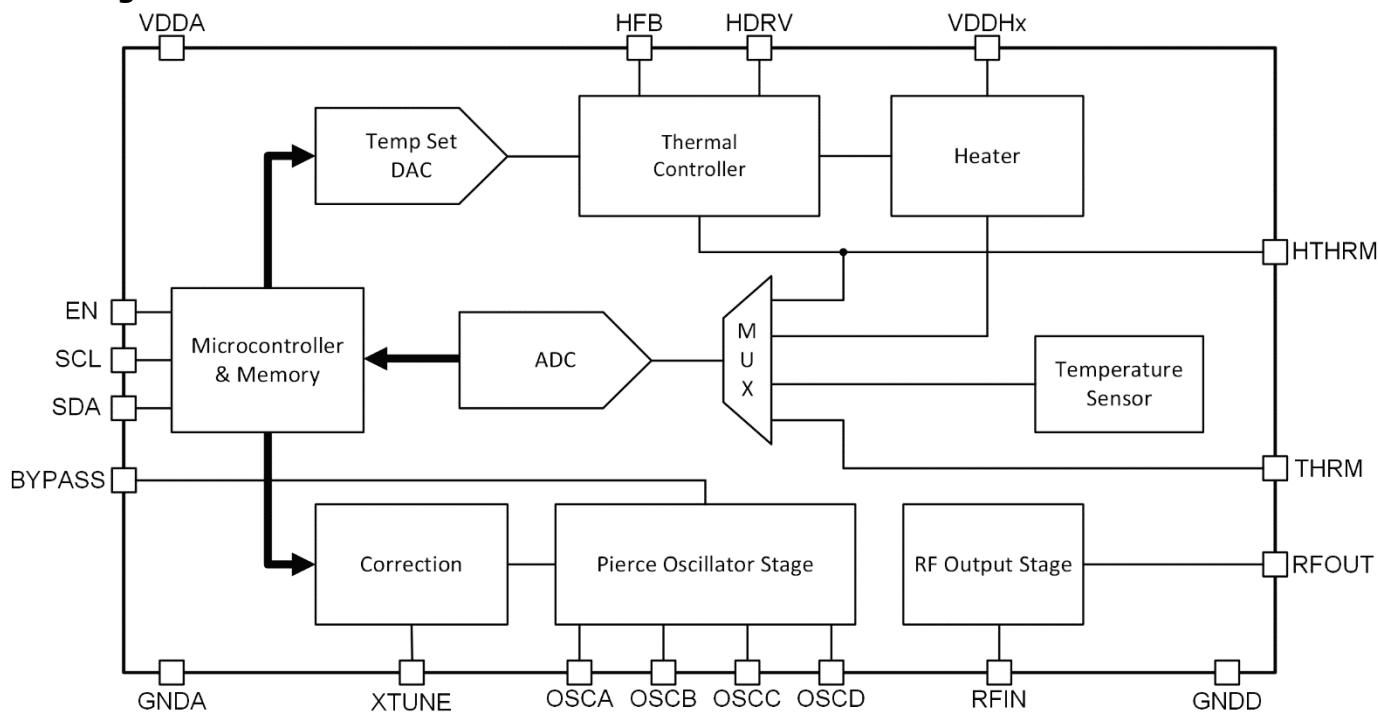


OCXO Thermal Management IC

Description

The TM200 is a fully integrated programmable thermal management unit that monitors, controls, and corrects analog circuitry across a wide temperature range. The TM200 is primarily intended for OCXO applications and includes a temperature sensor, internal Pierce oscillator & output stage, thermal controller, internal heater and data converters combined with a microcontroller (MCU) and memory structures. The TM200 controls and regulates the temperature environment of small enclosures by executing temperature stability and correction programs. The Pierce oscillator and output stage are designed to be flexible with a variety of oscillator and crystal configurations. The TM200 includes many programmable functionality options, and its software package makes it easy to configure and implement various crystal correction algorithms. It communicates via an I²C interface and is available in a 3mm x 3mm package or as die.

Block Diagram



Features

- Low phase noise oscillator
- Low Allan deviation for high stability clocks
- High accuracy temperature sensor
- Controls internal (1W) or external heaters

Applications

- OCXO Modules
- Thermal Protection & Management
- Environmental Control Systems
- Precision Measurement

Ordering Information

Order Number	Package	Quantity	RoHS	MSL Rating	Leadframe
TM200-T1	20L STSLP QFN	122	Yes	1	NiPdAu
TM200-R1	20L STSLP QFN	1000	Yes	1	NiPdAu
TM200-X	Die	Upon Request	n/a	n/a	n/a

SPECIFICATIONS

Environmental Specifications

Table 1 Recommended Operating Conditions

Parameter	Conditions	Min	Typ	Max	Unit
Supply Voltage	VDDA ± 5%	3.135	3.3	3.465	V
Operating Temperature		-40		125	°C
OTP Programming Temperature		0		50	°C

