

Advanced Materials & Solutions Overview 2023 Temperature Sensors

Strategic Supplier Presentation



CTS History

As technology has continued to move forward, we've been right alongside, engineering intelligent ways to meet people's ever-changing needs.

1896

In 1896, the enterprising father and son team of A.J. and George A. Briggs partnered with S.A. Buffington, a Chicago Lawyer, to establish Chicago Telephone Supply Company, later to become CTS.



1942

During WWII, the U.S. Army needed a link to the frontline troops. Chicago Telephone Supply Company integrated telephone and radio component technologies to develop the RM-29 remote telephone field set.

1963

A demand in the electronics industry called for the miniaturization of electronic products. CTS responded by manufacturing hybrid microcircuits.

1999

In 1999, CTS acquired Motorola's Component Division (CPD) and a late 1990's merger with Dynamics Corporation of America (DCA) bolstered CTS' position as a leading producer of electronic components.



2021

2021 marks CTS Corporation's 125th anniversary with a renewed commitment to carrying our guiding principles into the future: Play to Win, Responsiveness, Simplicity and Solution Oriented.



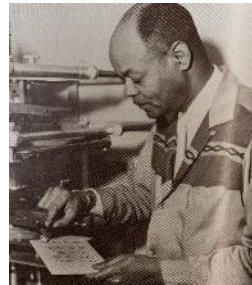
1922

The beginning of radio broadcasting in the 1920s triggered a boom for consumer radio receivers. During this time, the company evolved from a manufacturer of finished products to a manufacturer of components.



1958

In 1958, after 4 years of intensive research, CTS engineers introduced Cermet, a new type of stable resistance element. The stability of Cermet fulfilled the demand of miniaturized applications for the computer, as well as military industries.



1971

As CTS transitioned into the 1970s, concerns over environmental pollution led to US Government mandated automotive emissions control requirements. The need for throttle position sensing and exhaust gas recirculation controls immersed CTS into new market opportunities.

2007 - 2012

During the late 2000's and early 2010's CTS completed a series of acquisitions to expand into key markets and drive growth including Alpha ceramics, Tusonix inc., Valpy Fisher, and D&R Technology.

2023

CTS published their first sustainability report, reaffirming the commitment to making a difference in employees, stakeholders, and the communities CTS operates in

CTS is a Leading Designer and Manufacturer of Custom Engineered Solutions that Sense, Connect, and Move - Enabling an Intelligent and Seamless World

