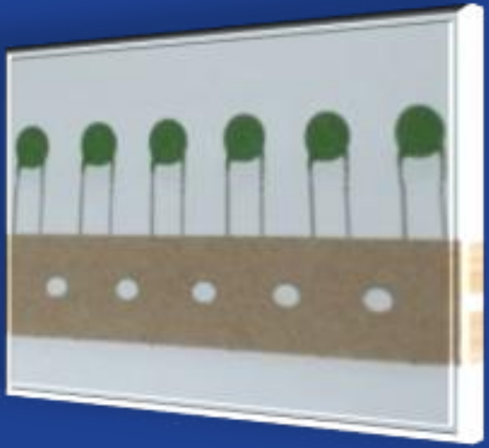
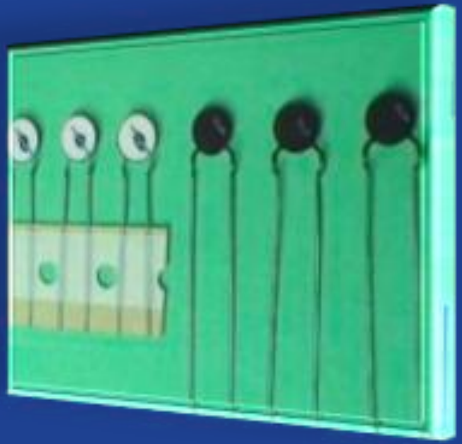
GE's Thermometrics Product Line

PTC Thermistors

Positive **T**emperature **C**oefficient Thermistors





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Agenda

1. PTC's definition & technical review
2. PTC Heater applications
3. PTC Fuse applications
4. Appendix
   - PTC Time Delay applications
   - PTC Liquid Level applications
   - Steady state current and time equations

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PTC's versus NTC's

PTC = Positive Temperature Coefficient thermistors. That is, the resistance increases as the temperature increases.

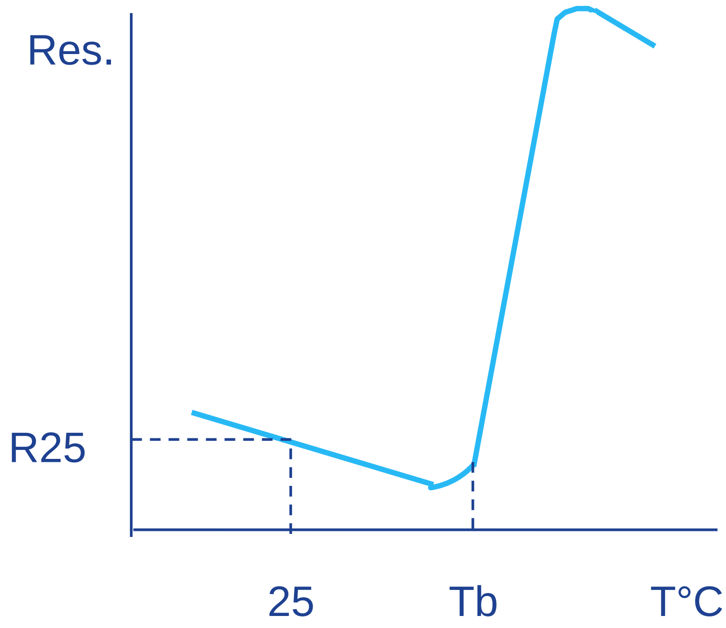
NTC = Negative Temperature Coefficient thermistors. That is, the resistance decreases as the temperature increases.

PTC's are used as heaters and self resettable fuses. They are not used for precise temperature control. PTC's can not be manufactured economically with tight resistance tolerances. Typically, the resistance of a PTC is around ±15 or ±20%.

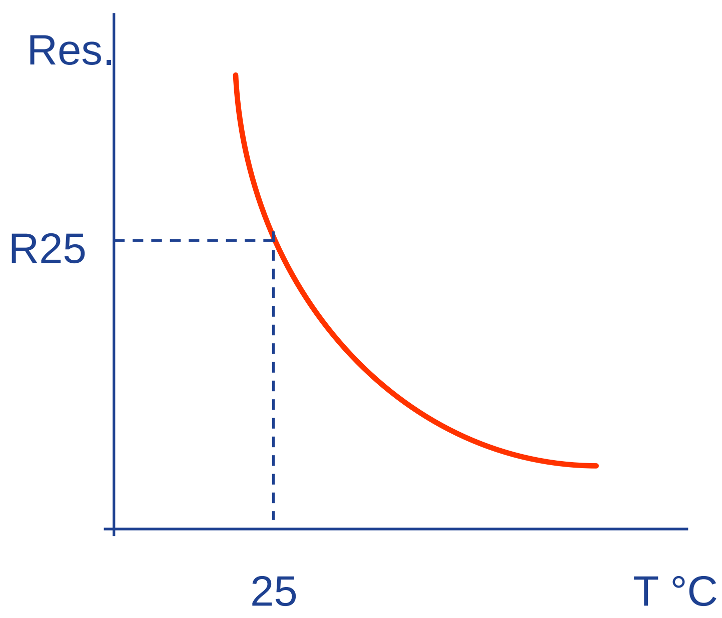
NTC's are used for precise temperature control. NTC's can be manufactured to very tight resistance tolerances and temperature accuracies. Typically, the resistance of a NTC is around ±5%, ±3%, ±2%, ±1% or less.

