Component Derating Guidelines

FOR

High Reliability Power Assemblies

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Version 1.01

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Change History

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Table 1: Change History

Revision Level	Date	Author of Change	Change Description
0.01	12/10/2001	Eric Swenson	Initial draft version of the document.
0.02	1/9/2002	Eric Swenson	Revised draft version of the document with input from reviewers.
0.03	2/6/2002	Eric Swenson	Additional revisions based on reviewer input.
0.04	3/8/2002	Eric Swenson	Final version for internal review before initial release.
1.00	8/6/2002	Eric Swenson	Initial formal release of the document. Minor changes made to several sections from reviewer input.
1.01	9/5/2002	Eric Swenson	Add comment about maximum board operating temperatures in Section 8.1.

About This Document

Scope

The purpose of this document is to define general derating guidelines for components used in power assembly. It also summarizes thermal acceptability criteria for these components.

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Reference Documents

Please reference the IBM AOP web site for generic component usage guidelines. This site can be referenced that the following URL:

http://procure.sby1.ibm.com/procure.nsf/WebPages/RFUR-3X5LKB?OpenDocument

Definitions

The following defines the acceptability terms used in this document. The three regions are defined as follows:

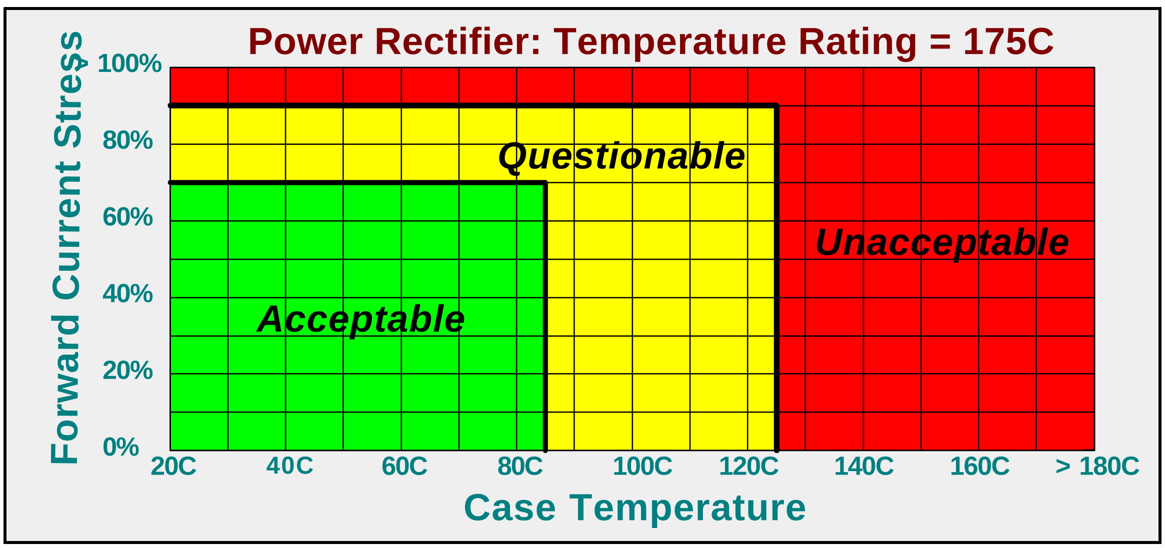
Acceptable: The component is operating within acceptable thermal and stress limits. No further actions are necessary. Use of the component under these conditions is considered a low risk.

Questionable: Stresses and use of the component should be further analyzed to determine why the component is operating at the measured temperatures. Engineering judgment is necessary to determine the acceptability of the use of the component. Use of the component under these conditions can be either a low, medium, or high risk depending on the actual stress conditions on the component.

Unacceptable: The component should not be used at this temperature or stress level. Use of the component in this condition is considered a high risk.

These regions are determined by a combination of the operating temperature and stress on the component. The operating temperature and stress are measured at the worst case operating condition for each component. For most cases, thermal and stress measurements are made in room ambient conditions. Results should be adjusted to account for the difference between room ambient conditions and the worst case conditions for the assembly as defined by IBM.

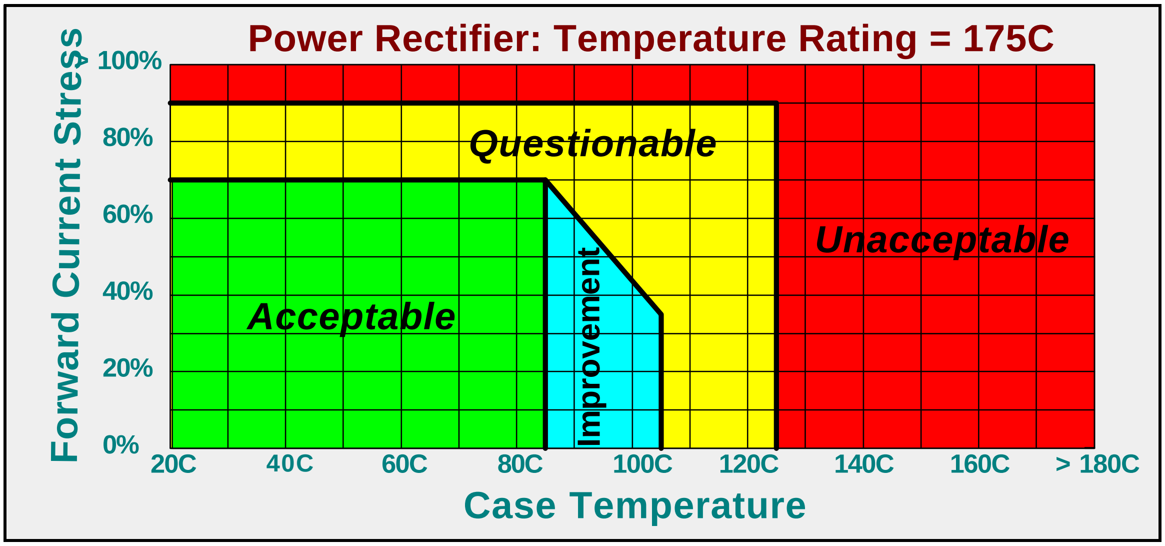
A graph of allowed stress versus operating temperature can be constructed for each parameter derated versus operating temperature of the component. This will not be done in this document. An example of how this can be done is given in the following for the forward current derating of a power rectifier with a junction temperature rating of 175ºC:



Often the questionable region is divided into a sub region called am "Improvement Area." This is an area where the operating temperature may be in the questionable region, but stress is within acceptable limits. This region is defined as follows:

Improvement: The component is operating at a temperature slightly above ideal thermal limits. Stresses and use of the component should be analyzed for possible improvements. Use of the component in this operating range is generally considered to be a low risk. Engineering judgment is necessary to determine if changes are needed.

For the proceeding example, adding the "Improvement Area" to the graph changes it as follows:



The improvement area is typically used to define low risk components which should be reviewed after thermal testing is completed.

For this document, it is assumed that all temperature measurements are made at 25ºC and that the assembly is rated for a maximum ambient environment of 45ºC unless otherwise stated.