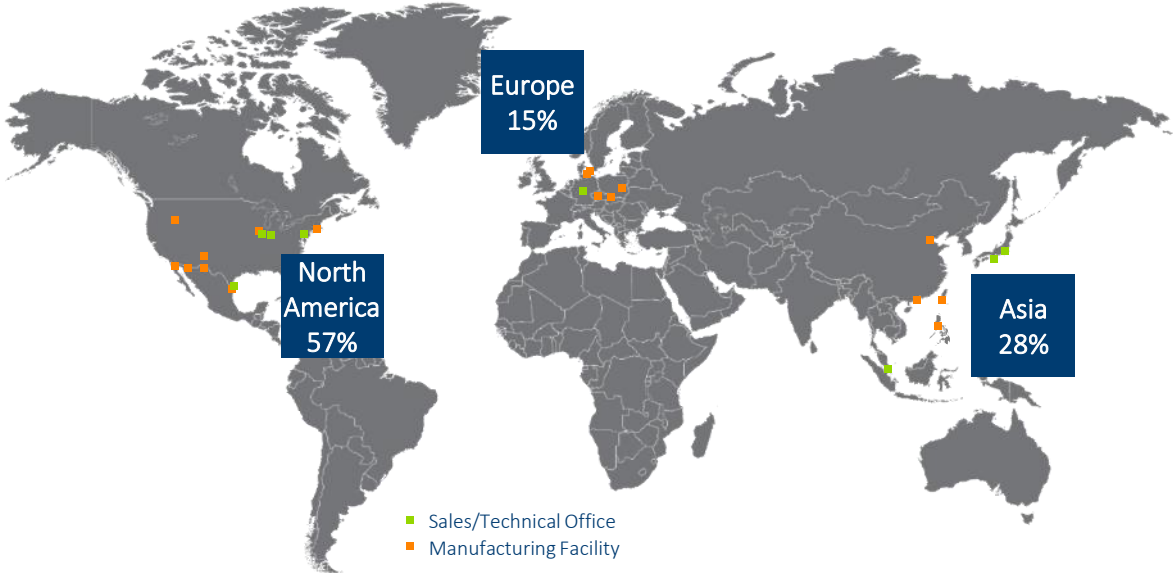
LTM Revenue
\$587
 Million ¹

LTM Adj. EPS
\$2.46

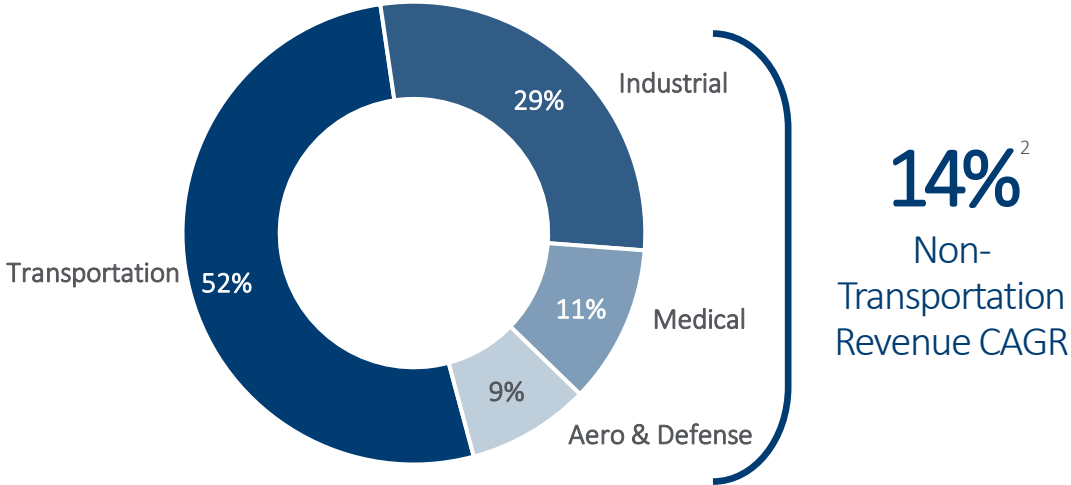
LTM Adj. EBITDA
23%

Non-Transportation
48%
 Of LTM Revenue

Global design and manufacturing capabilities



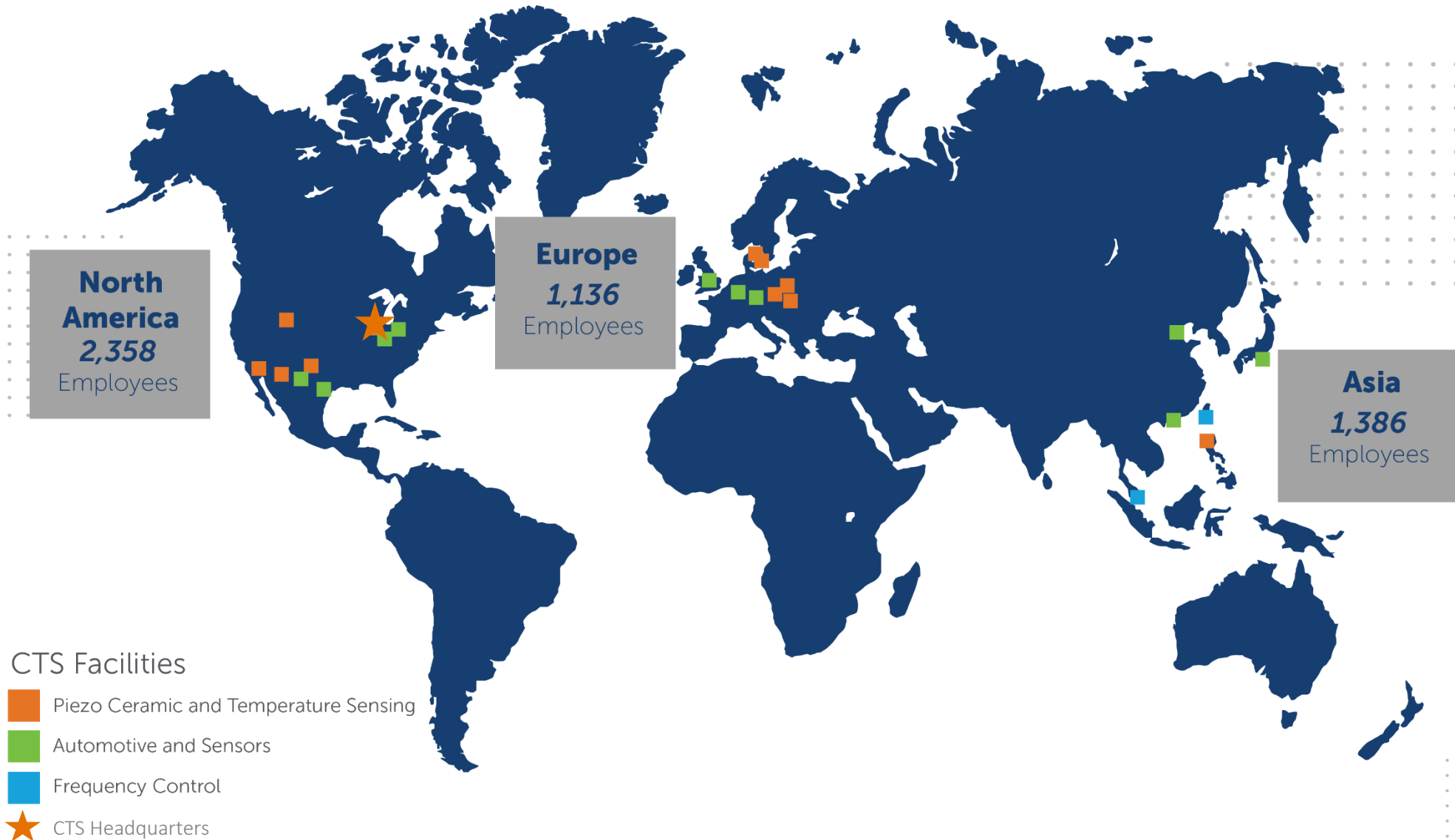
Technical and application expertise applied across diverse and growing end markets



¹ Last 12 months Revenue as of Dec 2022

² 2017-2022 including acquisitions

CTS Worldwide Footprint



CTS is a Leading Designer and manufacturer of Custom Engineered Solutions the Sense, Connect, and Move- enabling and Intelligent and Seamless World

Sense



- Controls
- Pedals
- Piezoelectric Products
- Position Sensors
- Switches
- Temperature Sensors
- Transducers

Connect



- EMI/RFI Filters
- Frequency Control Products
- RF Filters
- Specialty Capacitors
- Specialty Resistors

Move



- Piezoelectric Products
- Rotary Actuators



Industrial



Medical



Transportation



Aero & Defense



IoT



Telecomm & IT



Frequency

Our Core Operating Values

These are our core values that are applied across our organization and establish expectations of our suppliers.