PTC's versus NTC's
Resistance - Temperature characteristics

PTC



NTC



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PTC's – Definitions

Before we explain PTC Heater & Fuse applications, we first need to understand a few key terms:

R @ 25ºC – Resistance at 25°C. Most PTC's are 5 to 250 ohms

Voltage – The steady state or application voltage used in the circuit. As a margin of safety, PTC's are designed to survive a voltage that is 1.5 or 2 times the rated application voltage.

Voltage Standoff - The maximum voltage that a PTC can take. Given as volts/mm so this is a function of the PTC's thickness. That is, how much voltage can a 1mm thick PTC take and still remain functionally stable?

Transition Temperature – The temperature where the PTC "transitions from a low resistance to a very high resistance". This term is also known as the breakpoint, curie point and switch temperature.

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PTC's – Definitions

Operating Temperature – The temperature at which the PTC stabilizes after it heats up when power is applied to it. (**roughly 10°C to 25°C higher than the transition temp.**).

Assuming that there is enough power to switch the PTC, the operating temperature will depend on the transition temperature, the voltage level, the parts dimensions and how well the part is **thermally connected** to the application.

For example, a PTC held between two large copper plates will operate cooler than the same part held by alligator clips because the amount of heat shed (or dissipated) into the plates will be greater than what is shed into the clip.

Because of the large number of heating and cooling cycles that a PTC heater can see over it's lifetime, the solder used to affix it can start to fatigue and break down over the years. Thus, many PTC heaters are held in to place physically by clamps, clips or conductive paste as opposed to solder.

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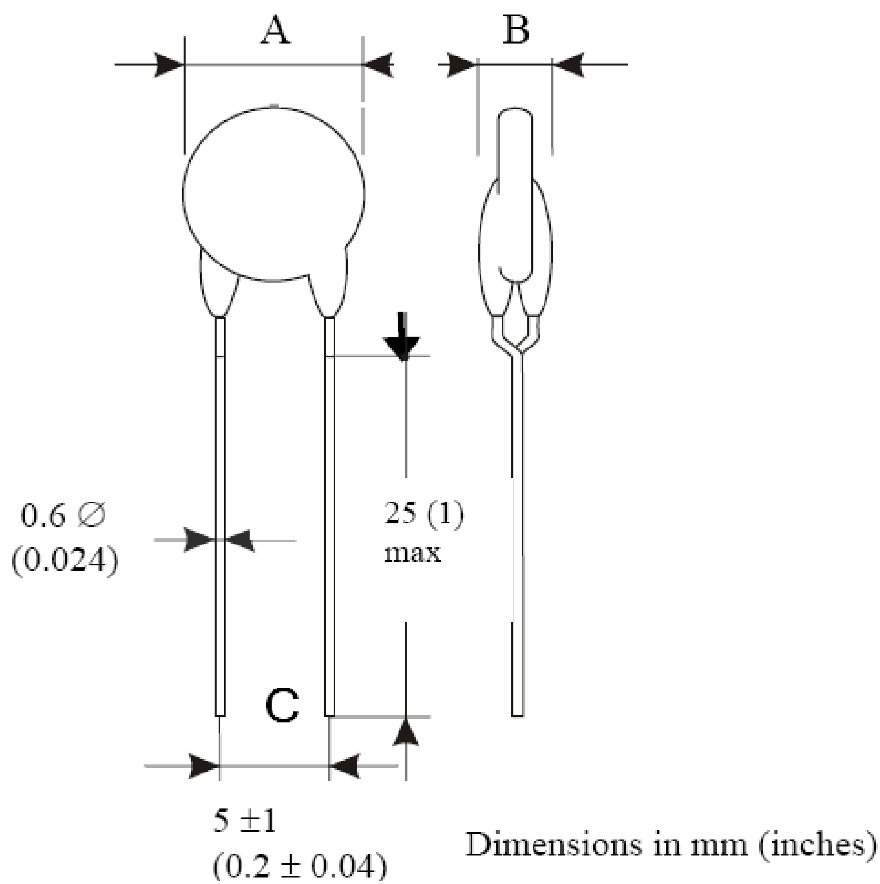
PTC's – Definitions

Physical Dimensions :

- A = Diameter
- B = Thickness
- C = Lead Spacing

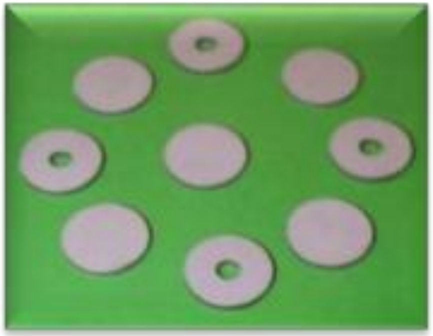
- PTC's typically are used as disc or uncoated wired parts for heaters
- PTC's typically are coated with a silicone resin for fuse applications