1.0 Semiconductor Devices

1.1 Failure Modes / Thermal Characteristics

The following lists common failure modes for FETs and transistors:

- Operating voltage or reverse voltage too high
- Forward current too high
- Excessive power dissipation
- Ambient temperature too high / ineffective cooling
- Excessive leakage or reverse currents
- Recovery times / frequency response
- Variations of reference voltages versus temperature

Power losses in these devices (especially FETS in switching applications) consist of 2 components:

Conduction losses: Ohmic losses which may be controlled by using low on-resistance devices or by operating at lower current levels.

Switching losses: Caused by the simultaneous presence of voltage and current during turn-on and turn-off. The effect reduced by using 0-voltage or 0-current switching schemes.

Power losses increase the junction temperature (T_j) of the device.

In general, the ambient or working temperature affects semiconductor devices as follows:

- Breakdown voltage increases with temperature
- On-resistance increases with temperature
- Leakage current increases with temperature
- Gate-to-source threshold voltage decreases with temperature
- Forward voltage drop decreases with temperature

These devices usually fail catastrophically and often damage several other components when they fail. Careful examination of the entire circuit on a repaired or undamaged sample is often required to determine the cause of the failure.

When evaluating the thermal stress and acceptability for these types of components, account for the junction-to-case thermal resistance. This factor defines the minimum difference between the junction and case temperature at a given level of power dissipation. High junction-to-case thermal resistance can make devices running hot appear deceptively cool.

1.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Forward Current (continuous)
- Peak Transient Voltage Stress
- Reverse Voltage Stress
- Reverse Current Stress
- Junction Temperature (T_j)

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Avalanche rating
- dV/dt requirements
- Peak repetitive reverse current
- Reverse recovery
- Gate to source voltage on FETs

All of the guidelines in the following sections must be met in the worst case operating environment for the component.

1.2.1 Derating Guidelines: Forward Current Stress

Component Type	Parameter	Acceptable Region	Questionable Region	Unacceptable Region
FET	I_D	< 60%	60% to 80%	> 80%
Transistors	I_C	< 60%	60% to 80%	> 80%
Small Signal Diodes	I_F	< 50%	50% to 75%	> 75%
Schottky Type Diodes	I_{PEAK}, I_F	< 65%	65% to 80%	> 80%
Power Rectifier	I_{PEAK}, I_F	< 70%	70% to 90%	> 90%
Transient Suppresser	I_{tm}, I_P	< 70%	70% to 80%	> 80%
Zener Type Diodes	I_{ZM}	< 60%	60% to 75%	> 75%
IGBT Types	I_C	< 60%	60% to 80%	> 80%
Thyristor / SCR Types	$I_{T(Ave)}$, $I_{T(RMS)}$	< 60%	60% to 80%	> 80%
Triac Types	$I_{T(RMS)}$ I_{TSM}	< 60% < 60%	60% to 80% 60% to 75%	> 80% > 75%
Other Types	I_D,I_C, I_F	< 60%	60% to 75%	> 75%
Note: Additional derating may be needed for devices operating in parallel.				

1.2.2 Derating Guidelines: Voltage Stresses

Component Type	Parameter	Acceptable Region	Questionable Region	Unacceptable Region
FET	V_{DSS} (1) $V_{DSS(AR)}$	< 80% < 90%	80% to 90% 90% to 100%	> 90% > 100%
Transistors	V_{CE}	< 70%	70% to 85%	> 85%
Small Signal Diodes	V_R	< 65%	65% to 75%	> 75%
Schottky Type Diodes	V_R	< 70%	70% to 85%	> 85%
Power Rectifier	V_R (2) $V_{R(SR)}$	< 70% < 80%	70% to 80% 80% to 90%	> 80% > 90%
Transient Suppresser	(3) V_M, V_C, V_{DR}	< 70%	70% to 80%	> 80%
Zener Type Diodes	V_R	< 65%	65% to 75%	> 75%
IGBT Types	V_{CE}	< 70%	70% to 85%	> 85%
Thyristor / SCR Types	V_{DRM}, I_{RRM}	< 65%	65% to 80%	> 80%
Triac Types	V_{DRM}, I_{RRM}	< 65%	65% to 80%	> 80%
Other Types	V_D,V_R, V_{DSS}, V_{CE}, etc.	< 50%	50% to 70%	> 70%

Note: **(1)** This higher derating is valid for "Avalanche Rated" parts only. The breakdown voltage rating may be allowed to be higher than $V_{DSS(BR)}$ during faults if the avalanche energy is low.
(2) For "Surge Rated" parts, the breakdown voltage rating may be higher than V_R.
(3) During faults, these devices may be used near 100% of the rates stress for short periods of time.

1.2.3 Derating Guidelines: Reverse or Off Current Stress

Component Type	Parameter	Acceptable Region	Questionable Region	Unacceptable Region
FET	I_{DSS}	< 60%	60% to 75%	> 75%
Transistors	N/A	N/A	N/A	N/A
Small Signal Diodes	N/A	N/A	N/A	N/A
Schottky Type Diodes	I_R	< 60%	60% to 80%	> 80%
Power Rectifier	N/A	N/A	N/A	N/A
Transient Suppresser	I_A	< 60%	60% to 80%	> 80%
Zener Type Diodes	I_R	< 60%	60% to 80%	> 80%
IGBT Types	N/A	N/A	N/A	N/A
Thyristor / SCR Types	N/A	N/A	N/A	N/A
Triac Types	N/A	N/A	N/A	N/A
Other Types	I_{DSS}, I_R	< 50%	50% to 70%	> 70%

1.2.4 Derating Guidelines: Junction Temperature (T_J)

For this type of component, the temperature measured is the case temperature. To calculate the junction temperature, use the following formula:

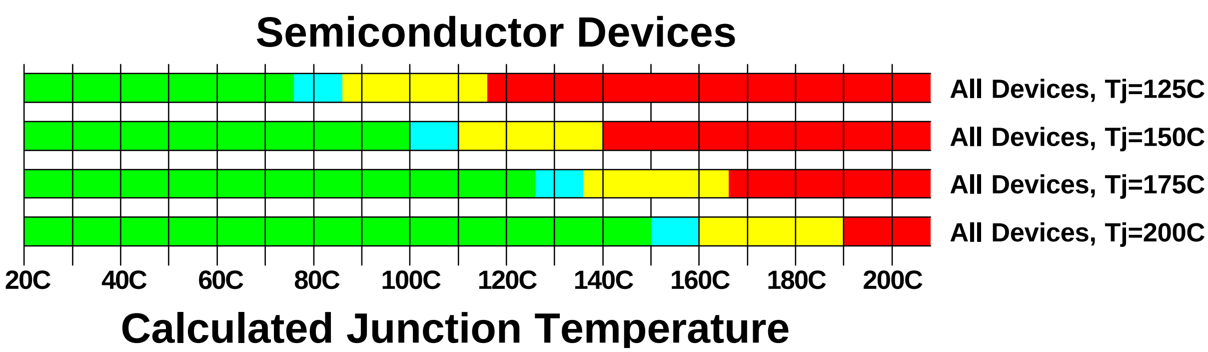
$$T_J = T_C + \theta_{JC}P$$

Where: T_J = Maximum Junction Temperature
T_C = Case Temperature
θ_{JC} = Junctions-to-Case Thermal Resistance
P = Power Dissipated In The Device

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
FET	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Transistors	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Small Signal Diodes	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Schottky Type Diodes	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Power Rectifier	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Transient Suppresser	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Voltage Reference	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Zener Type Diodes	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Thyristor / SCR Types	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Triac Types	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Other Types	< (T_J-50)°C	(T_J-50)°C to (T_J-10)°C	> (T_J-10)°C
Note: T_J is the maximum rated junction temperature of the component.			