Play to Win

Be ambitious for customers and ourselves. Seize opportunities to create outcomes that benefit everyone. Be prepared to challenge in order to get the best result. Act with humility, intelligence and integrity at all times.



Responsiveness

Be nimble and act fast, but never at the expense of quality. Take the time to understand our customers' needs. Respect the views and needs of others. Work with a sense of urgency that helps us exceed our customers' expectations.



Simplicity

Be straightforward and easy to deal with. Reduce bureaucracy and complexity to keep things simple. Use language our customers understand. Focus on delivering solutions efficiently and effectively, time after time.



Solution Oriented

Stay curious and resourceful. Embrace the challenge of solving our customer's problems. Put yourself in the customers' shoes to understand their challenges. Find new and better ways of working together to deliver greater value.

Long Term Relationship with Blue-chip Customers



Transportation



Industrial



Medical



Aero & Defense



AMS Manufacturing Footprint



About CTS Advanced Materials and Solutions (AMS)

CTS strives to deliver innovative solutions to enable an intelligent and seamless world. Our solutions enhance the body, home, and world connections from underwater to land and space.

Common Applications



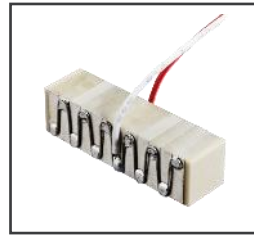
Piezoelectric Components and Devices

Piezoelectric materials can convert a mechanical signal into an electrical signal and vice versa. They can be used as actuators, sensors or transducers.



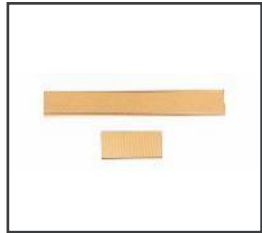
Bulk Ceramics

Geometries for specific applications
>30 materials
Textured and lead-free options



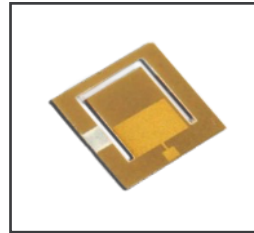
Multilayer

High strain actuators
Wide standard range
Customizable



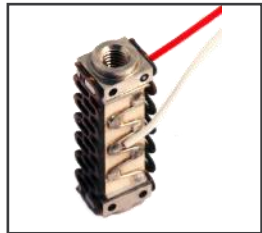
Single Crystal

High performance materials
Advanced shaping, etching
Ø100mm boule



Thick Film

High frequency ultrasound
Printed piezo
Flexible piezo elements



Piezo Devices

Custom assemblies
Mechanical and electrical
Composites



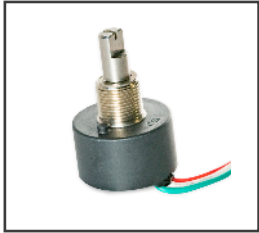
Transducers

In-house design or build-to-print
Volume assembly
UHF transducers



Sensors and Controls

Sensors and Controls products feed information about status, position, angle, speed or other data to a system, including products used to control a system's functions in HMI or MMI mode.



Rotary Position Sensors

Single & Multi-Turn
Hall-effect & mechanical
Multiple mounting options
and sealing ratings



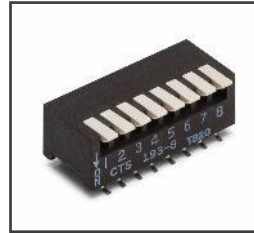
Rotary Potentiometers

Single & Multi-Turn
Small as 9mmØ
Customizable
IP67 available



Encoders

Mechanical & Optical
Ring encoders
Shaft or bushing



DIP Switches

Pitch 0.100" & 0.050"
Slide, toggle, piano
Bottom seal or top tape
Customizable



Tactile Switches

Multiple operating forces,
sizes, life-cycles and sealing
ratings available
LED illuminated versions
IP67 available



Rotary Selector Switches

Shaft or bushing
Termination or lug
IP67 available



Temperature Sensors

Temperature sensors monitor and control temperatures in critical applications where failure is not an option. Customized solutions meet specific requirements in applications for hospitals, backyard swimming pools, or even satellite communications.



Leaded Thermistors
High Precision NTC or PTC
Epoxy & Glass Coating
Commercial/ Mil Aero grades



SMD Thermistors
Sizes Available: 0402, 0603, 0805
Tin / Tin-lead / Gold plating options
Board level mounting



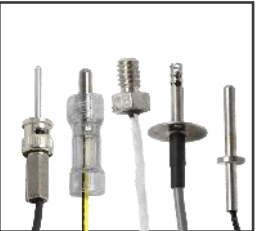
IP68 TPE Probe Assemblies
IP68 compliant
Waterproof
Thermistor /Pt RTD sensor elements



Temperature Probe Assemblies
Thermistor or Pt RTD
Fully customizable housings
Various cable/connector options.



Miniature/Micro
Small size down to 0.020"
+/-0.05C° accuracy
Bare thermistor or probe

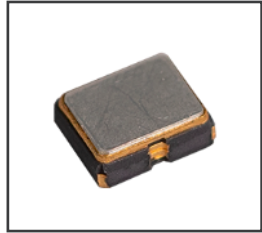


Medical Products
Disposable or Reusable
+/-0.05C° accuracy
YSI 400 series



Frequency Control Products

Electronic devices used in systems for data stream clocking through systems requiring precision radio frequency (RF) generation.