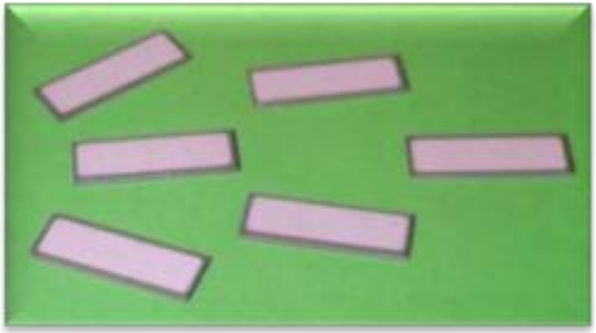


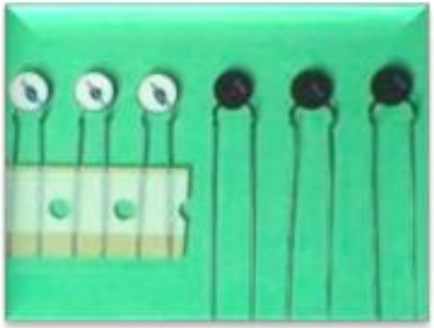
PTC's - Technical review

PTC's are **ceramic discs with metal (silver) contacts** applied on the top & bottom of the disc. These discs are used as is or they can be soldered to wire leads.

Nearly 90% of all uses of PTC's fall into two application categories: **Fuses and Heaters**. Thus, we will only concentrate on these two applications in this presentation.







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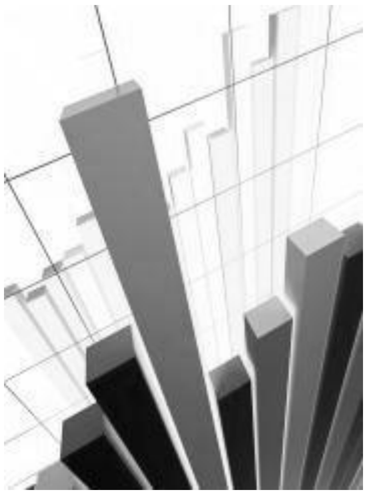
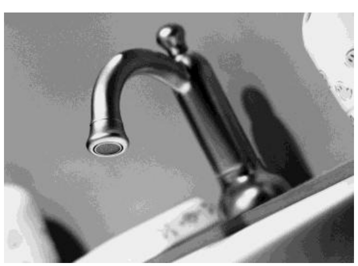
PTC's – Technical review



Like resistors, PTC's exhibit a resistance reading. The difference with PTC's is that there resistance changes greatly as the temperature changes.

When PTC's are in their cold resistance state, that is, when there is no power or low power in the circuit, the atoms making up the PTC ceramic are arranged in a specific pattern that allows some of the electrons to flow about freely. The electrons "carry" the electricity through the part and the more "free" electrons you have the easier electricity can pass through the ceramic. Hence, **the PTC is in it's low resistance state**.



An analogy would be an open water faucet that allows the water to flow. The open faucet is like the PTC in its low resistance state. And the flowing water is like the electricity moving through the ceramic.

PTC's – Technical review

However, when the circuit is energized with sufficient power (electricity), the PTC heats up almost instantaneously to around 180°C and it's low resistance reading changes to a value about 1000 times higher! The high resistance of the PTC essentially causes the electricity to cease "flowing" through the part. This would be analogous to shutting the water faucet off so that the flow of water stops…

The resistance of the PTC is able to change drastically because as the PTC heats up, the atoms making up the PTC ceramic re-arrange themselves in a different pattern **(hence the name transition temperature)** and this new atomic arrangement "locks" the free electrons in place so that they are no longer able to wander about freely in the ceramic.

Since the electrons, which "carry" the electricity through the part, are no longer roaming freely, the flow of electricity stops. Hence, **the PTC is said to be in it's high resistance mode**.

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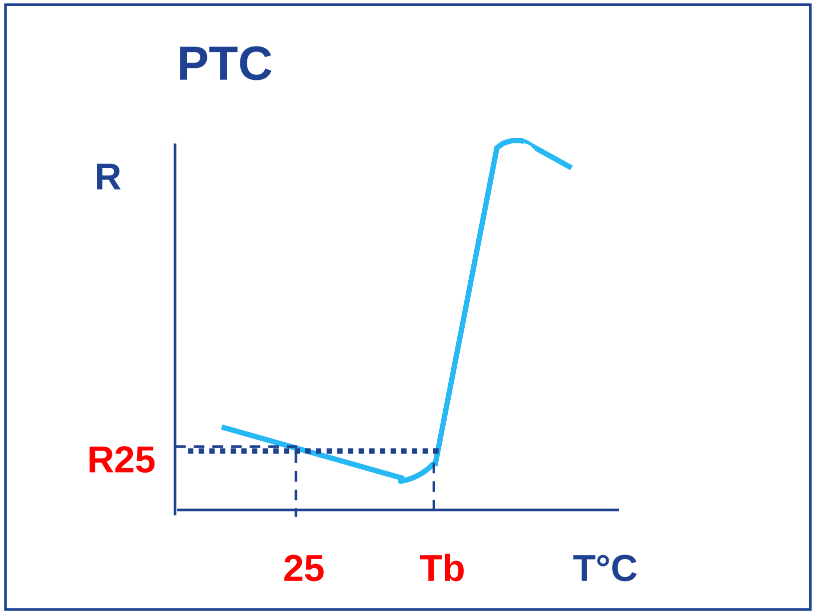
PTC's – Technical review



The resistance versus temperature graph shows how a PTC reacts to temperature changes.

Tb = transition temperature. The temperature where the ceramic microstructure changes. The resistance above this point is much higher than the resistance below this point.

