# THE RIAC 217PLUS™ SWITCH AND RELAY FAILURE RATE MODELS

*David Nicholls, RIAC (Quanterion Solutions Incorporated)*

In a previous edition of the RIAC Journal [Reference 1], we provided a high-level introduction to the 217PlusTM component failure rate prediction models, and in the last three editions we presented the 217PlusTM capacitor and diode failure rate models [Reference 2], the integrated circuit and inductor failure rate models [Reference 3], and the transformer and optoelectronic device models [Reference 4].

In this edition of the Journal, we present the Switch and Relay component models in their entirety. A brief example will be provided at the end of the article.

## 217Plus™ Switch Failure Rate Model

The failure rate equation for switches [Reference 5] is:

$$\lambda_P = \pi_G(\lambda_{OB}\pi_{DCO}\pi_{TO} + \lambda_{EB}\pi_{DCN}\pi_{TE} + \lambda_{TCB}\pi_{CR}\pi_{DT}) + \lambda_{IND}$$

where,

$\lambda_P$ = Predicted failure rate, failures per million calendar hours

$\pi_G$ = Reliability growth failure rate multiplier:

$$\pi_G = e^{(-\beta(Y-1993))}$$

$\beta$ = *Growth constant. Function of switch type (see Table 1)*

$\lambda_{OB}$ = Base failure rate, operating. Function of switch type (see Table 1)

$\pi_{DCO}$ = Failure rate multiplier for duty cycle, operating:

$$\pi_{DCO} = \frac{DC}{DC_{1op}}$$

$DC_{1op}$ = *Constant. Function of switch type (see Table 1)*

$\pi_{TO}$ = Failure rate multiplier for temperature, operating:

$$\pi_{TO} = e^{\left(\frac{-Ea_{op}}{0.00008617}\left(\frac{1}{T_{AO}+T_R+273}-\frac{1}{298}\right)\right)}$$

$Ea_{op}$ = *Activation energy, operating. Function of switch type (see Table 1).*

$T_R$ = *The junction temperature rise above the ambient operating temperature ($T_{AO}$). The junction temperature is, therefore, $T_{AO} + T_R$. $T_R$ can be determined in several ways:*

$T_{Rdefault}$ = Default temperature rise (see Table 1)

$T_R$ = Actual (measured) temperature rise, if known

$\lambda_{EB}$ = Base failure rate, environmental (see Table 1)

$\pi_{DCN}$ = Failure rate multiplier, duty cycle – nonoperating:

$$\pi_{DCN} = \frac{1-DC}{DC_{1nonop}}$$

$DC_{1nonop}$ = Constant. Function of switch type (see Table 1)

$\pi_{TE}$ = Failure rate multiplier, temperature:

$$\pi_{TE} = e^{\left(\frac{-Ea_{nonop}}{0.00008617}\left(\frac{1}{T_{AE}+273}-\frac{1}{298}\right)\right)}$$

$Ea_{nonop}$ = *Activation energy, nonoperating. Function of transformer type (see Table 1)*

$\lambda_{TCB}$ = Base failure rate, temperature cycling (see Table 1)

$\pi_{CR}$ = Failure rate multiplier, cycling rate:

$$\pi_{CR} = \frac{CR}{CR_1}$$

$CR_1$ = *Constant. Function of switch type (see Table 1)*

$\pi_{DT}$ = Failure rate multiplier, delta temperature:

$$\pi_{DT} = \left(\frac{T_{AO}+T_R-T_{AE}}{DT_1}\right)^2$$

$DT_1$ = *Constant. Function of switch type (see Table 1)*

$\lambda_{IND}$ = Failure rate, electrical overstress (see Table 1)

**NOTE**: Environment-type and equipment-dependent default values for DC, $T_{AO}$, $T_{AE}$ and CR were previously presented in Reference 1, where,

DC = Duty cycle (the percent of calendar time that the system in which the component is operating is in an operational state)

$T_{AO}$ = Ambient temperature, operating (in degrees C)

$T_{AE}$ = Ambient temperature, nonoperating (in degrees C)

CR = Cycling rate (the number of power cycles per year to which the system is exposed). In this case, it is assumed that the system transitions from a nonoperating environment to an operating environment at the same time that the power is applied.