Crystals

AEC-Q200 qualified
Operating Temp -40C° to +105 C°
Harsh environment capable
Wide-range of frequencies



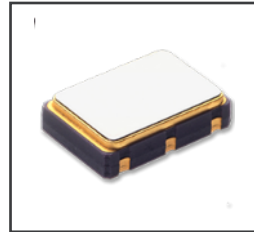
VCXO

PLL reference
Data stream modulation



OCXO

Low phase noise floor
Lowest power in the industry
High shock survivability
Precision RF source



Clock Oscillators (XOs)

AEC-Q200 compliant
Meets industrial environmental requirement
Wide-range of performance and frequency



TCXO/VCTCXO

IEEE 1588 Timing
3GPP performance
Meets GPS timing requirement



Electromagnetic Compatibility (EMC)

EMC is electronic equipment's interaction with the environment it operates in. EMC products help block unwanted electrical signals from the equipment to ensure proper performance. CTS EMC filters are a reliable solution to block unwanted conducted electromagnetic interference (EMI).



Feedthrough (Bushing) Filters
Highly Customizable
L,C, Pi Available
High Performance (Attenuation)



Mini & Sub-mini Filters
Press-in and Solder mount styles
Hermetically Sealed (optional)
Light weight



Filter Assemblies
Custom positions (up to 2 rows)
Custom assembly (Plate) design
Custom capacitance and lead length per pin



Surface Mount Filters
High power (20A)
Round and Square Body
Excellent
Solderability



Filter Terminal Blocks
UL Recognized
Custom positions (2-8)
12 AWG pins for high power
Rated to -55C to 105C



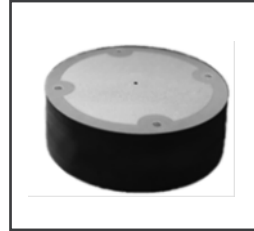
Radio Frequency Filters

RF filters are ceramic components that pass a specific range of signal frequencies (0.2 to 40GHz) and block out undesired frequencies commonly used in wireless communications or for sensing applications such as GPS or RADAR. Can support ITAR and cleared projects.



Diplexers and Duplexers

Freq 0.2 - 6 GHz
Power 0.1 - 200 Wpk
Sizes 11.5 - 65mm long
Universal footprint



Custom Fabricated Ceramic Antennas

Precision tolerances
No tuning,
Temperature stable
Low loss, high Dk (11-88)



Low Pass Filters

<0.5dB IL, >40dB Atten, 200Wpk
Suppress 2nd - 5th harmonics
Universal footprint



Bandpass Filters

Freq 0.2 - 40 GHz
Power 0.1 - 200 Wpk
Sizes 4 - 65mm long
Universal footprint



CTS Temperature Acquisitions

2019



2020

Sensor Scientific, Inc.



2022



TEWA

TEMPERATURE SENSORS

Industrial and Medical Applications



HVAC & Refrigeration



Boilers & Water Heating



Pool & Spa



Food Service

Medical Applications



Neonatal applications



Lab freezers



Fluid warmers



Analytical Instruments

Industrial, Medical and Automotive Applications



HVACR



WATER HEATING



AUTOMOTIVE



FOOD INDUSTRY

CTS Temperature Sensing Locations



-  TEMP Sensing Locations
-  Sales/Technical Office
-  Manufacturing Facility

North America

- Albuquerque, NM
- Boise, ID
- Elkhart, IN
- Fairfield, NJ
- Farmington Hills, MI
- Hopkinton, MA
- Lisle, IL
- Juarez, MX
- Matamoros, MX
- Nogales, MX
- Tecate, MX

Europe

- Kvistgaard, Denmark
- Ostrava, Czech Republic
- Prague, Czech Republic
- Lublin, Poland

Asia

- Calamba, Philippines
- Singapore
- Yokohama, Japan
- Kaohsiung, Taiwan
- Tianjin, China
- Zhongshan, China

Experts in Temperature Sensing

- We are the leader and provider of world class temperature sensing solutions.
- Over 45 years of proven expertise custom engineering the most reliable, high-quality sensors for mission critical applications.
- Global footprint with temperature sensor manufacturing locations in North America, Europe & Asia.
- Specialize in temperature sensors for the HVAC/R, Water heating, Pool & Spa, Medical/Instrumentation, Industrial, Food Service, Automotive and Aerospace/Defense markets.
- CTS has mitigated millions of dollars in sensor related failures and replacement/warranty costs.
- Reputation goes well beyond the products we make.



Design & Engineering support

Temperature Sensor Design Experts

At CTS, we've spent over 45 years building a reputation that goes well beyond the products we make. That's why for us, solving any problem is no problem.

The design process

- Drop-In Replacements or Custom Engineered Solutions
- Partnership with OEM to understand applications, environments, sensor functions and requirements
- Existing sensor design analysis & evaluation
- Designs that eliminate common sensor failure modes
- Sourcing of top-quality cost-effective materials through audited & approved vendor network