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PTC's Heaters – Typical values

Transition Temp: 60°C to 140°C

Resistance ranges from 0.8 - 1,000 ohms

Voltage ranges up to 12 V to 1000 V

The general sizes of the disc are:

- The diameters range from 2.5 – 18 mm.
- The thickness range from 1.0 – 4 mm.
- Normally supplied as non-leaded disc but can also be supplied as a leaded part.

PTC Heaters can also be used as fuses and vice versa. They are the same part but designed to handle different conditions.

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PTC's - Heaters

- PTC Heater Applications: Nearly ½ of all the PTC opportunities that you uncover will most likely be an application where the objective is to heat an object to a constant temperature.

- PTC's make good heaters because they tend to regulate themselves at a constant temperature (assuming that enough power is available to heat the PTC past it's transition temperature). This self regulating property allows PTC's to operate at nearly the same temperature irrespective of variations in the voltage and ambient temperature.

For example, a part can be sold as a heater in both North America and Europe and operate at nearly the same temperature irrespective of the different 120 / 240 voltages.

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PTC's as Heaters – Key Reasons

The PTC heater tends to operate in a temperature range of a few degrees as long as the maximum power rating of the part is not exceeded. If exceeded, the PTC could fail by going into thermal run away. That is, the part can get so hot that the solder connections will melt and lead to an open circuit or the part will continue heat up to the point where it will start to glow and blow itself apart.

By modifying the composition of the ceramic we can shift the transition temperature and therefore the temperature that the PTC heats up to. GE's range of transition temperatures is from 60°C to 140°C in roughly 10°C increments.

GE has the means to customize for different PTC dimensions and shapes and to some extent the transition temperature.

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PTC's - Heaters

The five questions to understand in heater applications are:

1. **What is the desired operating temperature?**
   - Why – this defines the PTC Transition temperature. So if an application calls for a PTC heater between this temperature range GE can most likely supply it.
2. **What is the applied voltage?**
   - Why – makes sure that GE picks a part that will survive in the application. The part can handle the voltage.
3. **What resistance range is acceptable?** Normally defined based on power requirements.
   - Why – enables GE to pick a suitable part number for the application once we understand what transition temperature, operating voltage and resistance is required.

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PTC's - Heaters

4. **What are the physical dimensions?**

- Why – defines the dimensions of the PTC.

5. **How will the part be installed in the application?**

- Why – Helps validate that the proper transition temperature is chosen for the application.
- Note - PTC's can deliver between 10 to 100 watts and this is a function of the parts size, it's resistance, the power it's under and the way that it is affixed to what it is heating. So applications that require higher wattages are better served by other technologies if using multiple PTC's in parallel is not economical.

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PTC Heater part number examples

Part Number	Resistance	Transition Temperature	Application Voltage	Diameter	Thickness
YQH100R80	100 ohms ±30%	80°C	500V	4.5mm	5.0mm
YQH560R80	560 ohms ±30%	80°C	800V	4.5mm	5.0mm
YQH1000R80	1000 ohms ±30%	80°C	900V	4.5mm	5.0mm
YQH100R100	100 ohms ±30%	100°C	420V	4.5mm	5.0mm
YQH560R100	560 ohms ±30%	100°C	650V	4.5mm	5.0mm
YQH1000R100	1000 ohms ±30%	100°C	800V	4.5mm	5.0mm
YQS5941PTH	25 ohms ±40%	65°C	120V	15.0mm	2.5 mm
YH100R100V24	10 ohms ±40%	110°C	24V	15.0mm	2.0 mm
YQS5637	3.3 ohms ±10%	120°C	14V	13.7mm	1.5 mm
YS6101	50 ohms ±40%	120°C	25V	8.0mm	1.5 mm
YQS5638	100 ohms ±35%	120°C	120V	12.7mm x 6.6mm oval	2.5 mm
YQS5940PTH	20 ohms ±30%	140°C	24V	15.00mm	2.0 mm

