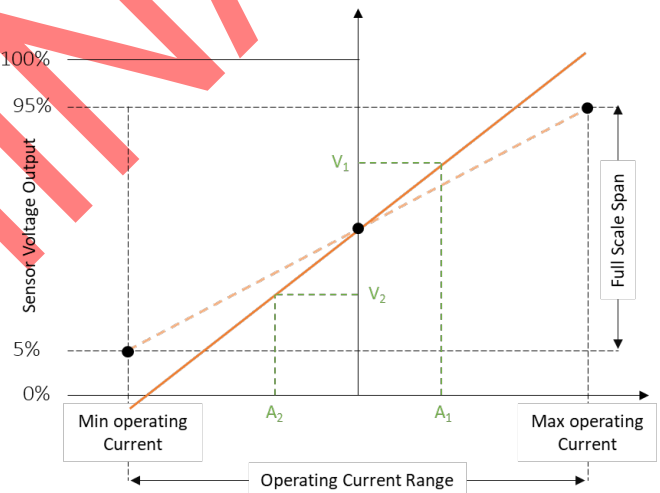


Figure 21. Gain Calibration

Both calculated coefficients “a” and “b” are then used to calculate the current:

$$Current = \frac{Voltage - b}{a}$$

## Applications Information – Overview

The CT220 is an ideal solution to measure current non-intrusively as it provides highly accurate current values by measuring the magnetic field that is generated by the flow of current through a PCB trace or busbar. Because this implementation is contactless, the isolation is infinite so there is no need to use isolation amplifiers. The CT220 only needs a 1.0  $\mu\text{F}$  bypass capacitor connected to the VDD pin. A resistor-capacitor filter on the ANA pin is recommended to minimize the output noise as shown in Figure 22. Please refer to Table 2 for recommended cut-off frequencies.