Internal Temperature Sensor Specifications

Table 2 Temperature Sensor Specifications

Parameter	Conditions	Min	Typ	Max	Unit
Absolute Accuracy		-0.25		0.25	°C
Voltage Range	-40C to 125C	1.32		2.5	V
Resolution	ADC LSB		0.11		°C
Linearity	-40C to 125C		0.6		%
	70C to 125C		0.2		

Thermal Controller Specifications

Table 3 Thermal Controller Specifications

Parameter	Conditions	Min	Typ	Max	Unit
Internal Heater Current	-40C	160		267	mA
	100C	160		221	
	125C	160		211	
Continuous Internal Heater Power	3.3V Supply (VDDHx)			0.5775	W
Thermal Controller Output Drive Range	Internal Heater	0		Vdd - 0.1	V
	External Heater	0		Vdd - 0.1	
Thermal Controller Drive Current	External Heater	7	8.1		mA
Thermal Controller Feedback Range	Internal Heater	0	0.653	0.782	V
	External Heater	0	1.5		
Current Limiting DAC Reference			2.9		V
Current Limiting DAC Resolution			7		bits
Current Limiting DAC Codes			128		steps
Current Limiting DAC LSB			22.7		mV
Temp Set Point Range	Internal resistor network	70		110	°C
	External resistor network	-20		110	
Temp Set Point Resolution	12-bit resolution			0.04	°C

Oscillator Specifications

Table 4 Oscillator Specifications

Description	Conditions	Min	Typ	Max	Unit
Input Frequency	Internal CA/CB capacitors only	5 ¹		155	MHz
CA Range	Adjustable	2		52	pF
CB Range	Adjustable	2		62	pF
RD Range	Adjustable	25		1000	Ω
RF Range	Adjustable	1.6k		100k	Ω
Duty Cycle	Adjustable	45	50	55	%

¹ Using external capacitors allows for operation below 5MHz

Output Specifications

Table 5 Output Stage Specifications

Parameter	Conditions	Min	Typ	Max	Unit
Maximum Output Frequency	15pF load		200		MHz
	50pF load		100		
Rise/Fall Time (10%-90%) of VDDA	8mA drive - 15pF Load		2.0		ns
	8mA drive - 50pF Load		4.8		
	4mA drive - 15pF Load		3.7		
	4mA drive - 50pF Load		9.1		

PIN CONFIGURATION AND FUNCTION

Table 6 TM200 Pinout

Pin	Name	I/O/P	Description
1	OSCD	I/O	Crystal drive when internal Varicap is used.
2	OSCC	I/O	Crystal drive when internal Varicap is bypassed and not used.
3	VDDH1	P	3.3V Internal Heater supply. The current on this pin can be up to 175mA.
4	BYPASS	I/O	Internal oscillator power supply. Will require either 22uF/0.01uF bypass capacitors or 1nF compensation capacitor depending on configuration.
5	GNDD	P	Digital ground
6	SCL	I/O	Tuning (EFC) & I ² C interface input clock. An external pullup resistor to VDDA of 10kΩ is needed during I ² C communications. The pin contains an internal pull-down resistor of 110 kΩ. 5V tolerant.
7	SDA	I/O	Open drain serial data input/output for the I ² C interface. An external pullup resistor to VDDA of 10kΩ is needed during I ² C communications. The pin contains a high value internal pull-down resistor. 5V tolerant.
8	N/C	n/a	Not connected
9	THRM	I	External NTC thermistor input. Use this input to use an external thermistor as an alternative crystal measurement method than the internal IC temperature sensor.
10	XTUNE	I/O	External Tuning Voltage. The pin is driven by the output of the Correction DAC and/or the EFC input. It typically controls the voltage on a varactor. It is not connected when the Correction block is configured to drive the internal Varicap.
11	EN	I/O	Enable signal. The polarity and default state is programmable through the internal processor. 5V tolerant.
12	HTHRM	I/O	Thermal Controller thermistor terminal. This pin is used to connect an NTC thermistor required to close the feedback loop of the Thermal Controller.
13	VDDH2	P	3.3V Internal Heater supply. The current on this pin can be up to 175mA.
14	RFOUT	O	RF Output. The RFOUT pin provides a CMOS output signal with properties defined in the output stage section.
15	RFIN	I	RF Input. RFIN is the input receiver connection from the oscillator stage output. It is usually driven via a capacitor from OSCB.
16	HDRV	O	External Heater Drive. This is used only when external heaters are being implemented and needs to be configured to drive either NMOS or NPN heater transistors and can drive up to 9mA
17	HFB	I	External Heater Feedback. Voltage signal connected to the load resistors of the external heaters that provides feedback to the thermal controller.
18	VDDA	P	3.3V Analog positive supply. The current on this pin can be up to 20mA.
19	OSCB	I/O	Pierce inverter state output. This signal is usually fed to RFIN via a series capacitance to provide a drive to the output stages.
20	OSCA	I/O	Pierce inverter stage input from crystal.
21	GNDA	P	Analog ground