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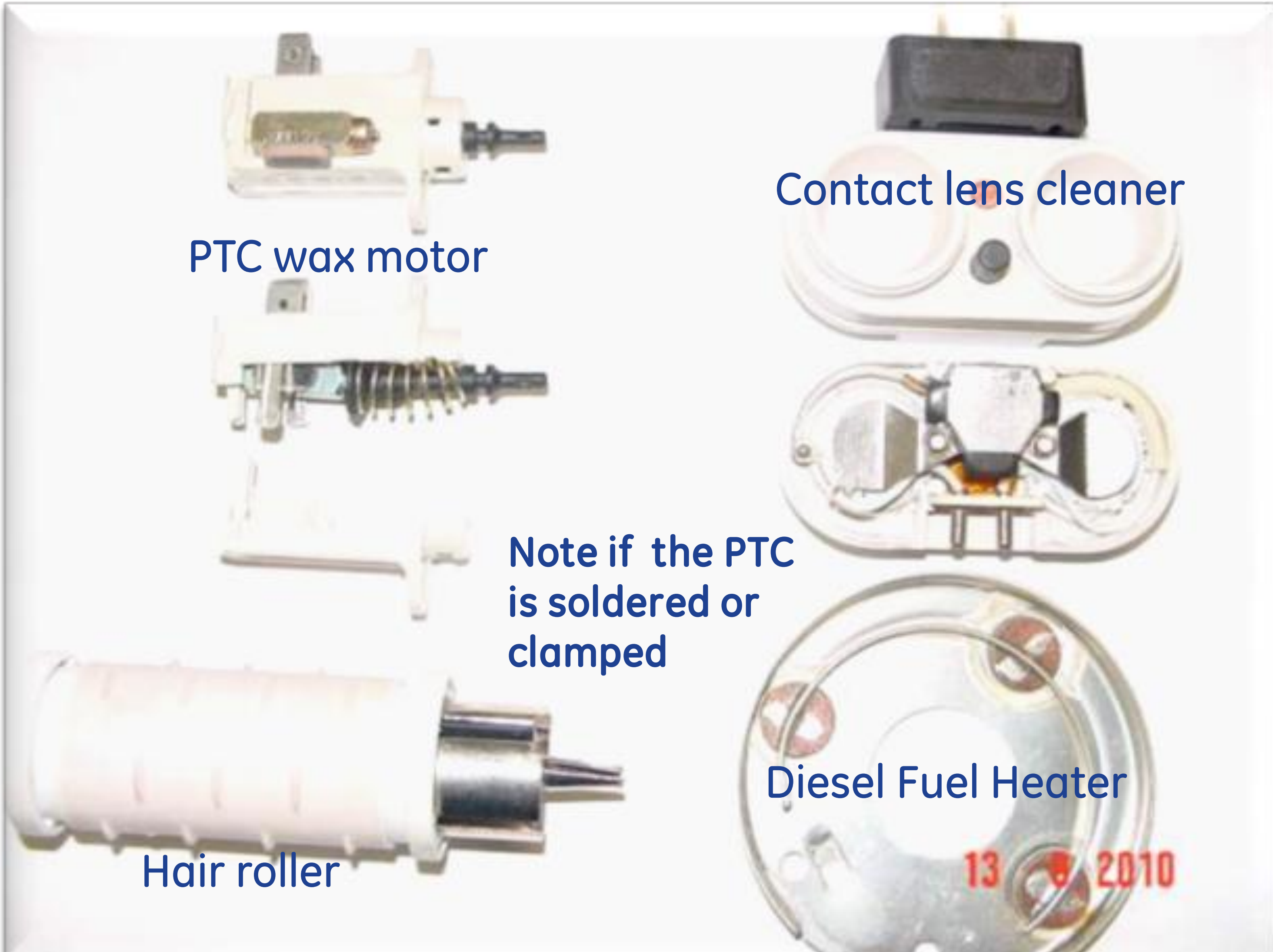
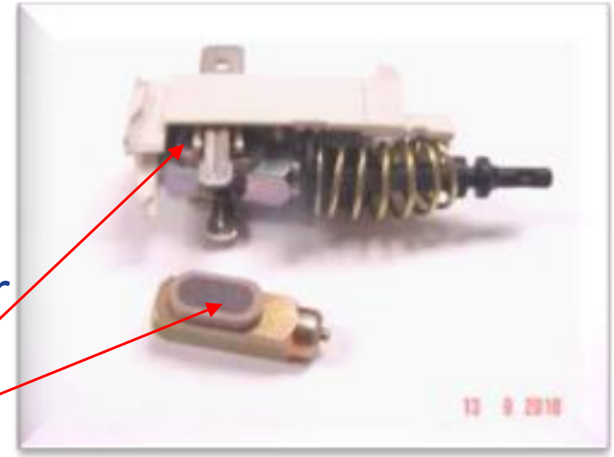
PTC Heaters – Examples



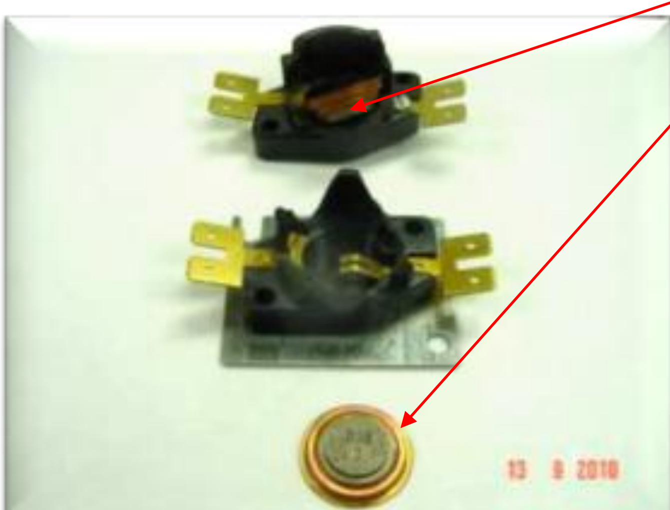
PTC Heaters - Examples

Diesel Fuel Heater



PTC wax motor

PTC



Bi-metal switch

Note if the PTC is soldered / clamped or a combination. Also note the PTC shapes

Inside of hair roller

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PTC Heater Applications

Diesel fuel heaters are used on vehicles to heat the diesel fuel as it passes through the fuel filter to allow for easier cold engine starts and it also helps prevent the build up of wax type deposits in the filter.

- The diesel fuel heater normally consist of a metal ring or washer that has 2 or 4 PTC's soldered to it.
- The resistance ranges are typically much tighter than other heater applications because the power output normally needed in these specific applications must be tightly controlled.

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PTC Heater Applications

Wax motors are widely used in the appliance industry. Dish washer soap dispensers and washer and dryer door safety locks are often controlled by a an actuator that is switched on and off by a wax motor.