1.3 Thermal Test Acceptability Guidelines

The following graph indicates the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25°C and that the worst case environment for the assembly is 45°C. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.



Note: The critical parameter for Semiconductor Devices is **Junction Temperature, T_J.** **T_J is not the case temperature.** The case temperature is measured and the junction temperature is calculated using the formula given in Section 1.2.4.

2.0 Resistors

2.1 Failure Modes / Thermal Characteristics

Common failure modes for resistors follow:

- Operating voltage too high
- Excessive power dissipation
- Ambient temperature too high / ineffective cooling
- Inductive losses at higher frequencies (especially for wire wound power resistors)

The resistance of resistors typically goes down as the temperature is increased, but the effect is generally minimal.

2.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Power Stress
- Voltage Stress
- Temperature Stress

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Aging effects on resistance value
- Temperature effects on resistance value
- Inductance of leads and resistive element
- Flammability issues
- Maintain needed spacing for the voltage on the resistor body

All of the guidelines in the following sections must be met in the worst case operating environment for the component.

2.2.1 Derating Guideline: Power

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Composition Types	10% to 50%	< 10%, 50% to 75%	> 75%
Carbon Film Types	< 50%	50% to 75%	> 75%
Insulated Film Types	< 50%	50% to 75%	> 75%
Metal Film Types	< 60%	60% to 80%	> 80%
Power Wirewound	< 65%	65% to 80%	> 80%
SMT Thin Film	< 40%	40% to 70%	> 70%
SMT Thick Film	< 50%	50% to 75%	> 75%
MELF (Cylindrical)	< 60%	60% to 75%	> 75%
PTC Resistors	< 60%	60% to 75%	> 75%
Fuses (current)	< 75%	75% to 90%	> 90%
Other Resistor Types	< 50%	50% to 80%	> 75%
Note: The surge energy for surge rated parts must never be exceeded.			

2.2.2 Derating Guideline: Voltage Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Composition Types	< 75%	75% to 85%	> 85%
Carbon Film Types	< 75%	75% to 85%	> 85%
Insulated Film Types	< 75%	75% to 85%	> 85%
Metal Film Types	< 75%	75% to 85%	> 85%
Power Wirewound	< 75%	75% to 85%	> 85%
SMT Thin Film	< 70%	70% to 80%	> 80%
SMT Thick Film	< 70%	70% to 80%	> 80%
MELF (Cylindrical)	< 70%	70% to 80%	> 80%
PTC Resistors	< 60%	60% to 80%	> 80%
Fuses	< 90%	90% to 100%	> 100%t
Other Resistor Types	< 75%	75% to 85%	> 85%

2.2.3 Derating Guideline: Temperature Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Composition Types *Flush Mount* *Stood Off*	 < 60°C < (Tr-30-Td)°C	 60°C to 80°C (Tr-30-Td)°C to (Tr-10-Td)°C	 > 80°C > (Tr-10-Td)°C
Carbon Film Types *Flush Mount* *Stood Off*	 < 60°C < (Tr-40-Td)°C	 60°C to 80°C (Tr-40-Td)°C to (Tr-10-Td)°C	 > 80°C > (Tr-10-Td)°C
Insulated Film Types *Flush Mount* *Stood Off*	 < 60°C < (Tr-40-Td)°C	 60°C to 80°C (Tr-40-Td)°C to (Tr-10-Td)°C	 > 80°C > (Tr-10-Td)°C
Metal Film Types *Flush Mount* *Stood Off*	 < 80°C < (Tr-40-Td)°C	 80°C to 100°C (Tr-40-Td)°C to (Tr-10-Td)°C	 > 100°C > (Tr-10-Td)°C
Power Wirewound *Flush Mount* *Stood Off*	 < 80°C < (Tr-25-Td)°C	 80°C to 100°C (Tr-25-Td)°C to (Tr-10-Td)°C	 > 100°C > (Tr-10-Td)°C
SMT Thin Film *Temperature Rise* *Absolute Temp.*	 < 25°C < 70°C	 25°C to 40°C 70°C to 90°C	 > 40°C > 90°C
SMT Thick Film *Temperature Rise* *Absolute Temp.*	 < 35°C < 70°C	 35°C to 50°C 70°C to 90°C	 > 50°C > 90°C
MELF (Cylindrical) *Temperature Rise* *Absolute Temp.*	 < 35°C < 85°C	 35°C to 50°C 85°C to 100°C	 > 50°C > 100°C
PTC Resistor Types *Flush Mount* *Stood Off*	 < 70°C < (Tr-30-Td)°C	 70°C to 80°C (Tr-30-Td)°C to (Tr-10-Td)°C	 > 80°C > (Tr-10-Td)°C
Fuses *Absolute Temp.*	 < 35°C	 35°C to 45°C	 > 45°C
Other Resistor Types *Flush Mount* *Stood Off*	 < 60°C < (Tr-30-Td)°C	 60°C to 80°C (Tr-30-Td)°C to (Tr-10-Td)°C	 > 100°C > (Tr-10-Td)°C

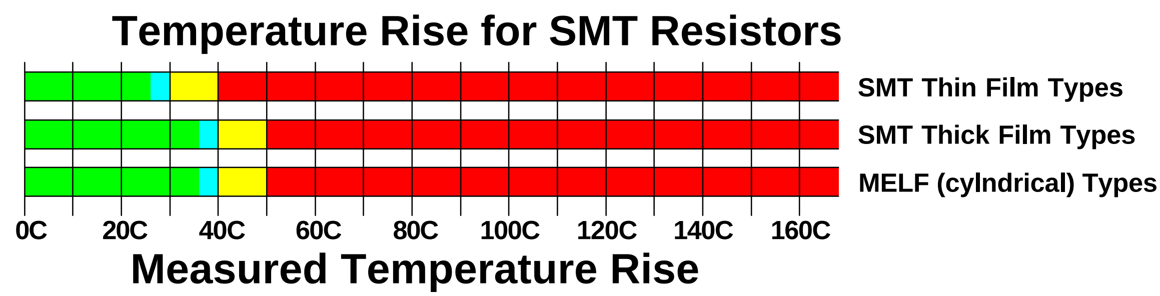
Note 1: **Tr** is the rated temperature of the component.
Tm is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25°C