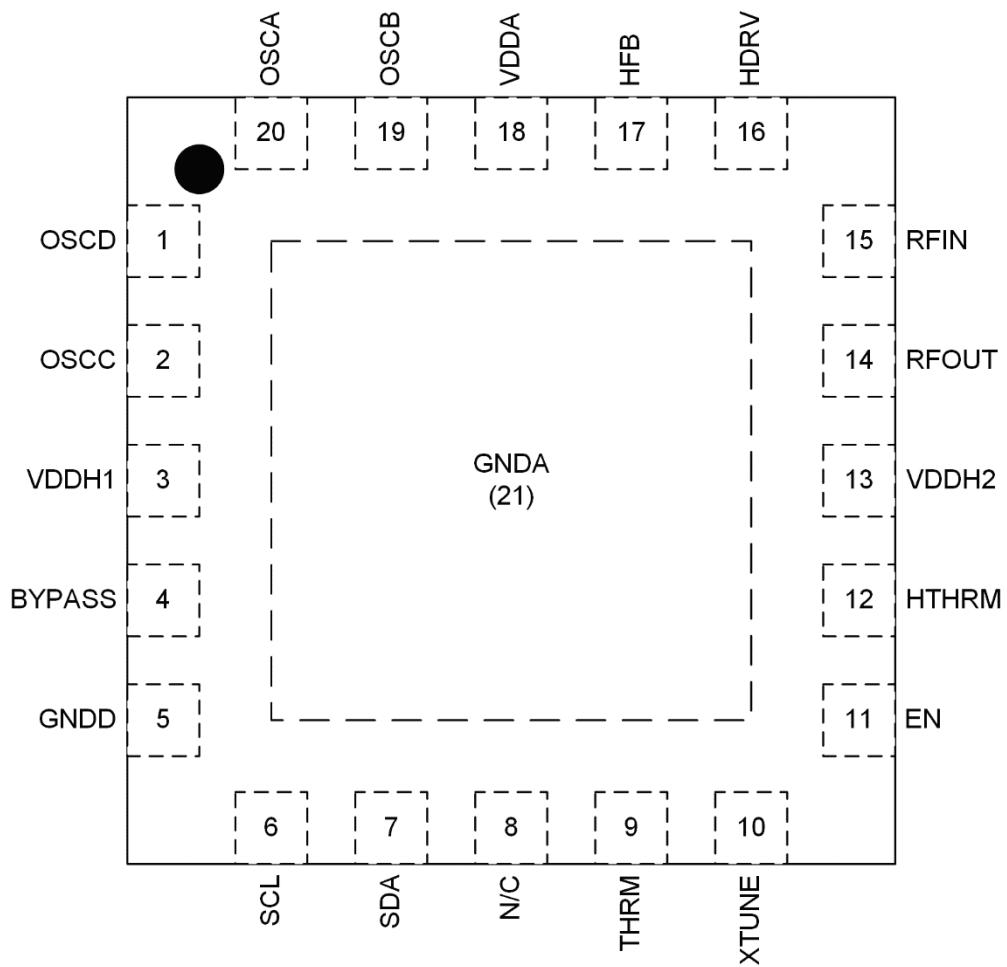


Figure 1 TM200 Package Pinout

BLOCK DESCRIPTION & FUNCTIONALITY

Oscillator Stage

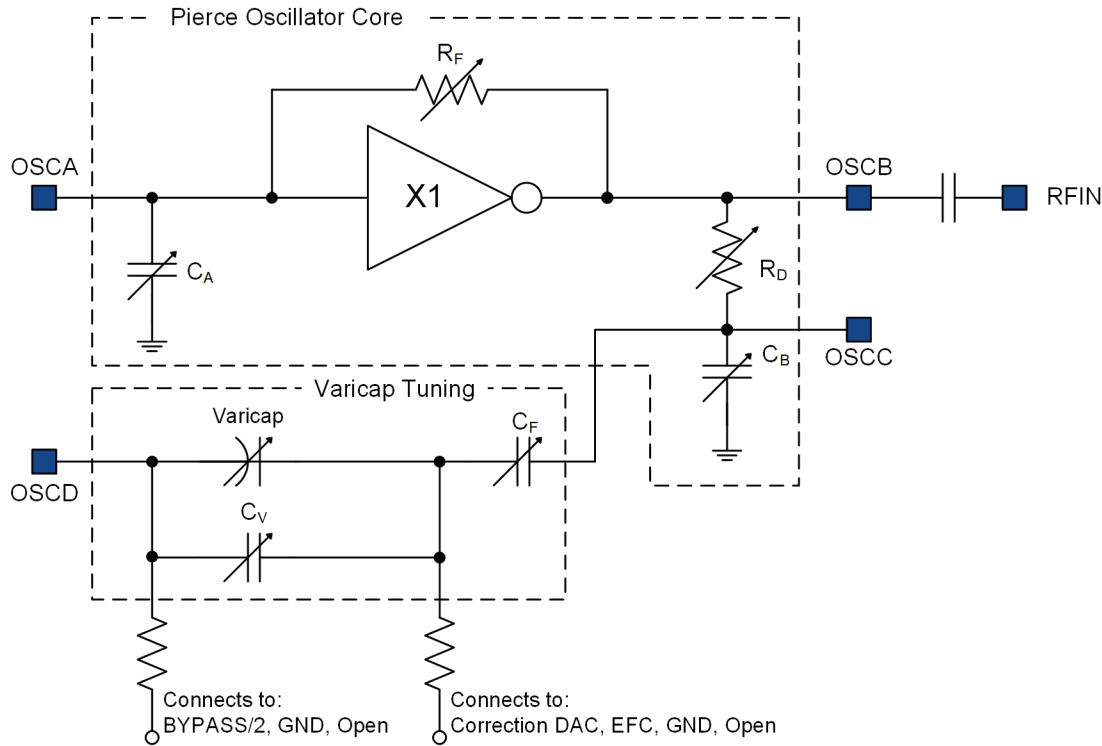


Figure 2 Oscillator Stage Architecture

Pierce Oscillator Core

The oscillator uses a Pierce architecture, designed to be compatible with fundamental or overtone AT cut crystals and overtone SC cut crystals up to 156MHz. It includes an embedded inverter with adjustable resistors and capacitors. The gain stage (X1) is an optimized P/N FET inverter pair. The values for C_A , C_B , C_F , C_V , R_F , and R_D are set using the control registers and are easily configured with the TMx00 Control Software. The oscillator stage is powered through the BYPASS pin and can be shorted to the VDDA pin of the IC or decoupled from VDDA by configuring an internally 2.9V regulator to drive the BYPASS pin. See the Application Notes more information.

Most oscillator applications can be met with the internal component value selections, thereby reducing the amount external components needed to construct an oscillator. Alternatively, the R_F and R_D select logic allows disabling the internal resistors for use with external components. C_A and C_B capacitors can be fully disabled especially for applications with matching and trap networks in series with overtone crystals. When the C_A and C_B capacitors are disabled, the minimum capacitance is ~2pF.

Oscillator Connections

OSCA is the Pierce inverter input, typically connected to one side of the crystal. OSCB is the Pierce inverter output used to feed an output stage. OSCA and OSCD are the crystal connections for applications that use the internal Varicap. A blocking cap is necessary between OSCC or OSCD and the crystal to prevent DC bias across the crystal. For applications that use an external varactor, the other side of the crystal is connected to OSCC and OSCD is left open.