A wax motor is a small metal canister filled with wax and a plunger. Upon heating, the wax melts and expands (about 10% of its solid volume) forcing the plunger out. The plunger then activates a switch. When cooled, the wax shrinks and a spring drives the plunger back to it's starting position.

The faster the wax melts, the faster this action takes place. Thus, a wax motor can be thought of as a time delay switch.

The parts for these applications are often rectangular, square, oval or lozenge in shape to "fit" the canister.

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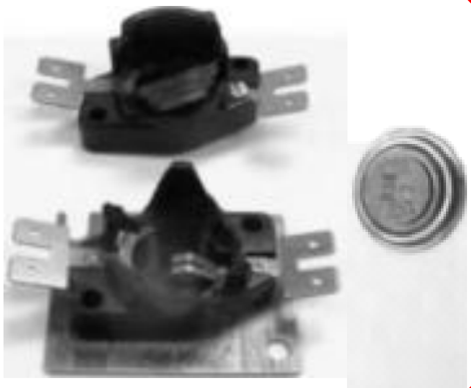
PTC Heater Applications



Bimetal Switches are used in many industrial type applications as time delayed switches. For example, to reduce the power draw on a heating system, a series of bimetal switches will control when the heaters turn on. They are designed so that all the heaters don't turn on at the same time. So by sequencing when the heaters turn on, the power draw can be reduced.

- Bimetal Switches are similar to the wax motor application but instead of using melting wax to activate a switch it uses a metal configured or mounted in such a way that when its heated it expands and makes contact with another switch and closes the circuit enabling current to flow.
- So by varying the metal composition, the metal geometry and the operating temperature of the PTC, you can vary how fast or slow the switch turns the circuit on.

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PTC Heater Applications

Angle of Attack Sensors are used on airplanes to relay how the aircraft is traveling through (attacking) the air. These sensors can be seen protruding from around the nose of the aircraft. Embedded PTC's are used to heat these vanes to prevent ice formation. It's critical that these vanes don't freeze. The PTC self-stabilizes its temperature and minimizes the power consumption when the vane is not in an icing condition. This improves the reliability of the vane assembly. Thus, suppliers must be able to demonstrate best in class processing controls to ensure uniformity in the ceramics microstructure. This leads to guaranteeing part to part and batch to batch consistency.

Typical specs for these applications are:

- Transition temp to ± 3°C & operating temp tolerances ±5°C
- Thermal shock from –54°C to 85°C under power

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PTC Heater Applications

Thermoelectric Actuator Valves operate on the principle of the expansion of refined wax when heated through its melting point.

A PTC (positive temperature coefficient) semi-conductive disc is both temperature control and heat source, controlling typically at 90°C. The wax, chemically refined melts at ~70°C. The element expands, driving the stem through its travel to close /open the single or multi zone valves.

Typical applications

- ✓ HVAC water & steam heating systems
- ✓ Direct radiator control
- ✓ Radiant floor heating systems

Key Performance CTQ's

- PTC heat up … Fast, continuous and stable
- Open circuit operation : 3 mA

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Other PTC Heater Applications

Automotive:

- Crankcase (engine block) heaters – cold climate regions
- Mirror de-icing
- Nozzle de-icing
- LED lights – heat the outer lens to prevent ice build up
- Instant HVAC heaters – provide warm air out of the air vents as soon as the key is turned on

White Goods:

- Coffee pot heaters
- Hair curling tongs
- Glue guns – often need very high temperatures ~ 250°C
- Ceramic office heaters

Others:

- Security cameras – to prevent the lenses from fogging over
- Plug in air fresheners
- Insect insecticide dispensers
- Plastic bag sealers
- Copy machine ink driers

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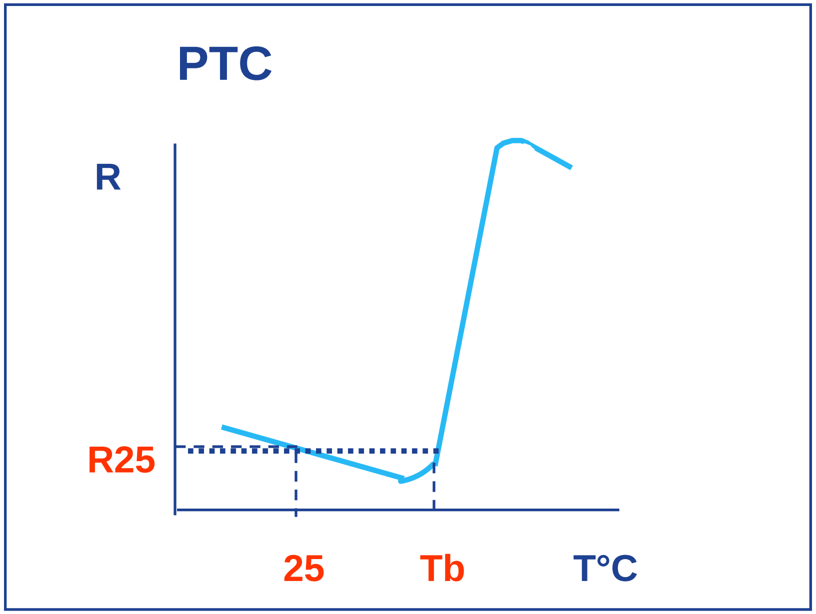
PTC's – Explained (Fuses)

The resistance versus temperature graph below shows how a PTC reacts to temperature changes.