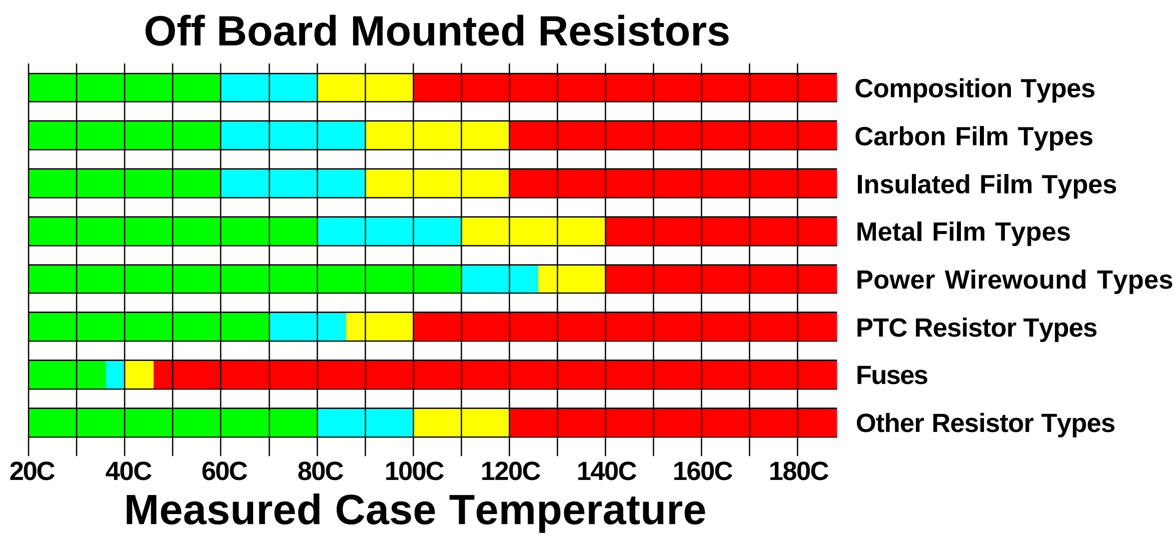
Note 2: In addition to these requirements, the PC board and solder joints near the resistor must be kept below their maximum limits under all operating conditions.

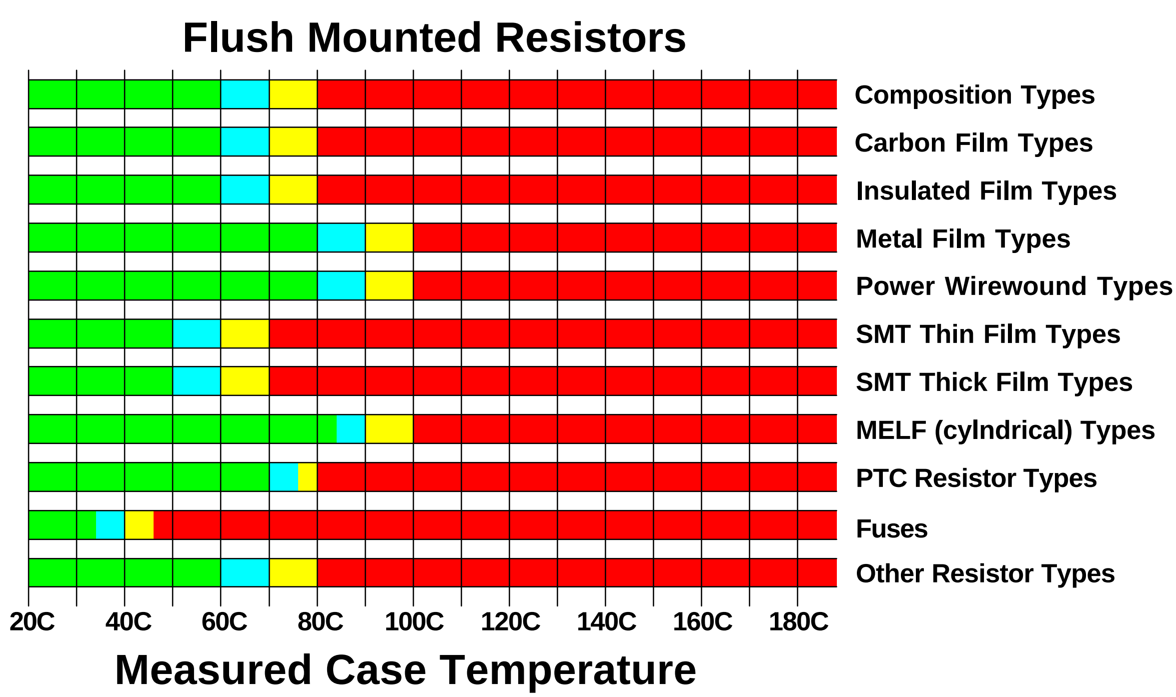
Note 3: All measurements are assumed to be made at an ambient temperature of 25°C. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25°C.

2.3 Thermal Test Acceptability Guidelines

The following graphs indicate the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25°C and that the worst case environment for the assembly is 45°C. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.


Temperature Rise for SMT Resistors
SMT Thin Film Types
SMT Thick Film Types
MELF (cylndrical) Types
0C
20C
40C
60C
80C
100C
120C
140C
160C
Measured Temperature Rise


Off Board Mounted Resistors
Composition Types
Carbon Film Types
Insulated Film Types
Metal Film Types
Power Wirewound Types
PTC Resistor Types
Fuses
Other Resistor Types
20C
40C
60C
80C
100C
120C
140C
160C
180C
Measured Case Temperature


Flush Mounted Resistors
Composition Types
Carbon Film Types
Insulated Film Types
Metal Film Types
Power Wirewound Types
SMT Thin Film Types
SMT Thick Film Types
MELF (cylndrical) Types
PTC Resistor Types
Fuses
Other Resistor Types
20C
40C
60C
80C
100C
120C
140C
160C
180C
Measured Case Temperature

3.0 Capacitors

3.1 Failure Modes / Thermal Characteristics

The following are common reasons for capacitor failure:

- Too high a working voltage
- Too low a working voltage (mainly electrolytic capacitors)
- Operating or ambient temperature too high
- Capacitance changes over lifetime or due to ambient temperature changes (especially high capacitance ceramic and aluminum electrolytic capacitors)
- Surges beyond ratings
- Ripple current

In general, the ambient or working temperature affects capacitors as follows:

- Large value capacitors (especially electrolytic and ceramic type) are quite sensitive to temperature variations. Capacitance decreases as temperature increases.
- The ESR (equivalent series resistance) of electrolytic capacitors increases as the temperature increases. The ripple current varies proportionally with the ESR.
- Increased temperature accelerates evaporation of the electrolyte in electrolytic capacitors, reducing capacitance and creating pressure inside the capacitor.

Electrolytic capacitors usually have the shortest expected lifetime of all the components used in power assemblies. As the components age, electrolyte volume decreases. This results in incomplete filling of the etch tunnels with electrolyte, reducing the capacitance and increasing the ESR. Increased ambient and internal temperatures accelerate this process. The internal temperature of electrolytic capacitors increases when the component is subjected to high levels of voltage or ripple current stress. Problems usually manifest themselves as excessive ripple current due to reduced output capacitance, physical failure of the device, or stability problems due to the increased ESR.

Many types of ceramic capacitors are sensitive to temperature variations, especially high value capacitors with Z5U, Y5V, or other types of dielectric with a high dielectric constant. The capacitance may change significantly over the life and operating temperature range of the assembly. This may cause stability problems if the capacitor is used in a feedback loop or timing problems if it is part of a timing circuit. Also, the initial capacitance value for these types of capacitors tends to have a much wider specified range. This can also lead to various types of problems.

Tantalum capacitors are very sensitive to the applied voltage. Often, tantalum capacitor failures only cause a temporary failure of the assembly because tantalum capacitors tend to heal themselves. Excessive current in the failure area burns the short circuit open. These types of problems can be very difficult to find. Many times a tantalum capacitor needs to fail several times before degrading to the point where the problem can be identified.

There are many other types of capacitors present in power assemblies. Their reaction and sensitivity to stress varies widely from one component type to the next. If failures occur, determine the cause of the failure and compare it to the capabilities of the component.