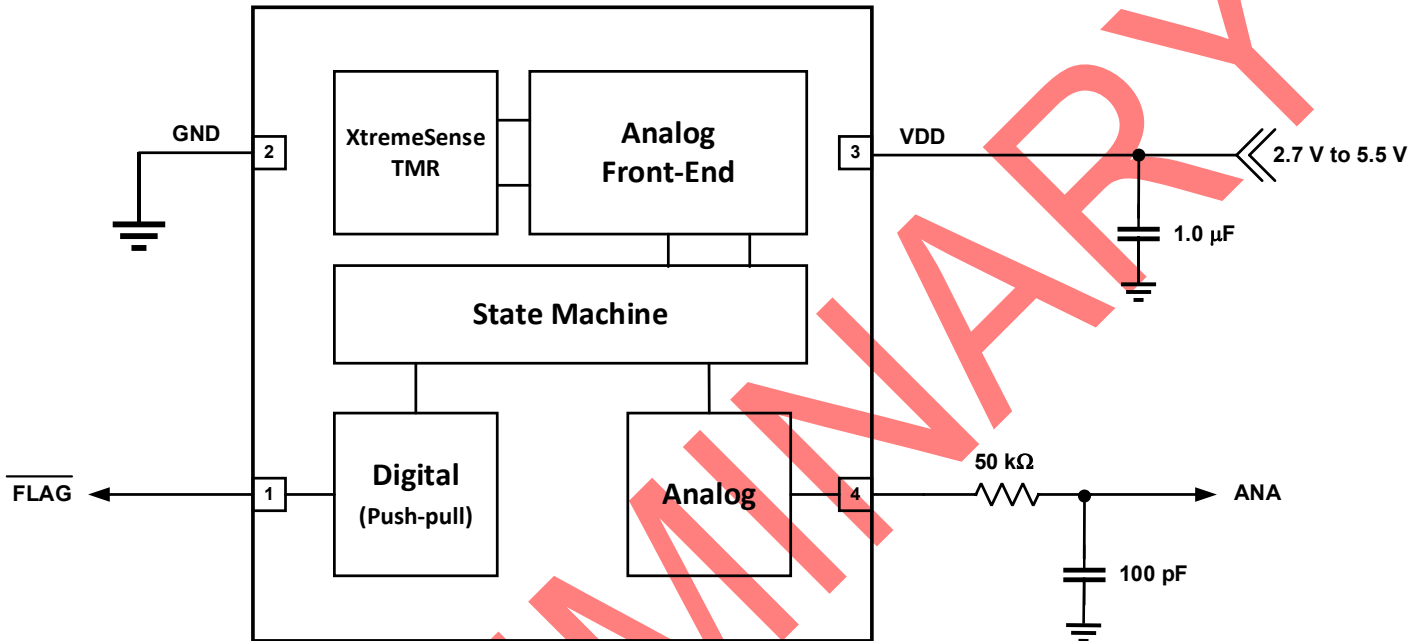


Figure 22. CT220 with Analog and  $\overline{\text{FLAG}}$  Outputs Application Block Diagram

Table 1. Recommended External Components for CT220

Component	Description	Vendor & Part Number	Parameter	Min.	Typ.	Max.	Unit
$C_{\text{BYP}}$	1.0 $\mu\text{F}$ , X5R or Better	Murata GRM155C81A105KA12	C		1.0		$\mu\text{F}$
$R_{\text{FILTER}}$	50 k $\Omega$ , $\pm 5\%$	Various	R		50		k $\Omega$
$C_{\text{FILTER}}$	100 pF, X5R or Better	Various	C		100		pF

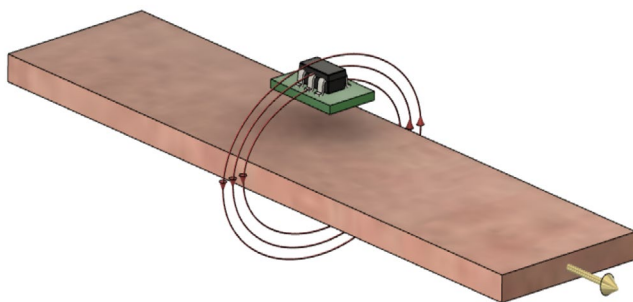
Table 2. Recommended Cut-off Frequencies for CT220 and its Resistor-Capacitor Values

Cut-off Frequency (kHz)	Resistor Value (k $\Omega$ )	Capacitor Value (pF)
1	105	1,500
10	105	150
30	50	100

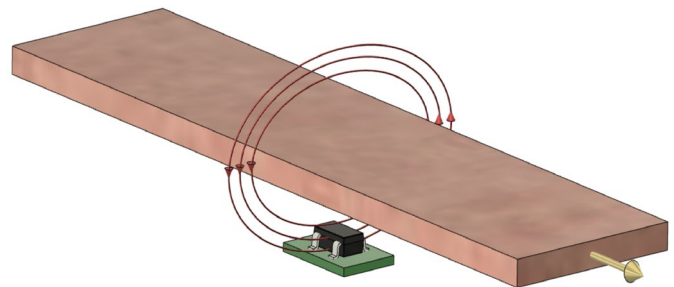
## Applications Information – DC Current Measurement

The CT220 must be placed in the correct orientation on the PCB to measure DC current in either a PCB trace or a busbar above or beneath the device. The axis of sensitivity of the CT220 for unipolar magnetic fields, i.e. DC current is along the vertical direction of the surface of the package pointing towards pin 1, see Figure 4 for reference.

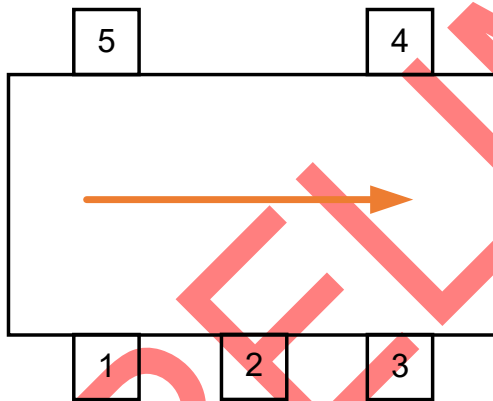
For DC measurements of either a top or bottom PCB trace and a busbar below the CT220, the flow of DC current is from left to right as shown in Figure 23. This direction is derived using Ampere's right-hand rule where the thumb represents the direction of the current and the curl of the fingers is the direction of the magnetic field. In the case of an application using a busbar that is placed above the CT220 the current flows right to left, see Figure 24.