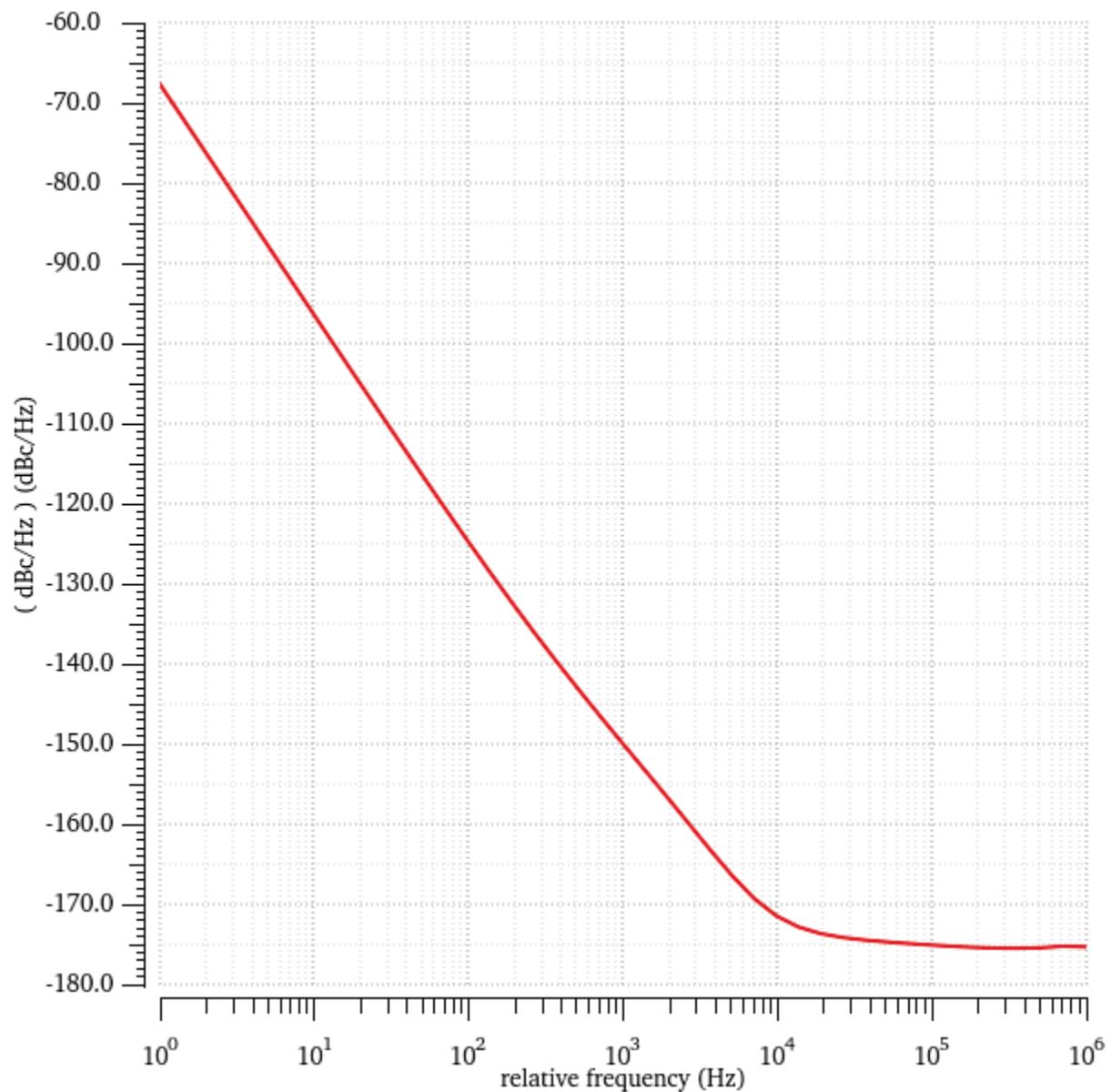


Figure 3 20MHz Fundamental, AT-Cut, Internal Varicap Phase Noise

Thermal Controller

The Thermal Controller is used to control the thermal characteristics of an enclosed module or section of an assembly. It was specifically designed to implement an *oven-controlled crystal oscillator (OCXO)* with low Allan deviation but can be used to construct other thermal application designs. For an OCXO design, the thermally controlled section encloses the crystal resonator in a temperature-controlled region.

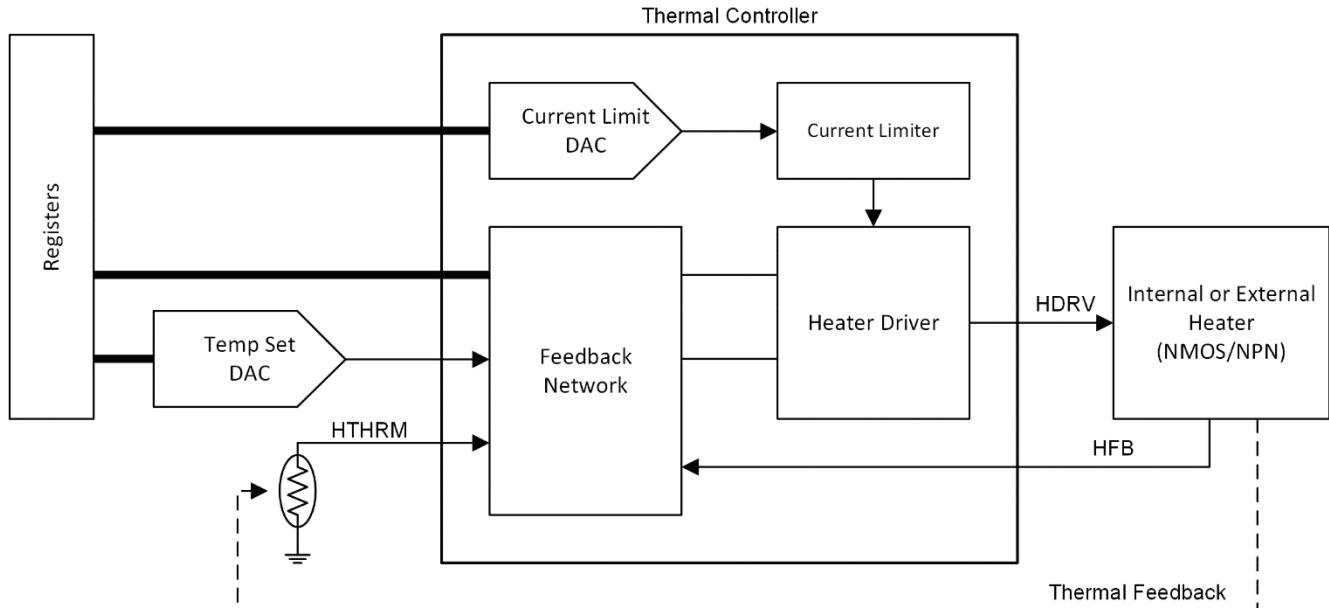


Figure 4 Thermal Controller Architecture

The Thermal Controller uses a driver to control a heater circuit that dissipates heat and causes the cavity temperature to rise. When it is initially turned on, the controller produces more heat until the cavity temperature stabilizes. During this warmup period, the Current Limit DAC & Limiter limits the maximum supply current. After the warmup period, proportional control allows the cavity to remain at the desired temperature via an external thermistor. Heater power provides a data input into the feedback network to adjust and stabilize the cavity temperature. The Temp Set DAC allows for fine grained temperature control managed by the TM200 MCU.