3.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Voltage Stress
- Ripple Current Stress
- Temperature Stress

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Aging effects
- Operating frequency effects
- Temperature effects
- Dissipation factor, ESR, leakage current, Q, etc.

All of the guidelines in the following sections must be met in the worst case operating environment for the component.

3.2.1 Derating Guidelines: Voltage Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Multilayer Ceramic Types	< 60%	60% to 70%	> 70%
Disc Ceramic Types	< 70%	70% to 80%	> 80%
Aluminum Electrolytic < 250V rated > 250V rated	 30% to 70% 30% to 85%	 < 30%, 70% to 80% < 30%, 85% to 90%	 > 80% > 90%
Tantalum (PTH)	< 45%	45% to 55%	> 55%
Solid Tantalum (SMT)	< 30%	30% to 40%	> 40%
Solid Polymer	< 70%	70% to 85%	> 85%
Plastic Film Types	< 70%	70% to 85%	> 85%
X/Y Capacitor Types	< 100%	N/A	>= 100%
Other Capacitor Types	0% to 50%	50% to 70%	> 70%
Note: Any short term surge voltages must be below the upper limit of the "Questionable" region.			

3.2.2 Derating Guidelines: Ripple Current Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Multilayer Ceramic Types	< 70% (Note 1)	70% to 80% (Note 1)	> 80% (Note 1)
Disc Ceramic Types	< 70% (Note 1)	70% to 80% (Note 1)	> 80% (Note 1)
Aluminum Electrolytic	< 70%	70% to 80%	> 80%
Tantalum (PTH)	< 40%	40% to 80%	> 80%
Solid Tantalum (SMT)	< 40%	40% to 80%	> 80%
Solid Polymer	< 70%	70% to 80%	> 80%
Plastic Film Types	< 70%	70% to 85%	> 85%
X/Y Capacitor Types	< 100%	N/A	>= 100%
Other Capacitor Types	< 60%	60% to 80%	> 80%
Note 1: Only if this parameter is rated on the components chosen. Otherwise, use temperature rise as an indicator.			

3.2.3 Derating Guidelines: Temperature Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Multilayer Ceramic Types *Trise (Note 2)* *Absolute Temp.*	 < 30°C < (Tr-20-Td)°C	 30°C to 40°C (Tr-20-Td)°C to (Tr-10-Td)°C	 > 40°C > (Tr-10-Td)°C
Disc Ceramic Types	< (Tr-20-Td)°C	(Tr-20-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Aluminum Electrolytic	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Tantalum (PTH)	< 65°C	65°C to 75°C	> 75°C
Solid Tantalum (SMT)	< 65°C	65°C to 75°C	> 75°C
Solid Polymer	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C

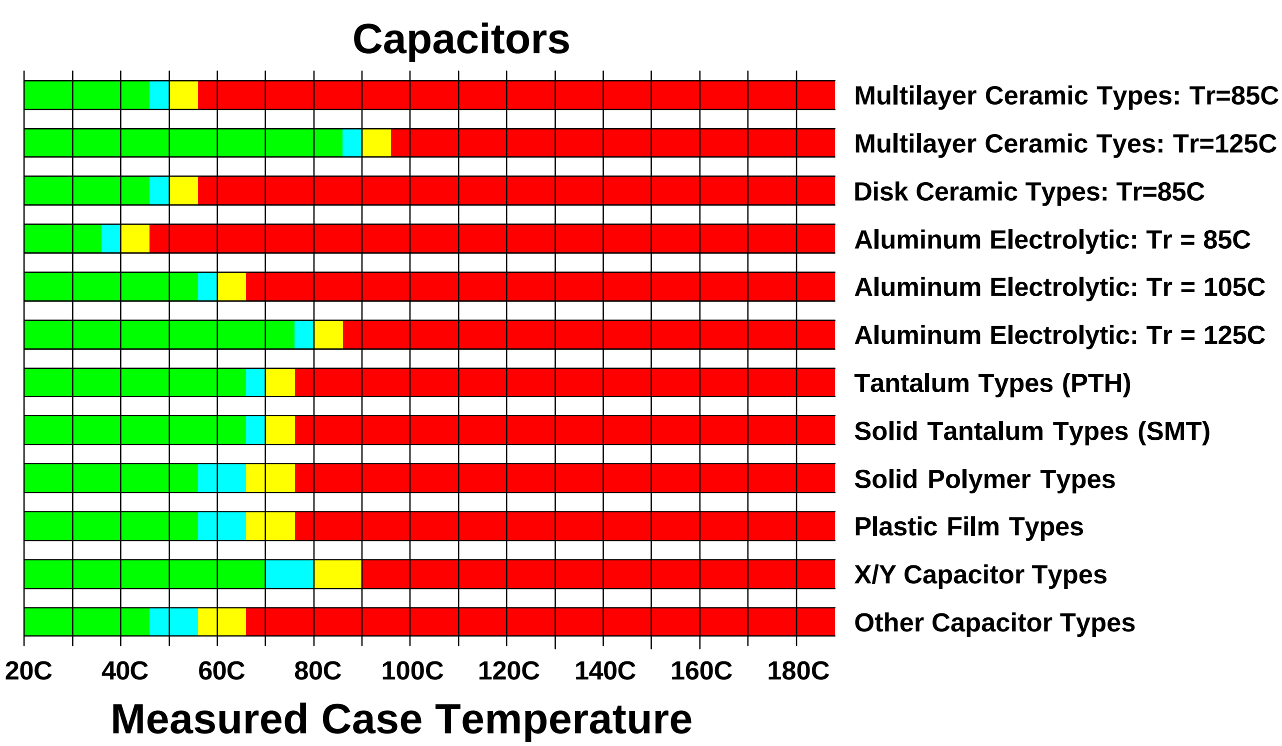
Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Plastic Film Types	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
X/Y Capacitor Types	< 100%	N/A	>= 100%
Other Capacitor Types	< (Tr-20-Td)°C	(Tr-20-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C

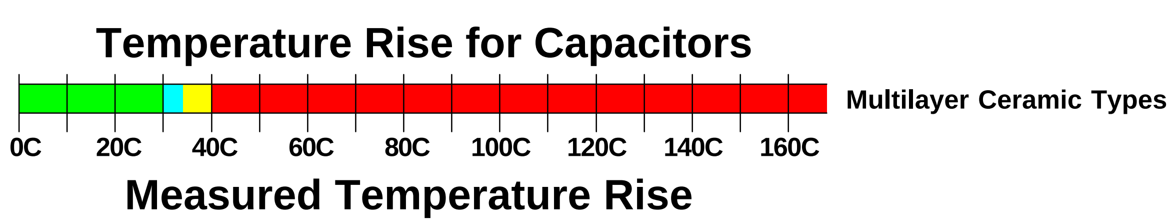
Note 1: **Tr** is the rated temperature of the component.
Tm is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25°C

Note 2: All measurements are assumed to be made at an ambient temperature of 25°C. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25°C.

3.3 Thermal Test Acceptability Guidelines

The following graphs indicate the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25°C and that the worst case environment for the assembly is 45°C. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.





4.0 Magnetic Components

4.1 Failure Modes / Thermal Characteristics

The following are common reasons for failure of transformers and inductors:
- Operating voltage or current levels too high
- Excessive power dissipation
- Ambient temperature too high / ineffective cooling
- Operating frequency versus self resonant frequency
- Material selection of core, insulation, and windings

Magnetic components may be improved by using core materials with lower loss and by replacing standard wire in the windings with Litz wire, multi-filar wire, or copper ribbon, especially in higher frequency applications. Often, these types of changes are needed to reduce power losses and leakage inductance while producing symmetric, predictable voltages at the output windings. Magnetics may also be improved by using plastics and insulation rated for higher temperatures.