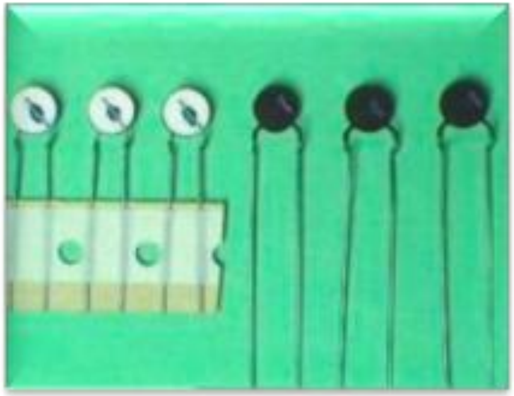
Tb = transition temperature. The resistance above this point is much higher than the resistance below this transition temperature. This property allows PTC's to be also used as fuses.



PTC's as Fuses (Circuit protection)

To help protect circuit components, designers will use PTC's as self resettable fuses in their circuits. If something happens to cause a jolt of electricity to surge through the circuit, the PTC will heat up to a very high resistance and limit the electrical flow so damage can be prevented to products further down in the circuit from the PTC.

Most PTC Fuses are leaded thermistors



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PTC Fuses (Circuit protection)

We can take advantage of the PTC low resistance properties below the transition temperature in fuse applications. If the part is placed into a circuit so that it will normally operate at it's low resistance after the circuit is powered up, then the electricity flows through the circuit uninhibitedly.

But if something happens to cause an electrical surge (such as a lightning strike), this will cause the PTC to instantaneously heat up above it's transition temperature and thus it will go into a very high resistance state that essentially stops the flow of electricity in the circuit.

Thus PTC's make excellent fuses and they are naturally resettable because as soon as you remove the condition that caused the PTC to heat up, the PTC will cool and return to it's low resistance value.

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PTC Fuse – Definitions

Steady State Current or non trip current = The highest current that the PTC can take over the entire application temperature range without heating the PTC above it's transition temperature (high resistance state). The electricity will flow through the circuit. Analogy: The water faucet remains open and the water flows freely.

Trip Current = is the current level that sufficiently heats up the PTC so that it switches into its high resistance mode. The electricity will cease to flow though the circuit. Analogy: The faucet closes and the flow of water stops.

Since PTC's fuses are designed to remain in their low resistance state at the circuits normal current levels, something wrong happens to the circuit to cause the current to increase high enough to send the PTC above it's transition temperature. The PTC will automatically reset itself when the current returns to normal levels, hence the name self resettable fuses.

Equations for trip and steady state current are in the appendix

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PTC Fuse - Typical Values

- Resistance Range = 0.8 to 5,000 ohms
- Voltage Range = 5V - 1000V
- The diameters range from 2.5 – 18 mm.
- The thickness range from 1.0 – 4 mm.
- Normally supplied as leaded disc but can also be supplied as a non-leaded part.
- Steady state current range is between 0.014 Amps – 1.0 Amps. At current levels above this, the size of the PTC needed to work in this application would make it cost prohibitive so another fuse technology needs to be considered.
- Because PTC fuses are used for safety, and most circuits never see a fault condition, the vast majority of PTC fuses are never used. That is, they never operate above their transition temp.

PTC - Fuse Fundamentals

The five questions to understand in fuse applications are:

1. **What is the steady state current?**
   - Why – this defines what PTC can be used in the circuit.
     GE will select a PTC that will remain in it's low resistance state under all normal circuit operating conditions. The PTC fuses listed in the data sheets include a column for steady state current ratings.
2. **What is the Trip current?**
   - Why – this defines what current level will heat the PTC above it's transition temperature to put it in high resistance operating mode. The PTC fuse data sheets will also include the trip current information.
3. **Temp range that the part will see in the application?**
   - Why – because the maximum steady state current that the PTC will handle without heating above it's transition temperature will decrease as the ambient (or outside air temperature) increases. Thus the part needs to be designed to remain in it's low resistance state even at the highest application temperature.
4. **What resistance and voltage is needed for the application?**
   - Why – ensures that the proper part is picked to survive in the application
5. **Are there any size limitations?**
   - Why – helps GE determine which of our parts will work best in the application

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PTC Fuse part number examples