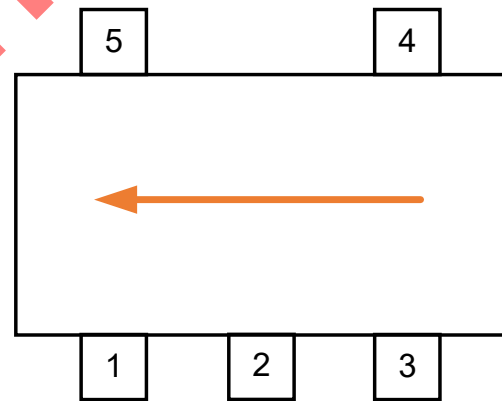
(a)



(a)



(b)



(b)

**Figure 23.** CT220 measuring DC current in a busbar below it where (a) indicates the DC current and magnetic field directions; and (b) is the direction of DC current flow that the CT220 must be oriented.

**Figure 24.** Measuring DC current of a busbar placed above the CT220 where (a) shows the direction of the DC current and magnetic field; and (b) is the direction of DC current flow with respect to the CT220 package.



## Applications Information

The x, y dimensions of CT220's XtremeSense TMR sensor location in a 5-lead SOT23 are shown in Figure 25 while Figure 26 illustrates the z dimension. All dimensions in the figures below are nominal and in millimeters (mm).

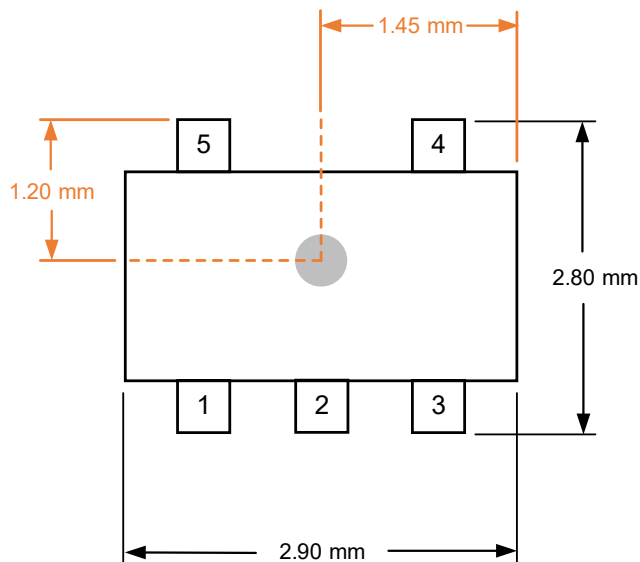


Figure 25. XtremeSense TMR Sensor Location in x-y Plane for CT220 in SOT23-5 Package

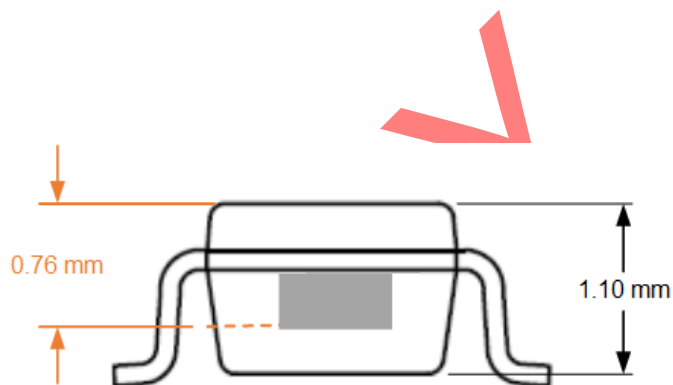


Figure 26. XtremeSense TMR Sensor Location in z Dimension for CT220 in SOT23-5 Package