4.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components based on the type of material used to construct the core:
- Core Flux Density
- Insulation Breakdown Voltage
- Plastic Part Temperature Ratings
- Winding Material Temperature Ratings
- Core Temperature Ratings

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:
- Current density in the windings
- Frequency effects in the windings (skin effect losses)
- Surge currents
- Operational and surge voltages

All of the following guidelines in the following sections must be met in the worst case operating environment for the component.

4.2.1 Derating Guidelines: Core Flux Density

Core Material	Acceptable Region	Questionable Region	Unacceptable Region
Ferrite			
Continuous	< 60%	60% to 80%	> 80%
< 50kHz	< 50%	50% to 60%	> 60%
50kHz to 100kHz	< 45%	45% to 55%	> 55%
100kHz to 500kHz	< 25%	25% to 35%	> 35%
500kHz to 1MHz	< 10%	10% to 20%	> 20%
Powdered Iron	< 60%	60% to 80%	> 80%
Metglas	< 60%	60% to 80%	> 80%
Amorphous	< 60%	60% to 80%	> 80%

Core Material	Acceptable Region	Questionable Region	Unacceptable Region
Laminent	< 60%	60% to 80%	> 80%
Other Types	< 60%	60% to 80%	> 80%

Note: Percentages given are the percent of peak core flux density versus $\mathbf{B_{sat}}$ when the supply is working under worst case conditions.

4.2.2 Insulation Breakdown Voltage

Requirement	Acceptable Region	Questionable Region	Unacceptable Region
Agency (Note 1)	> 1.1(AR)	(AR) to 1.1(AR)	< (AR)
Working Voltage	> 3(WV)	2(WV) to 3(WV)	< 2(WV)
Peak Voltage	> 2(PV)	1.5(PV) to 2(PV)	< 1.5(PV)

Note 1: Agency is the most stringent applicable safety agency requirement for the assembly.
Definitions: **AR** = Agency Requirements (for example, EN60950)
WV = Working Voltage
PV = Peak Voltage

4.2.3 Plastic Material Temperature Rating

Insulation Class	Acceptable Region	Questionable Region	Unacceptable Region
135°C	< (110-Td)°C	(110-Td)°C to (125-Td)°C	> (125-Td)°C
150°C	< (125-Td)°C	(125-Td)°C to (140-Td)°C	> (140-Td)°C
180°C	< (155-Td)°C	(155-Td)°C to (170-Td)°C	> (170-Td)°C

Note 1: **Tm** is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25°C
Note 2: All measurements are assumed to be made at an ambient temperature of 25°C. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25°C.

4.2.4 Winding Material Temperature Rating

Winding Material	Acceptable Region	Questionable Region	Unacceptable Region
All Types	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C

Note 1: **Tr** is the rated temperature of the component.
Tm is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25°C
Note 2: All measurements are assumed to be made at an ambient temperature of 25°C. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25°C.
Note 3: Temperatures must be measured with a thermocouple between each layer or winding to find the worst case operating temperature. The temperature between the first winding and the core should also be measured with the thermocouple.

4.2.5 Derating Guidelines: Core Temperature

Core Material	Acceptable Region	Questionable Region	Unacceptable Region
Ferrite	< (Tr-20-Td)°C	(Tr-20-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Powdered Iron	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Metglas	< (Tr-20-Td)°C	(Tr-20-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Amorphous	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Laminent	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C
Other Types	< (Tr-30-Td)°C	(Tr-30-Td)°C to (Tr-10-Td)°C	> (Tr-10-Td)°C

Core Material	Acceptable Region	Questionable Region	Unacceptable Region

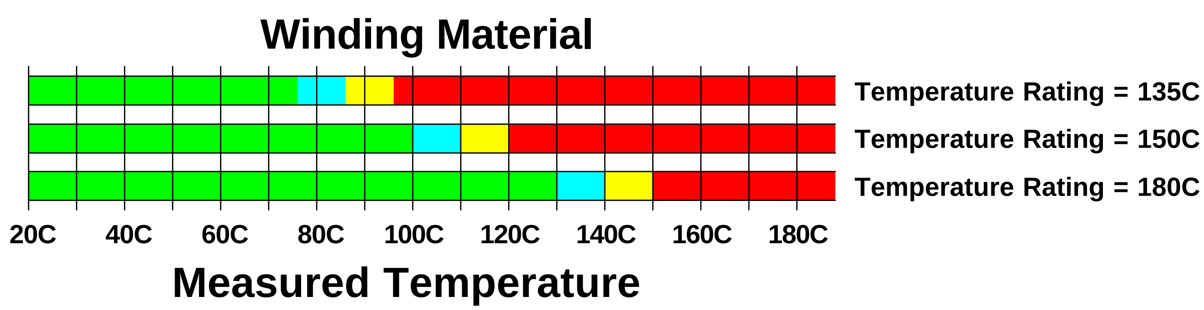
Note 1: **Tr** is the rated temperature of the component.
Tm is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25ºC

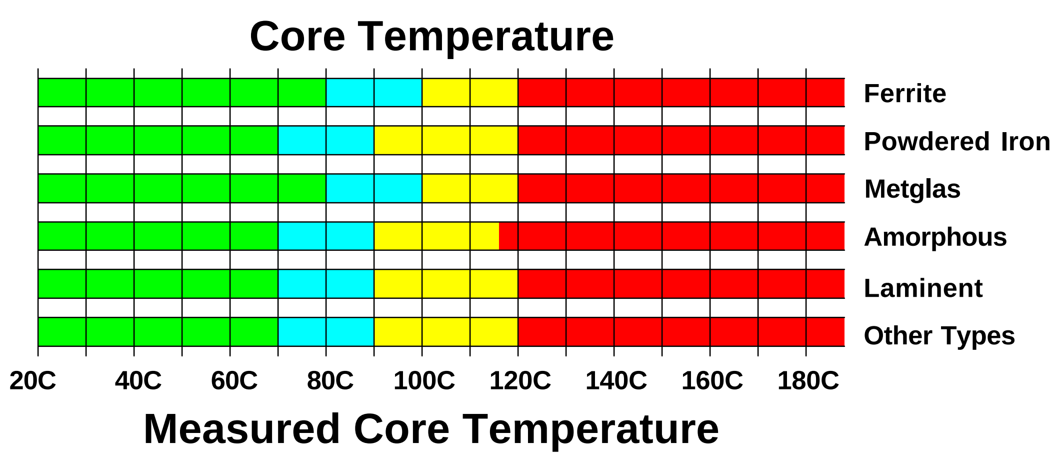
Note 2: All measurements are assumed to be made at an ambient temperature of 25ºC. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25ºC.

Note 3: All measurements must be made on the core itself. Measurements of case or winding temperatures are not adequate. The temperature between the core and the first winding should also be measured with a thermocouple.

4.3 Thermal Test Acceptability Guidelines

The following graphs indicate the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25ºC and that the worst case environment for the assembly is 45ºC. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.