Validation

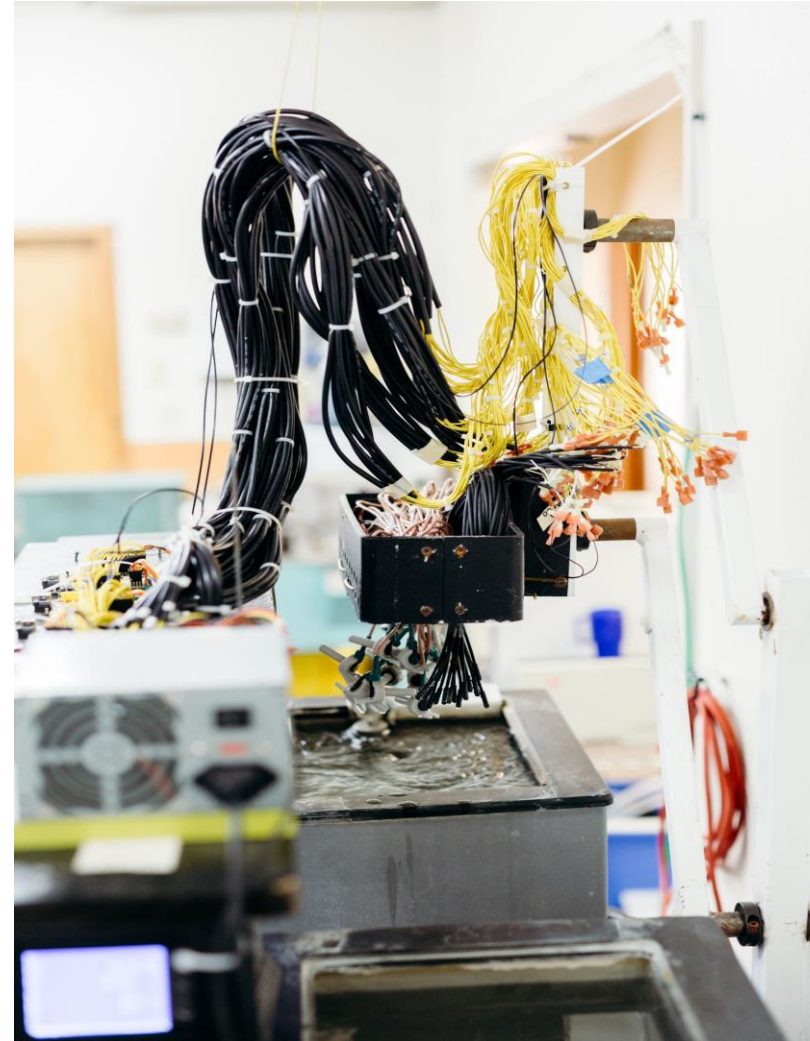
Because Failure is not an Option

We understand that the highest quality products require mission-critical parts that refuse to fail. We also recognize that many of our competitors sacrifice the quality of their temperature sensors for cheap solutions that COST YOU significantly in the long run.

Validation = Warranty Mitigation

➤ In-House Validation Capabilities

- HALT (Dunk Testing)
- Salt Fog
- X-Ray
- Thermal Shock/Cycling
- Time-response
- Salt-water immersion
- Extreme temperature exposure (-200C to +300C)



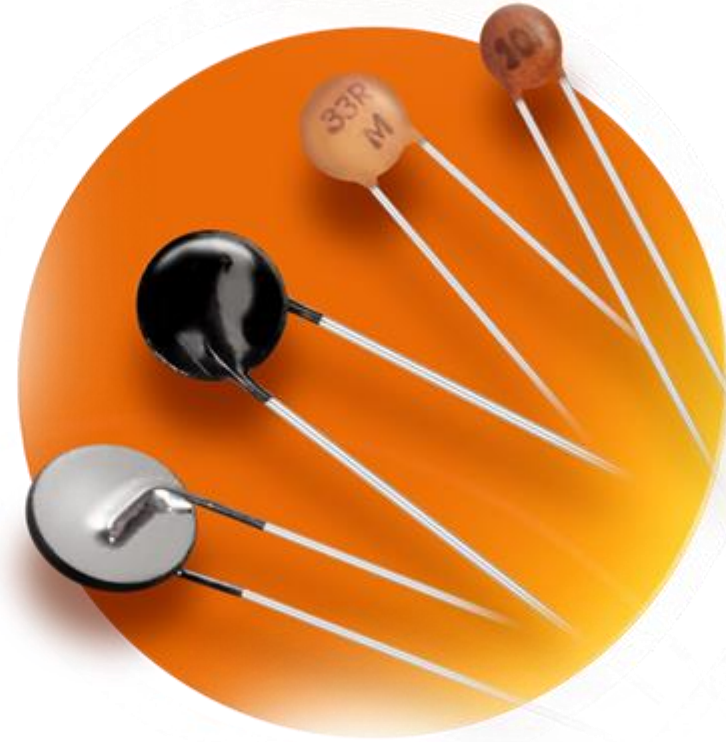
NTC Thermistor Product Introduction

NTC Disc Thermistor

TT-1 SERIES

FACTS AND FEATURES

- ❖ Old, historical applications
- ❖ Proven Stability and Reliability
- ❖ Designed for temperature, measurement, control and compensation
- ❖ Available as bare discs or with insulated/non insulated leads
- ❖ Voltage insulation provided by epoxy resin
- ❖ Normally big thermal mass and long response time
- ❖ Resistance tolerance down to $\pm 5\%$



NTC Thermistor Product Introduction

Glass Encapsulated NTC Thermistor

TT-2 SERIES

FACTS AND FEATURES

- ❖ Glass encapsulation provides extra moisture protection and stability at high temperatures, up to 300°C typically
- ❖ Available with dummet wire with or without polyimide tubes insulation or with welded teflon extension wires
- ❖ Available in custom probe assemblies
- ❖ Long glass body, up to 50mm
- ❖ Typical resistance tolerance between $\pm 1\%$ and $\pm 10\%$ point matched