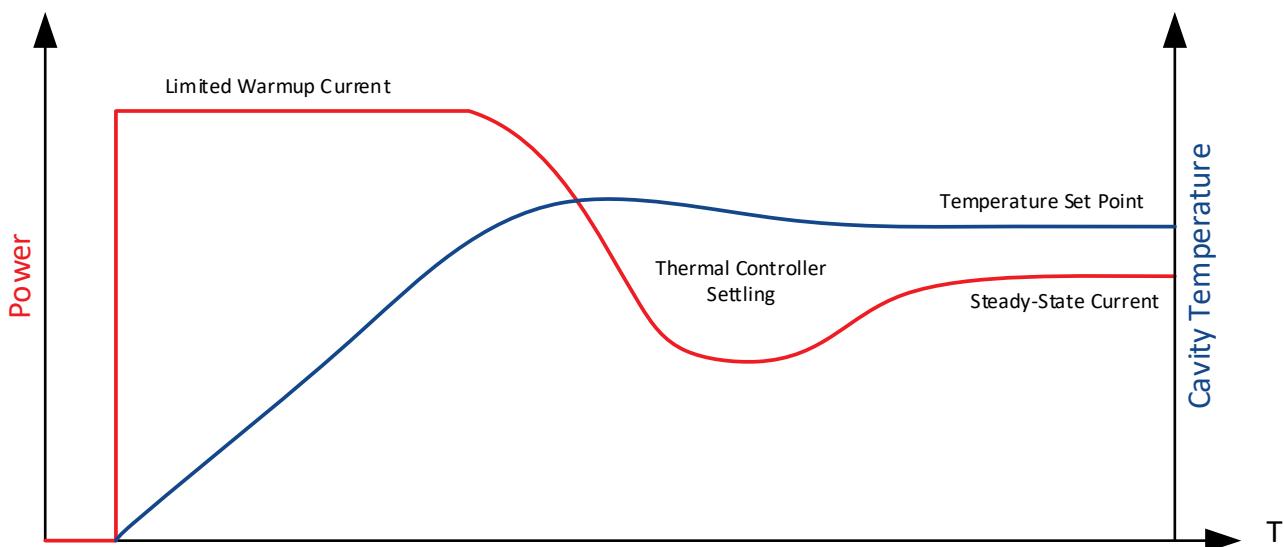


Figure 5 Thermal Controller Current & Cavity Temperature

Correction System

The correction system is designed to correct the frequency shifts of a crystal across temperature with either the TM200's internal Varicap or an external varactor. Using the ADC to convert temperature sensor data, the MCU provides the input code to a 12-bit DAC with an output voltage that adjusts the internal Varicap or external varactor to corrects crystal frequency variation across a defined temperature range. For OCXO applications, the range will likely be limited around the turnover point of the crystal since the module is designed to have the cavity operate at a constant temperature.

The correction system uses either the internal Varicap or an external varactor to provide the appropriate crystal pull. The internal Varicap is suitable for low-cost designs that require minimal components. For higher performance requirements, an external varactor may be used and controlled with the XTUNE pin. Please refer to the Design Examples for more information.

The internal Varicap or XTUNE pin can also be controlled from the dual use SCL (EFC) pin via an analog connection. Alternately the EFC and MUX pins can be used as an input to the ADC. The digitized value is processed in the MCU via correction algorithms and fed out via the correction DAC to control the Varicap or external varactor.