5.0 Digital and Linear Microcircuits

5.1 Failure Modes / Thermal Characteristics

The following are common reasons for failure of active logic and control modules:

- Too much output current required from the module
- Input signals at too high a voltage
- Input voltage source at too high a voltage
- Too high of an operating temperature
- Losses due to high frequency effects

Increased ambient temperature may affect these types of components by:

- Changing current available from current sources
- Changing voltage reference or threshold levels
- Changing the operating frequency or delay times
- Increasing power dissipation

5.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Input Voltage Stress
- Input Sink Current Stress
- Output Current Stress (or fan out)
- Supply Voltage Stress
- Junction Temperature (T_j)

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Frequency of operation
- Frequency drift
- Thermal drift
- The use of internal zener diodes to clamp bias voltages

All of the following guidelines must be met in the worst case operating environment for the component.

5.2.1 Derating Guidelines: Input Voltage Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Linear Microcircuits			
Continuous	< 100%	NA	> 100%
Surge	< 100%	NA	> 100%
LSI, VLSI, ASIC's	< 100%	NA	> 100%
Drivers			
Continuous	< 100%	NA	> 100%
Surge	< 100%	NA	> 100%
Microprocessors	NA	NA	NA
Memory	NA	NA	NA
Other Applicable Types			
Continuous	< 100%	NA	> 100%
Surge	< 100%	NA	> 100%
Note: The input voltage stress pertains to gate signal inputs to the component.			

5.2.2 Derating Guidelines: Input Sink Current Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Linear Microcircuits	< 60%	60% to 75%	> 75%
LSI, VLSI, ASIC's	< 60%	60% to 75%	> 75%
Drivers, PWM's	< 60%	60% to 75%	> 75%
Microprocessors	< 60%	60% to 75%	> 75%
Memory	< 60%	60% to 75%	> 75%
Other Applicable Types	< 60%	60% to 75%	> 75%

5.2.3 Derating Guidelines: Output Current Stress (Fan Out)

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Linear Microcircuits	< 75%	75% to 85%	> 85%
LSI, VLSI, ASIC's	< 80%	80% to 90%	> 90%
Drivers, PWM's	< 75%	75% to 85%	> 85%
Microprocessors	< 80%	80% to 90%	> 90%
Memory	< 80%	80% to 90%	> 90%
Other Applicable Types	< 75%	75% to 85%	> 85%

5.2.4 Derating Guidelines: Supply Voltage (V_{cc}) Stress

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Linear Microcircuits	< 100%	NA	> 100%
LSI, VLSI, ASIC's	within specified range	NA	outside specified range
Drivers, PWM's	< 100%	NA	> 100%
Microprocessors	within specified range	NA	outside specified range
Memory	within specified range	NA	outside specified range
Other Applicable Types	< 100% within specified range	NA NA	> 100% outside specified range

5.2.5 Derating Guidelines: Junction Temperature (T_J)

For this type of component, the temperature measured is the case temperature. To calculate the junction temperature, use the following formula:

$T_J = T_C + \theta_{JC}P$

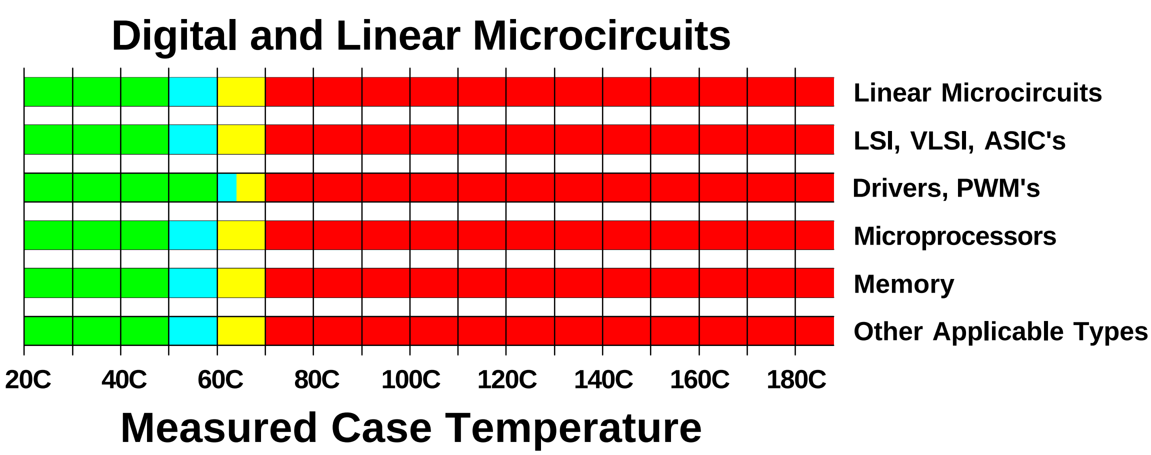
Where: T_J = Junction Temperature
T_C = Case Temperature
θ_{JC} = Junctions-to-Case Thermal Resistance
P = Power Dissipated In The Device

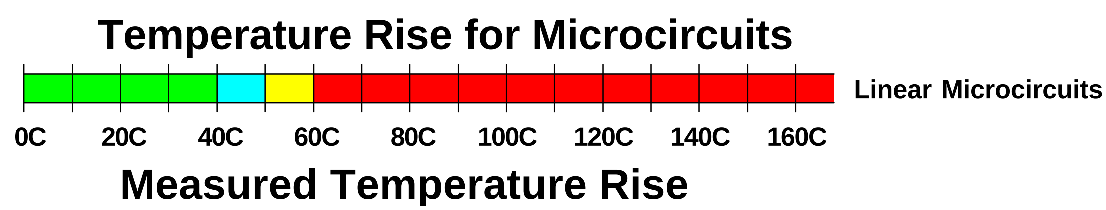
Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Linear Microcircuits *Absolute Temperature* *Temperature Rise*	 < 70°C < 40°C	 70°C to 90°C 40°C to 60°C	 > 90°C > 60°C
LSI, VLSI, ASIC's	< 70°C	70°C to 90°C	> 90°C
Drivers, PWM's	< 80°C	80°C to 90°C	> 90°C
Microprocessors	< 70°C	70°C to 90°C	> 90°C
Memory	< 70°C	70°C to 90°C	> 90°C
Other Applicable Types	< 70°C	70°C to 90°C	> 90°C

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Note: T_J is the maximum rated junction temperature of the component.			

5.3 Thermal Test Acceptability Guidelines

The following graphs indicate the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25ºC and that the worst case environment for the assembly is 45ºC. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.





6.0 Connectors and Cables

6.1 Failure Modes / Thermal Characteristics

The following are common reasons for failure of connectors and cables:

- Physical build problems
- Wrong or incompatible plating materials
- Terminal push out
- Wrong terminal length
- Insertion problems

Increased ambient temperature may affect these types of components by:

- Brittle or melted cable insulation or connector housings
- Formation of oxide layers
- Mechanical breakage

6.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Current per pin
- Overall temperature rise
- Low current metallurgy

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Crimp quality (over-crimp, under-crimp, crimp on insulation, lose strands, etc.)
- Metallurgy for mating
- Plating thickness
- Porosity

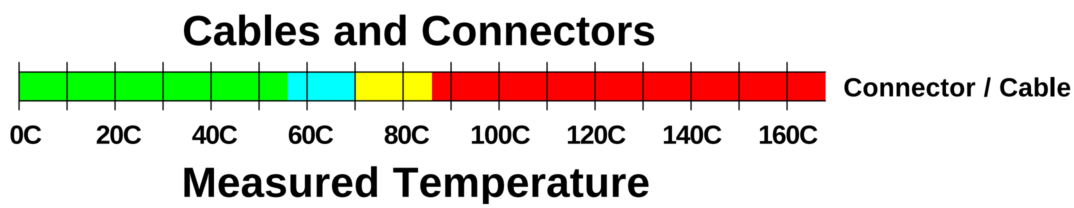
All of the following guidelines must be met in the worst case operating environment for the component.