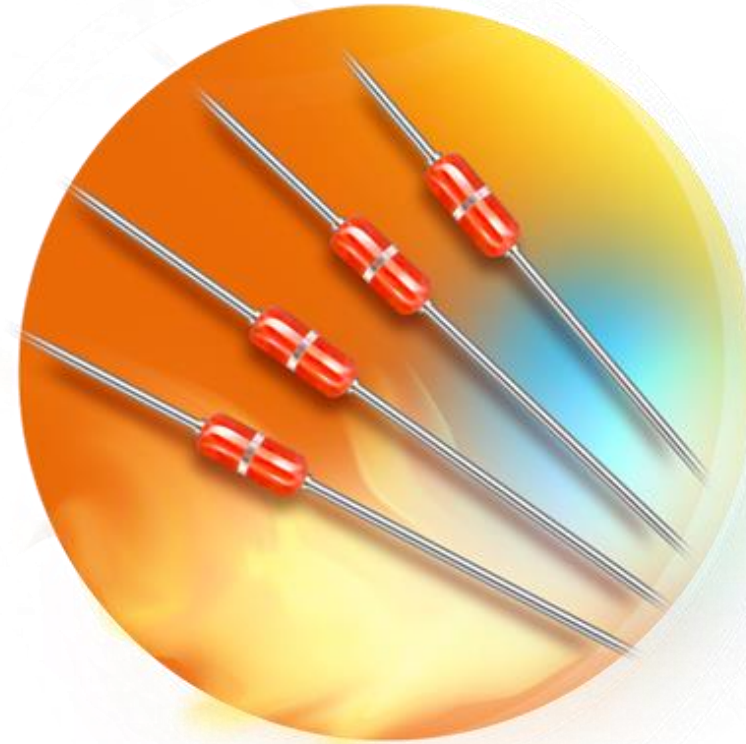
NTC Thermistor Product Introduction

Diode Type Glass NTC Thermistor

TT-DO SERIES

FACTS AND FEATURES:

- ❖ Maximum temperature – 250°C/300°C
- ❖ Available with $\pm 1\%$ point matched tolerance at custom temperature points or as **curve matched** $\pm 0.2^\circ\text{C}$ from 0°C to 70°C for standard RT
- ❖ Customized RT characteristics are available
- ❖ Excellent price/quality ratio
- ❖ Dumet leads coated with tin or nickel are suitable for soldering or welding
- ❖ Tape and Reel packaging available



NTC Thermistor Product Introduction

Epoxy Coated NTC Chip Thermistor

TT-S SERIES

FACTS AND FEATURES:

- ❖ Curve matched characteristics, down to $\pm 0.05^\circ\text{C}$ tolerance between 0°C and 70°C or point matched down to $\pm 0.5\%$
- ❖ Custom bead size and wire configuration
- ❖ Tight resistance and Beta Value tolerance
- ❖ Excellent stability and reliability
- ❖ Wide range of RT curves and resistance values available
- ❖ Operating temperature range between -40°C to 150°C



NTC Thermistor Product Introduction

NTC Microchip Thermistor

TT-5 SERIES

FACTS AND FEATURES:

- ❖ Small size down to **0.5mm** diameter
- ❖ Fast Response Time down to **200ms** in well stirred liquid
- ❖ Fully compliant with **YSI400 Medical Probes**
- ❖ Point or Curve matched characteristics
- ❖ Custom size tube and wire configuration
- ❖ Tight resistance and Beta Value tolerance



NTC Thermistor Product Introduction

Thin-Film NTC Thermistor

TT-6 SERIES

FACTS AND FEATURES:

- ❖ Small thickness down to 0.55mm
- ❖ Available with custom kapton film shapes
- ❖ Excellent price/quality ratio
- ❖ Point Matched Characteristics down to $\pm 0.5\%$ at 25°C
- ❖ Typical range of Resistance and Beta Values
- ❖ Operating temperature range from -40°C to 125°C
- ❖ Frequently used for heat cost allocators or fire detectors



NTC Thermistor Product Introduction

Lead Frame NTC Thermistor

TT-7 SERIES

FACTS AND FEATURES:

- ❖ Industry Standard Resistance and Beta Values
- ❖ Cost effective
- ❖ Point Matched Characteristics down to $\pm 0.5\%$ at 25°C
- ❖ Very good endurance against thermal shock and moisture due to **powder coating**
- ❖ Operating temperature range from -40°C to 125°C
- ❖ Tape and Reel/BOX Packaging Available



NTC Thermistor Product Introduction

SMD NTC Thermistor

TT-8 SERIES

FACTS AND FEATURES:

- ❖ High accuracy down to $\pm 0.5\%$ at 25°C for specific types and RT curves
- ❖ Available in 0402, 0603, 0805 sizes
- ❖ Industry standard range of beta constant and resistance values
- ❖ Available in tape and reel configuration
- ❖ Cost Effective



NTC Thermistor Product Introduction

PTC thermistor sensors

TT-PTC SERIES

FACTS AND FEATURES:

- ❖ Custom size and wire configurations
- ❖ Standard resistance values, according to DIN44081 and DIN44082
- ❖ Available with Kynar insulating tubes or epoxy coated beads only
- ❖ Single, double, triple or more PTC sensors available in one harness