## SOT23-5 Package Drawing and Dimensions

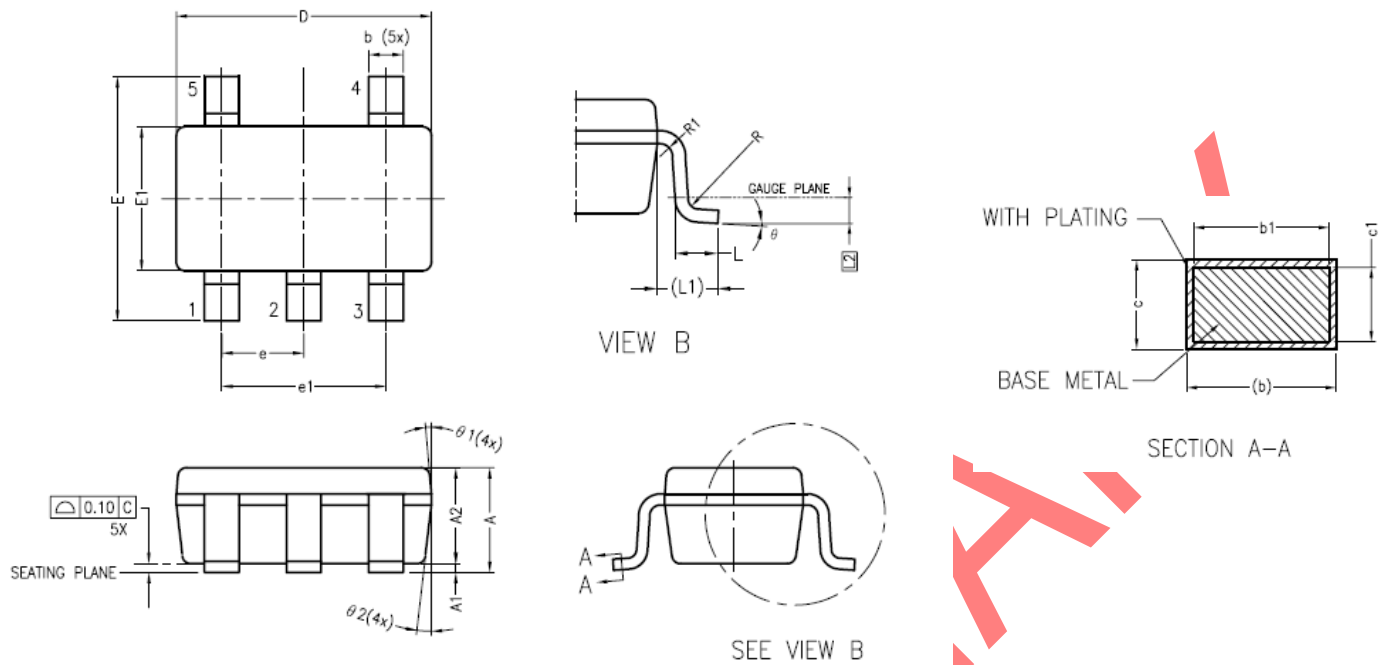


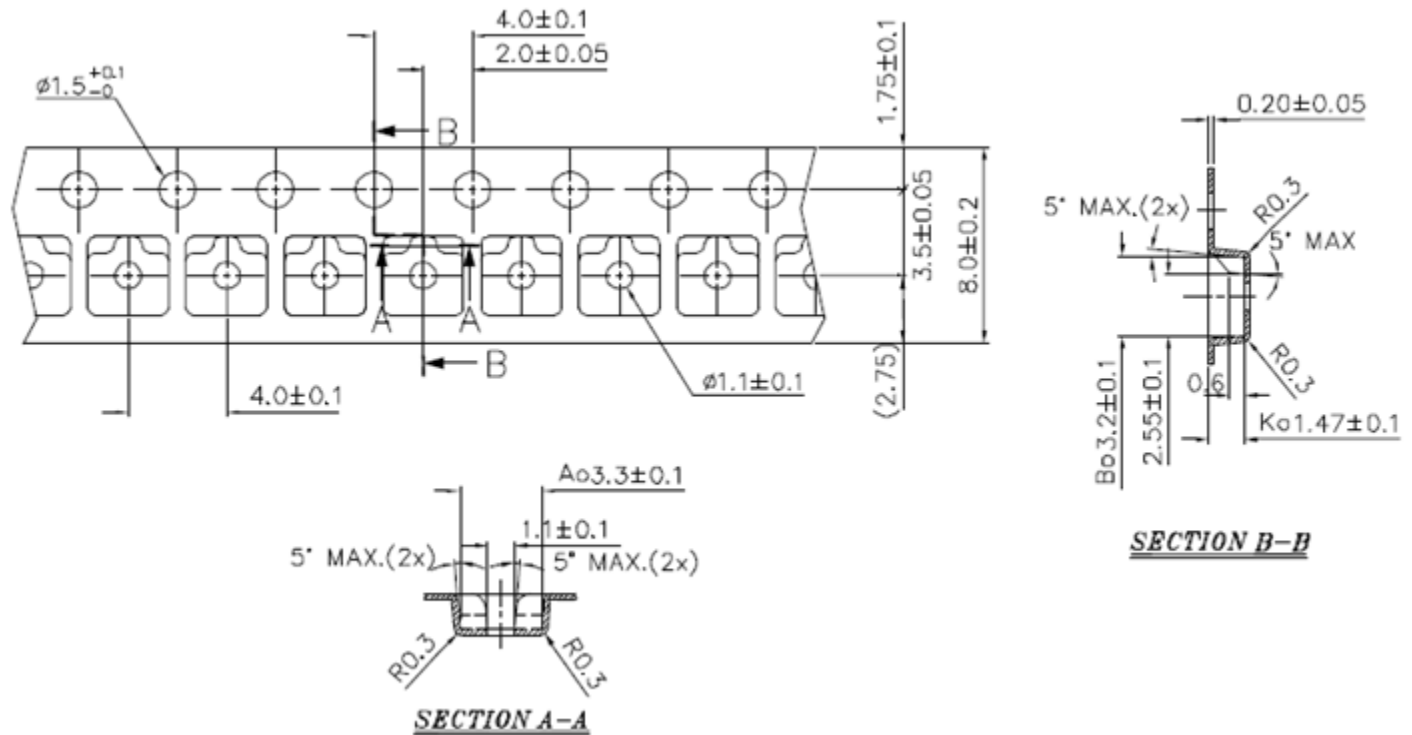
Figure 27. 5-Lead SOT23 Package Drawing

Table 3. CT220 5-Lead SOT23 Package Dimensions

Symbol	Dimensions in Millimeters (mm)		
	Min.	Typ.	Max.
A	1.05	1.20	1.35
A1	0.00	0.10	0.15
A2	1.00	1.10	1.20
b	0.40	-	0.50
b1	0.40	0.40	0.45
c	0.08	-	0.22
c1	0.08	0.13	0.20
D	2.80	2.90	3.00
E	2.60	2.80	3.00
E1	1.50	1.60	1.70
e	0.95 BSC		
e1	1.90 BSC		
L	0.35	0.43	0.60
L1	0.60 REF		
L2	0.25 BSC		
R	0.10	-	-
R1	0.10	-	0.25
theta	0°	4°	8°
theta1	5°	6°	15°
theta2	5°	8°	15°

Crocus Technology provides package drawings as a service to customers considering or planning to use Crocus products in their designs. Drawings may change without notice. Please note the revision and date of the data sheet and contact a Crocus Technology representative to verify or obtain the most recent version. The package specifications do not expand the terms of Crocus Technology's worldwide terms and conditions, specifically the warranty therein, which covers Crocus Technology's products.