6.2.1 Derating Guidelines:

Derating Parameter	Acceptable Region	Questionable Region	Unacceptable Region
Current Per Pin			
Single pin	< 80%	80% to 100%	> 100%
Multiple pins	< 70%	70% to 100%	> 100%
Temperature			
Percent of Rating	< 70%	70% to 100%	> 100%
Rise	< 30°C	30°C to 60°C	> 60°C
Metallurgy			
Gold	< 90%	90% to 100%	> 100%
Tin/Lead - low current	> 0.5A	0.2A to 0.5A	< 0.2A
Tin/Lead - percent	< 90%	90% to 100%	> 100%
Note: Percentages are the percent of the maximum rating for the connector.			

6.3 Thermal Test Acceptability Guidelines

The following graph indicates the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25°C and that the worst case environment for the assembly is 45°C. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures. For all temperature measurements, the cables and connectors must be operating at least 10°C below the specified limit for the materials under worst case conditions.



7.0 Electromechanical Devices

7.1 Failure Modes / Thermal Characteristics

Electromechanical devices requiring derating include:

- Relays
- Fans and blowers
- Circuit breakers

The following are common reasons for failure of electromechanical devices:

- Shorted winding
- Contact stick
- Bearing problems

Increased ambient temperature may affect these types of components by:

- Evaporation of lubricant in fans
- Change of trip levels for circuit breakers
- Various mechanical failures

7.2 Derating Guidelines

The following lists critical parameters typically derated for these types of components:

- Relays
  - Current
  - Voltage
  - Coil voltage
- Fans and blowers
  - Input voltage
- Circuit Breakers
  - Continuous current
  - Voltage

There are several critical parameters where derating guidelines are very difficult to specify. These parameters have to be evaluated on a case by case basis when applicable. Components may be considered to be operating under unacceptable levels of stress by IBM even if the component is operating within all the derating guidelines in the following sections. Some of these additional critical parameters include:

- Relays
  - Number of picks during life
  - Pick frequency
  - Make or break current
  - Contact metallurgy
  - Contact heating
  - Contact resistance

  - De-bouncing requirements
  - Arch suppression
- Fans and blowers
  - Voltage slew rate during power on
  - Acoustics
  - Bearing grease
  - Bearing type
  - Retaining clip method
  - Air flow variation
  - Microcode quality
  - Hall output
- Circuit Breakers
  - Surge current versus time
  - Heating
  - Resistance
  - Construction
  - Reset method

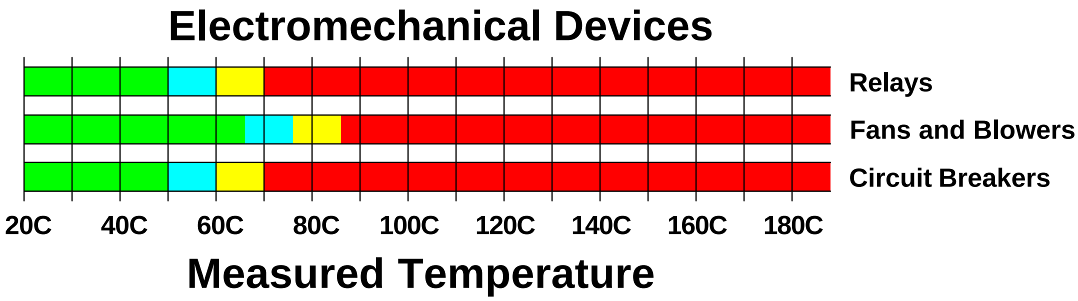
All of the following guidelines must be met in the worst case operating environment for the component.

7.2.1 Derating Guidelines:

Component Type	Acceptable Region	Questionable Region	Unacceptable Region
Relay			
Voltage	< 90%	90% to 100%	> 100%
Current	< 80%	80% to 100%	> 100%
Coil Voltage	within specified limits	NA	outside specified limits
Fans and blowers			
Input voltage	within specified limits	NA	outside specified limits
Circuit breakers			
Continuous current	< 80%	80% to 95%	> 95%
Voltage	< 90%	90% to 100%	> 100%

7.3 Thermal Test Acceptability Guidelines

The following graph indicates the acceptability of the component based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25ºC and that the worst case environment for the assembly is 45ºC. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.



8.0 Other Electronic Components

Other types of components that do not fit into any of the previous categories may also require derating. Derating guidelines for these components will be defined in this section. Critical parameters to be derated will be listed along with thermal acceptability criteria. Additionally, any critical parameters where deratings are difficult to specify may be included along with the effects of increased ambient temperature on these components.

8.1 Printed Circuit Boards (PCBs)

PCBs are stable until they are exposed to thermal conditions somewhat above the temperature rating of the material for a long period of time. However, long term exposure to temperatures near the temperature rating of the material can also result in discoloring and the eventual failure of the board.

The following parameter should be derated for PCB assemblies:
- Temperature Stress

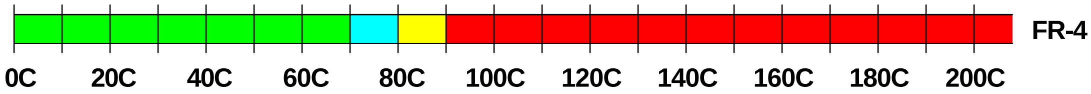
PCB Temperature Stress Derating Guidelines			
Material Type	Acceptable Region	Questionable Region	Unacceptable Region
All Materials	< (Tr-10-Td)°C	(Tr-10-Td)°C to (Tr-Td)°C	> (Tr-Td)°C

Note 1: **Tr** is the rated temperature of the material.
Tm is the maximum specified ambient operating temperature for the assembly.
Td = Tm - 25ºC
Note 2: All measurements are assumed to be made at an ambient temperature of 25ºC. The temperatures listed above must be adjusted accordingly if the ambient temperature is not 25ºC.

Additionally, any component touching the PCB must meet these derating guidelines.

The following graph indicates the acceptability of the PCBs based on thermal testing. It is assumed that measurements were taken at an ambient temperature of 25ºC and that the worst case environment for the assembly is 45ºC. If the ambient temperature of the measurement or the worst case environment differs from these values, the graphs must be adjusted accordingly. In cases where fan speed is proportional to the ambient temperature, this test should be repeated at the minimum and maximum specified operating temperatures for the assembly. The additional testing is needed to insure that no thermal problems occur due to the different airflow available at those temperatures.

PCBs



Measured Temperature

Note: The effects of different coefficients of thermal expansion between the solder joint and the PC board must be evaluated, especially a large temperature rise in the solder joint occurs. The different coefficients of thermal expansion can cause solder joint cracks and eventual failure. This is especially critical for solder joints where heavy mechanical stress is expected when heavy components (such as transformers or power switches) are directly attached to PC board. Also, if the solder joint carries large amounts of current or has a high voltage, a solder joint crack could potentially result in a smoke incident.

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