Group	Code	R25 (Ω)	Int (A) Steady State	It (A) Trip Current	Imo (A)	A max mm	A max inch
265Vrms Tb=120°C	YQD120N0006	6	0.39	0.78	3.1	17.5	0.69
	YQD120N0010	10	0.25	0.5	1.8	13.5	0.53
	YQD120N0015	15	0.18	0.35	1.2	11	0.43
	YQD120N0025	25	0.13	0.25	0.8	9	0.35
	YQD120N0045	45	0.105	0.2	0.8	9	0.35
	YQD120N0055	55	0.09	0.18	0.8	9	0.35
	YQD120N0070	70	0.065	0.13	0.3	6.5	0.26
	YQD120N0120	120	0.035	0.08	0.3	6.5	0.26
265Vrms Tb=100°C	YQD100N0150	150	0.038	0.08	0.3	6.5	0.26
	YQD100N0300	300	0.027	0.055	0.3	6.5	0.26
	YQD100N0600	600	0.02	0.04	0.2	6.5	0.26
	YQD100N1000	1000	0.015	0.03	0.2	6.5	0.26
265Vrms Tb=80°C	YQD080N0025	25	0.085	0.17	0.8	9	0.35
	YQD080N0050	50	0.06	0.12	1	9	0.35
	YQD080N0100	100	0.05	0.1	0.6	8	0.32
	YQD080N0150	150	0.022	0.045	0.2	4.5	0.18
140Vrms Tb=120°C	YQC120N4.70	4.7	0.425	0.85	3.1	17.5	0.69
	YQC120N5.60	5.6	0.4	0.8	3.1	17.5	0.69
	YQC120N6.80	6.8	0.3	0.6	1.8	13.5	0.53
	YQC120N0010	10	0.225	0.45	1.2	11	0.43
	YQC120N0022	22	0.135	0.27	0.8	9	0.35
	YQC120N0033	33	0.09	0.175	0.3	6.5	0.26

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PTC Fuse Applications

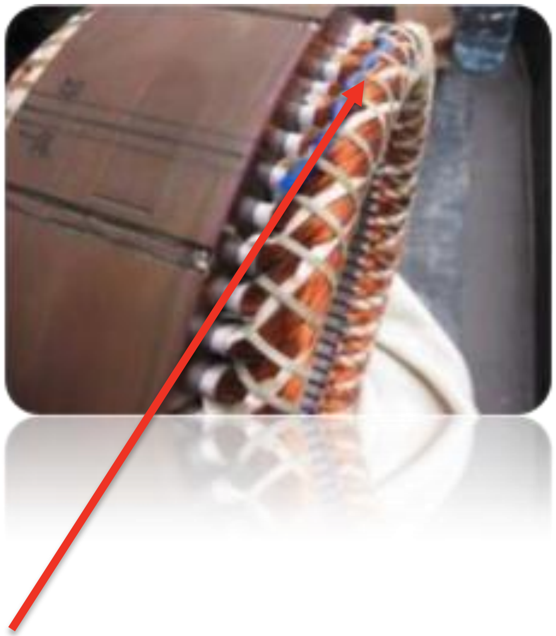
Locked Rotor Fan Protection

- Locked rotor protection works like any other PTC fuse. If a motor freezes up, both the current draw and temperature increase will cause the PTC to go to its high resistance mode shutting the current down and thus the circuit before any damage occurs.
- The PTC remains in the high resistance state until the fault condition is removed.

Battery Charging

- The PTC remains in it's low resistance state until a rise in ambient temperature causes it to transition into it's high resistance mode.
- The PTC remains at high resistance until the temperature decreases. That is, the charging stops and the circuit cools.

PTC Fuse Applications



PTC Fuse
(at the tip of the blue wire)

Motor winding

The PTC is buried into the motor windings and remains in it's low resistance state during normal motor operation. If something causes the motor to work unusually hard, the temperature of the windings will heat the PTC above it's transition temperature causing the PTC to read very high resistance. This signal is interpreted as a fault condition and the motor is stopped before any over temperature damage to the motor is done.

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PTC Fuse Applications

Various safety circuits

- Power supply
- Lighting ballast
- Money exchange machines
- Rechargeable batteries
- Satellite dish systems
- Electrical motors and electronic circuits

Telecoms

- Terminal equipment
- Ancillary equipment – burglar alarms & safety alarms

Appendix

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PTC Time Delay Applications

In a Time Delay application, the PTC allows current to flow through the circuit for several seconds until the PTC self heats enough to cause it to switch into its high resistance mode. Thus the PTC is similar to a fuse in this respect. Current will flow when the PTC is low resistance but is halted very quickly when the PTC heats up to its high resistance.

Physical size as well as current level are big factors in determining the amount of time needed to transition the PTC into it's high resistance mode in these applications.

Applications involving these PTC's are:

- Control of auxiliary starting phase in ac motors
- Relay delays
- Motor start PTC's for commercial refrigerator applications

PTC Liquid level/Air Flow Applications

There is a large difference in how a PTC dissipates in when exposed to air versus in a liquid. A PTC cools and thus increases its resistance when it dissipates more. As the PTC resistance decreases the current through it increases when you have a constant voltage source.

This property makes it an ideal candidate for overflow or liquid level detection.

Parts are typically used at low voltages.

- Overflow protection in tanks
- Liquid level measurement
- High and low liquid level cut off
- Leakage sensing

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Steady State Current Equations

$$I_{\min} = \sqrt{\frac{\delta(T_{tr} - T_{\min})}{R@25°C}}$$

$$I_{\max} = \sqrt{\frac{\delta(T_{tr} - T_{\max})}{R@25°C}}$$

Where:

I = Current
T_{tr} = Switch temperature
T_{min} = Min temperature
R@25 = Resistance @ 25
T_{max}= Max temperature

GE imagination at work

PTC Fuse Equations for Time to Trip

$$t \cong \left(H/\delta\right) \ln\left[\frac{P_o}{P_o - \delta(T_{tr} - T_{amb})}\right]$$

Where: δ = Dissipation constant
H = Heat capacity
T_O = Transition temperature
Ta = Ambient temperature
P_o = Initial power input

$$t \cong \frac{H}{P_o}(T_{tr} - T_{amb})$$

GE imagination at work

imagination at work