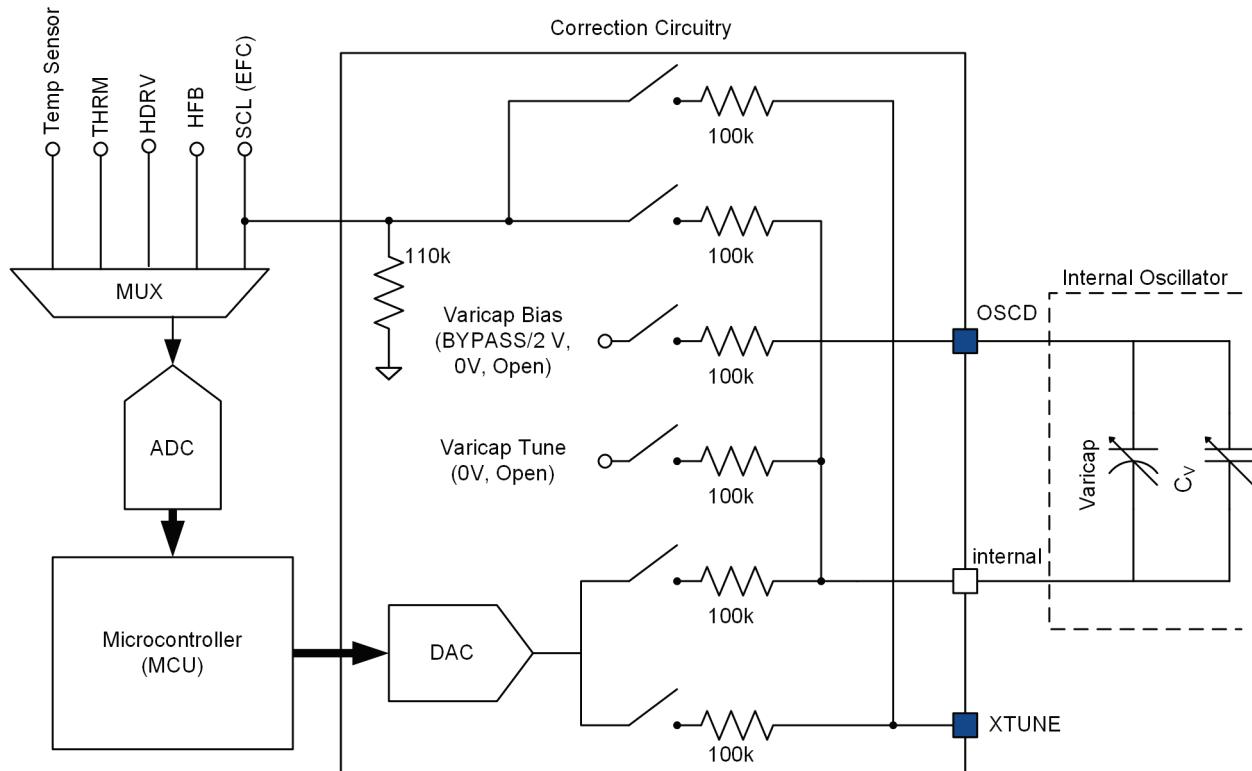


Figure 6 Correction System Diagram

OCXO TEMPERATURE CORRECTION ALGORITHM OVERVIEW

The TM200 supports three correction algorithms to compensate for temperature and voltage non-idealities:

1. **Lookup Table** – Temperature correction algorithm
2. **Temperature Polynomial Curve Fit** – Temperature correction algorithm
3. **Supply Voltage Curve Fit** – Voltage correction algorithm

The TMx00 correction algorithms use integer numbers (digital codes) that represent temperatures and voltages to make compensation adjustments. The ADC converts analog signals into the digital domain for the MCU to calculate the appropriate Correction DAC input code and produce an analog correction voltage.

The first two algorithms use a *Temp Code* input to generate a *CorrDAC Code* from the Correction DAC output to correct frequency variations over temperature. Only one of the temperature correction algorithms may be used during operation.

The *Temp Code* value is an integer with the range of 0 to 4095 and corresponds to the temperature being measured and digitized through the ADC. A -40C to 90C temperature range will utilize a *Temp Code* range of approximately 2000 to 3200. The *Temp Code* is produced from either the IC internal temperature sensor or an external thermistor (via the THRM pin).

The *CorrDAC Code* value is an integer with the range of 0 to 4095 and corresponds to the DAC input code needed to vary the capacitance across an external varactor or the internal TMx00 Varicap to correct the frequency variation for a given temperature.

The *CorrDAC Voltage* is resulting Correction DAC output voltage for a given *CorrDAC Code*. It is calculated by multiplying the Correction DAC's reference voltage by the ratio of the *CorrDAC Code* to the Correction DAC's full-scale code (4095).

$$\text{CorrDAC Voltage} = \frac{\text{CorrDAC Code}}{4095} * \text{BYPASS Pin Voltage}$$

As a brief relationship example, a measured temperature of 25C may produce a *Temp Code* of 2541 and results in a *CorrDAC Code* of 1983 and a *CorrDAC Voltage* of 1.4043V for the correct center frequency of a unique OCXO assembly.