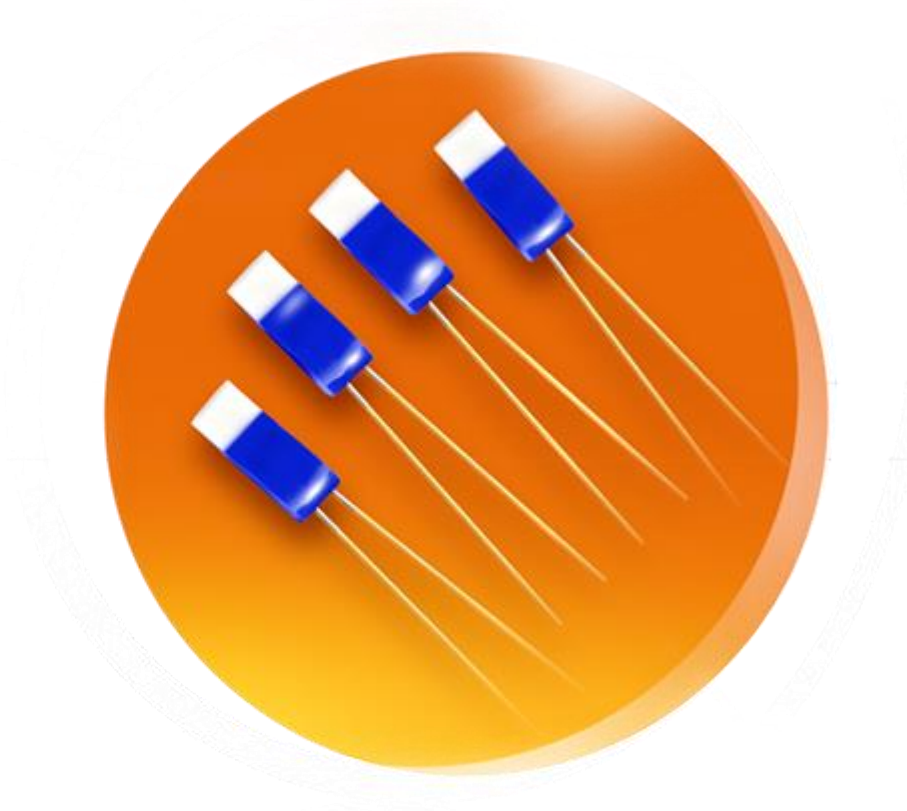
NTC Thermistor Product Introduction

Platinum Temperature Sensors

TT-PT SERIES

FACTS AND FEATURES:

- ❖ Operating Temperature Range between -40°C and 500°C
- ❖ Available in PT100, PT500, PT1000 industry standard characteristics
- ❖ Typical sizes 2x5mm, 1.6x3.6mm, others under development
- ❖ Tolerance Classes A, B, 1/3DIN (AA)
- ❖ Very good long-term stability and reliability also at high temperatures
- ❖ Very good resistance against shock and vibrations



Thermistor Manufacturing Capabilities

- ❖ IN-HOUSE DEVELOPED AND CONTROLLED PROCESS OF MANUFACTURING NTC THERMISTOR CERAMICS
- ❖ WIDE RANGE OF CUSTOMISED R/T CURVES
- ❖ ABILITY TO DESIGN R/T CURVES MEETING CUSTOMER'S REQUIREMENTS
- ❖ FLEXIBILITY IN ADJUSTING RESISTANCE VALUES DEPENDING ON APPLICATION REQUIREMENT
- ❖ HIGH STABILITY AND RELIABILITY OF CERAMICS

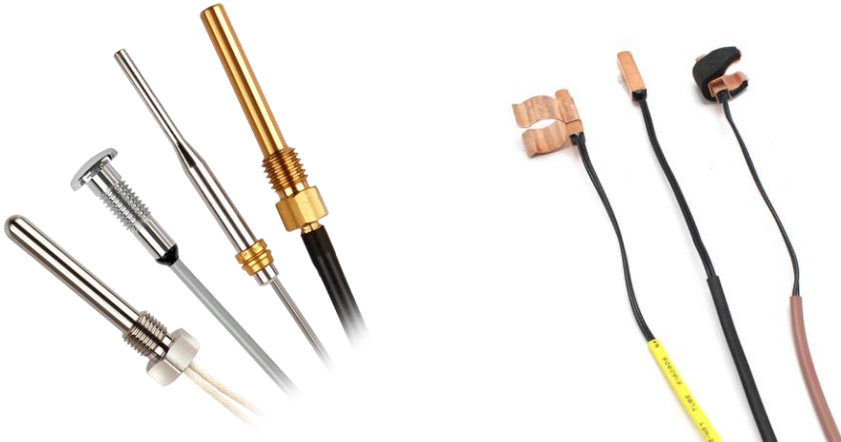
Custom Temperature Sensors



CTS has the expertise to be an integral part of your design process, from engineering to validation and manufacturing.

**If you can dream it,
we can build it.**

Our temperature probes service a wide range of needs and can be used for a multitude of applications.



Temperature Sensors Introduction

Custom Temperature Sensors

TT-4 SERIES

Tewa Temperature Sensors offers wide range of standard and customized temperature sensors designed according to individual customer's requirements covering applications in temperature range between -150°C and $+800^{\circ}\text{C}$.



Temperature Sensors Introduction

Custom Temperature Sensors

TT-4 SERIES

FACTS AND FEATURES:

- ❖ Provide best possible protection against the environment conditions
- ❖ Proven stability and reliability for new designs by internal laboratory testing
- ❖ Variety of metal and plastic housings for different mounting arrangements
- ❖ Potted with different kinds of resin for good sensor protection
- ❖ Wide range of Sensing Elements:
NTC, PT100/1000, KTY81/84, DS18B20, LM335, many others



Temperature Sensors Introduction

Custom Temperature Sensors

TT-4 SERIES

FACTS AND FEATURES:

- ❖ Available with special kinds of cables, connectors, assembled in harnesses
- ❖ Customized solutions for small quantities
- ❖ Quick sample delivery
- ❖ Cost effective solutions for small, medium and big projects



Waterproof Temperature Sensors Introduction

Waterproof Temperature Sensor

TT-O SERIES

TT-O series sensors are IP68 waterproof temperature probes encapsulated with thermoplastic elastomer materials in overmoulding technology.