## SOT23 Tape &amp; Pocket Drawing and Dimensions



## NOTES:

1. Material: Conductive Polystyrene
2. Dimensions in mm.
3. 10 sprocket hole pitch cumulative tolerance  $\pm 0.20$  mm.
4. Camber bot to exceed 1 mm in 100 mm.
5. Pocket position relative to sprocket hole measured as true position of pocket and not pocket hole.
6. (S.R.  $\Omega/\text{sq}$ ) means surface electric resistivity of the carrier tape.

Figure 28. Tape and Pocket Drawing for SOT23 Package

## Package Information

Table 4. CT220 Package Information

Part Number	Package Type	# of Leads	Package Quantity	Lead Finish	Eco Plan <sup>(1)</sup>	MSL Rating <sup>(2)</sup>	Operating Temperature <sup>(3)</sup>	Device Marking
CT220BMC-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220BMC-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220BMV-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220BMV-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220FMC-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220FMC-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220FMV-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220FMV-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220PMC-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220PMC-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220PMV-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220PMV-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220RMC-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220RMC-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD
CT220RMV-IS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +85°C	TBD
CT220RMV-HS5	SOT23	5	3,000	Sn	Green & RoHS	1	-40°C to +125°C	TBD

(1) RoHS is defined as semiconductor products that are compliant to the current EU RoHS requirements. It also will meet the requirement that RoHS substances do not exceed 0.1% by weight in homogeneous materials. Green is defined as the content of Chlorine (Cl), Bromine (Br) and Antimony Trioxide based flame retardants satisfy JS709B low halogen requirements of  $\leq 1,000$  ppm.

(2) MSL Rating = Moisture Sensitivity Level Rating as defined by JEDEC standard classifications.

(3) Package will withstand ambient temperature range of -40°C to +150°C and storage temperature range of -65°C to +160°C.

(4) Device Marking for SOT23 is defined as XZ YWWS where XZ = part number and Y = Year, WW = work week and S = sequential number.

## Ordering Information

Part Number	Operating Temperature Range	Magnetic Field Range	Package	Packing Method
CT220BMC-IS5	-40°C to +85°C	±1.5 mT (±15 G)	5-lead SOT23 2.90 x 2.80 x 1.24 mm	Tape & Reel
CT220BMC-HS5	-40°C to +125°C			
CT220BMV-IS5	-40°C to +85°C			
CT220BMV-HS5	-40°C to +125°C			
CT220FMC-IS5	-40°C to +85°C	±5.0 mT (±50 G)	5-lead SOT23 2.90 x 2.80 x 1.24 mm	Tape & Reel
CT220FMC-HS5	-40°C to +125°C			
CT220FMV-IS5	-40°C to +85°C			
CT220FMV-HS5	-40°C to +125°C			
CT220PMC-IS5	-40°C to +85°C	±10.0 mT (±100 G)	5-lead SOT23 2.90 x 2.80 x 1.24 mm	Tape & Reel
CT220PMC-HS5	-40°C to +125°C			
CT220PMV-IS5	-40°C to +85°C			
CT220PMV-HS5	-40°C to +125°C			
CT220RMC-IS5	-40°C to +85°C	±15.0 mT (±150 G)	5-lead SOT23 2.90 x 2.80 x 1.24 mm	Tape & Reel
CT220RMC-HS5	-40°C to +125°C			
CT220RMV-IS5	-40°C to +85°C			
CT220RMV-HS5	-40°C to +125°C			

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## Product Status Definition

Data Sheet Identification	Product Status	Definition
Objective	Proposed New Product Idea or In Development	Data sheet contains design target specifications and are subject to change without notice at any time.
Preliminary	First Production	Data sheet contains preliminary specifications obtained by measurements of early samples. Follow-on data will be published at a later date as more test data is acquired. Crocus reserves the right to make changes to the data sheet at any time.
None	Full Production	Data sheet contains final specifications for all parameters. Crocus reserves the right to make changes to the data sheet at any time.
Obsolete	Not in Production	Data sheet for a product that is no longer in production at Crocus. It is for reference only.