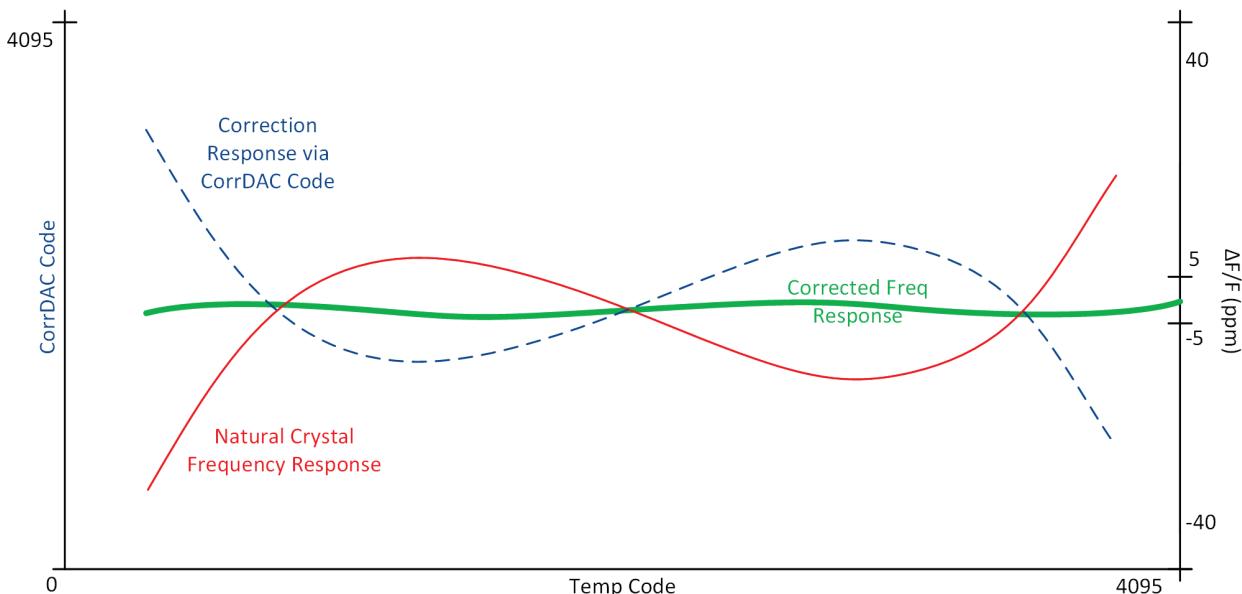
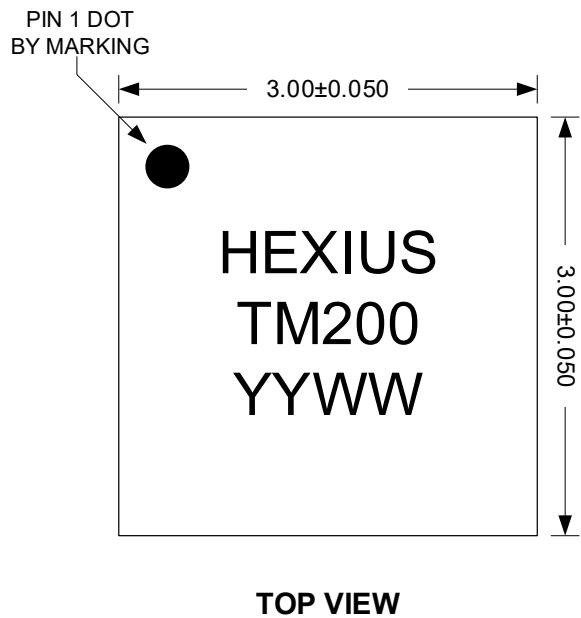
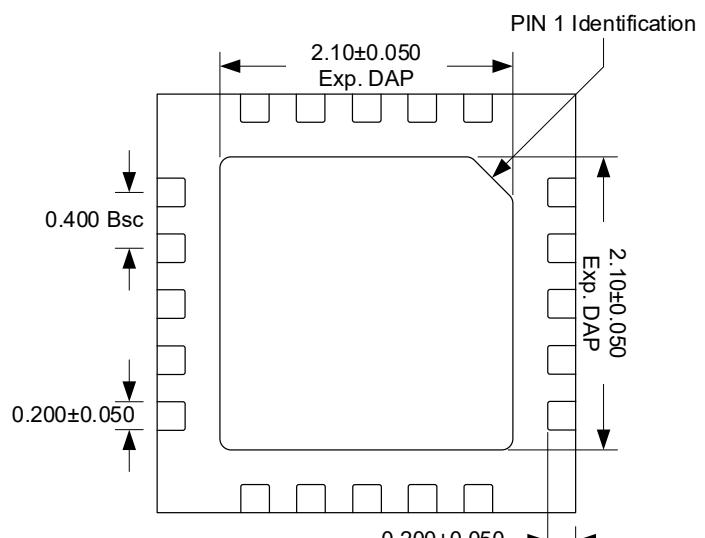


Figure 7 Temp Code and CorrDac Code Relationship

PACKAGE OUTLINE

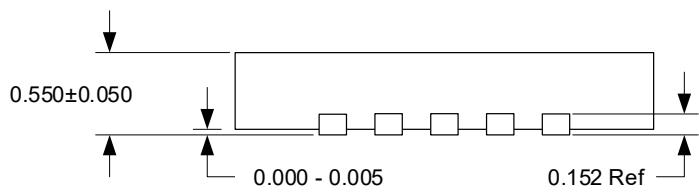


TOP VIEW



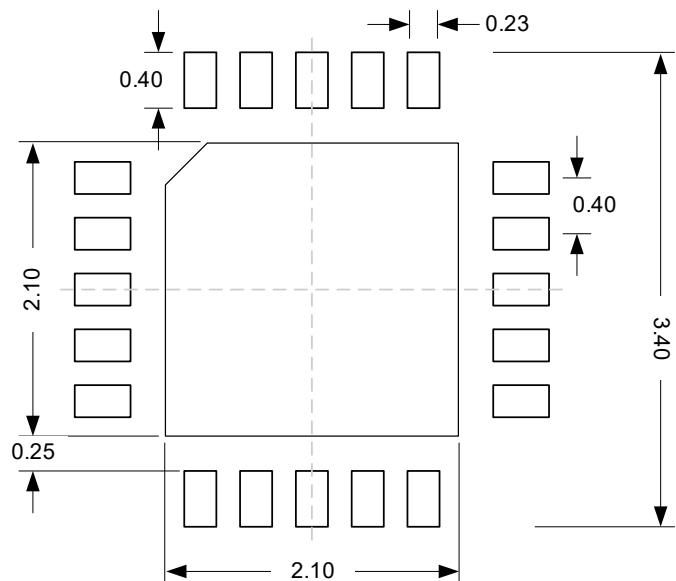
BOTTOM VIEW

All units are in millimeters



SIDE VIEW

PCB LAND PATTERN/FOOTPRINT





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