The TT-O **overmoulded** probes are a perfect solution for applications where the best waterproof and moisture protection is required.



Waterproof Temperature Sensors Introduction

Waterproof Temperature Sensor

TT-0 SERIES

FACTS AND FEATURES:

- ❖ Excellent insulation against moisture
- ❖ Degree of waterproof protection **IP68**
- ❖ NTC and PTC thermistors, PT100/PT1000 versions are available
- ❖ Overmoulded tip diameters from 3.5mm, 4.0mm, 4.5mm, 5x20mm, 6.5x25mm, customized sizes are available
- ❖ Very flexible, standard or rigid cable version available depending on mounting arrangement
- ❖ Available with steel cap for better mechanical protection



Waterproof Temperature Sensors Introduction

Waterproof Temperature Sensor

TT-O SERIES

TYPICAL APPLICATIONS:

- ❖ Refrigeration (evaporator)
- ❖ Vending machines, Chilled cabinets
- ❖ Air Conditioning
- ❖ Underfloor heating
- ❖ Climate control systems
- ❖ Industrial Process control
- ❖ Refrigerated transport



Sensor Assembly Capabilities

- ❖ DESIGNING TEMPERATURE SENSORS, MEETING INDIVIDUAL CUSTOMER'S REQUIREMENTS
- ❖ ENGINEERING SUPPORT IN SENSOR/APPLICATION DESIGN
- ❖ IN HOUSE LABORATORY FOR RELIABILITY TESTING
- ❖ BUILDING TEMPERATURE SENSORS BASED ON:
 - NTC/PTC THERMISTORS
 - PLATINUM TEMPERATURE DETECTORS (PT100, PT1000, etc.)
 - OTHER TEMPERATURE SENSING ELEMENTS

Temperature Sensor Applications



Automotive



Industrial



Medical

Temperature Sensor Applications

temperature
sensing
solutions for:



BOILERS

- ✓ WATER BOILERS & HEAT PUMPS
- ✓ COFFEE MACHINES
- ✓ INSTANT & SOLAR WATER HEATERS
- ✓ VENDING MACHINES



TEMPERATURE
SENSORS

Temperature Sensor Applications

temperature
sensing
solutions for:



REFRIGERATION

- ✓ CHILLERS, FREEZERS AND REFRIGERATORS
- ✓ REFRIGERATED TRANSPORT
- ✓ VENDING MACHINES & BLAST CHILLERS (FOOD FREEZING)
- ✓ LABORATORY EQUIPMENT- (CRYO)

to the humidity that occurs during the condensation



TEMPERATURE
SENSORS

Temperature Sensor Applications

temperature
sensing
solutions for:



AIR CONDITIONING & VENTILATION

- ✓ BUILDING AUTOMATION (HVAC) & ON-WALL THERMOSTATS
- ✓ SUPPLEMENTARY HEATING SYSTEMS
- ✓ COMMERCIAL AIR CONDITIONING/VENTILATION



TEMPERATURE
SENSORS

Temperature Sensor Applications

temperature
sensing
solutions for:



BIOMEDICAL

- ✓ BODY TEMPERATURE MONITORING
- ✓ DRUGS, CLINICAL SAMPLES TRANSPORTATION (DATALOGGING)
- ✓ MEDICAL REFRIGERATION (CRYOGENIC)
- ✓ DIALYSIS MACHINES & BLOOD TEMPERATURE MEASUREMENT



**TEMPERATURE
SENSORS**

Temperature Sensor Applications

temperature
sensing
solutions for:



CUSTOM DESIGNS

- ✓ AUTOMOTIVE APPLICATIONS
(E-MOBILITY, E-MOTOR, HV-CONTROL BOX, BMS)
- ✓ HIGH POWER WELDING MACHINES
- ✓ POOLS AND SPAS
- ✓ FIRE AND SMOKE DETECTORS



TEMPERATURE
SENSORS

Temperature Sensor Applications

temperature
sensing
solutions for:



CUSTOM DESIGNS

- ✓ AGRICULTURE APPLICATIONS (GREENHOUSES, MUSHROOM FARMS, CHICKEN INCUBATORS)
- ✓ PROFESSIONAL & CONSUMER FOOD RELATED EQUIPMENT (GRILLING, COOKING, BAKING, FRYING)
- ✓ BATTERY PACKS (AUTOMOTIVE, POWERTOOLS)



TEMPERATURE
SENSORS

The contact information & location

- ❖ Przeskok 18
20-403 Lublin
Poland
- ❖ Tel. 00 48 81 532 10 79
- ❖ Fax. 00 48 81 534 79 64
- ❖ website: www.tewa-sensors.com
- ❖ email: info@tewa-sensors.com



About CTS Corporation

CTS is a leading designer and manufacturer of products that Sense, Connect, and Move. We manufacture sensors, actuators, and electronic components in North America, Europe, and Asia, and provide solutions to OEMs in the aerospace & defense, medical, industrial, communications, information technology, and transportation industries.

Contact

For more information visit:

www.ctscorp.com

Sales@ctscorp.com



Your Partner in Smart Solutions

What does this mean for you?

- Our team embraces the challenges you are facing and helps to create a solution that best fits your unique system.
- We are a partner that stays in touch with today's technology and is connected to current market standards.
- Our experts understand that solutions come from collaboration and exploration.
- CTS builds partnerships that ensure respect and professionalism.
- True customer intimacy is at the core of how we operate. We recognize your needs and make decisions that best fit you.



Thanks for your attention