*Table 1: Switch Parameters*

| Part Type | $\lambda_{OB}$ | $\lambda_{EB}$ | $\lambda_{TCB}$ | $\lambda_{IND}$ | $\beta$ | $DC_{1op}$ | $Ea_{op}$ | $T_{Rdefault}$ | $DC_{1nonop}$ | $Ea_{nonop}$ | $CR_1$ | $DT_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Centrifugal | 0.1763992 | 24.3578773 | 1.1371796 | 1.3841695 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Coaxial | 0.0108773 | 0.3389856 | 0.0619184 | 0.0145728 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| DIP | 0.0008827 | 0.0026479 | 0.0035170 | 0.0003568 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Float | 0.0186419 | 0.9506430 | 0.1694149 | 0.0056024 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Flow | 0.0766708 | 2.5128573 | 0.3233836 | 0.1653016 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| General | 0.0633936 | 2.7259861 | 0.2610704 | 0.2151248 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Humidity | 0.1212009 | 6.1184867 | 0.6478834 | 0.2485436 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Limit | 0.0481070 | 3.7267871 | 0.4346893 | 0.1707682 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Microwave | 0.1298078 | 0.0872547 | 0.7027604 | 0.0365085 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Pressure | 0.1199343 | 9.5751997 | 0.3924477 | 0.3608724 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Push Button | 0.0061385 | 0.8036260 | 0.0325822 | 0.0116812 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Reed | 0.0051377 | 0.2857773 | 0.0155062 | 0.0035639 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Rocker | 0.0328250 | 0.0312763 | 0.1468059 | 0.0110910 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Rotary | 1.1377350 | 2.7045401 | 2.6269820 | 0.5794457 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Sensitive | 0.0051602 | 0.3813068 | 0.0337622 | 0.0034288 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Slide | 0.0021569 | 0.0042558 | 0.0067203 | 0.0006768 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Thermostatic | 0.0088297 | 0.3185724 | 0.0313801 | 0.0244460 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Thumbwheel | 0.0181690 | 0.1479348 | 0.0334797 | 0.0224719 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Toggle | 0.0020129 | 0.1911024 | 0.0051910 | 0.0045012 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |
| Wave Guide | 0.1871445 | 4.5453838 | 1.1776141 | 0.1846414 | 0 | 0.54 | 1.0 | 0 | 0.46 | 1.0 | 520 | 27.52 |

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## 217Plus™ Relay Failure Rate Model

The failure rate equation for relays [Reference 5] is:

$$\lambda_P = \pi_G(\lambda_{OB}\pi_{DCO}\pi_{TO} + \lambda_{EB}\pi_{DCN}\pi_{TE} + \lambda_{TCB}\pi_{CR}\pi_{DT}) + \lambda_{IND}$$

where,

$\lambda_P$ = Predicted failure rate, failures per million calendar hours

$\pi_G$ = Reliability growth failure rate multiplier:

$$\pi_G = e^{(-\beta(Y-1993))}$$

$\beta$ = *Growth constant. Function of relay type (see Table 2).*

$\lambda_{OB}$ = Base failure rate, operating (see Table 2)

$\pi_{DCO}$ = Failure rate multiplier for duty cycle, operating:

$$\pi_{DCO} = \frac{DC}{DC_{1op}}$$

$DC_{1op}$ = *Constant. Function of relay type (see Table 2)*

$\pi_{TO}$ = Failure rate multiplier for temperature, operating:

$$\pi_{TO} = e^{\left(\frac{-Ea_{op}}{0.00008617}\left(\frac{1}{T_{AO}+T_R+273}-\frac{1}{298}\right)\right)}$$

$Ea_{op}$ = *Activation energy, operating. Function of relay type (see Table 2).*

$T_R$ = *The junction temperature rise above the ambient operating temperature ($T_{AO}$). The junction temperature is, therefore, $T_{AO}+T_R$. $T_R$ can be calculated in several ways:*

$T_{Rdefault}$ = Default temperature rise (see Table 2)

$T_R$ = Actual temperature rise, if known

$\lambda_{EB}$ = Base failure rate, environmental (see Table 2)

$\pi_{DCN}$ = Failure rate multiplier, duty cycle – nonoperating:

$$\pi_{DCN} = \frac{1-DC}{DC_{1nonop}}$$

$DC_{1nonop}$ = *Constant. Function of relay type (see Table 2)*

$\pi_{TE}$ = Failure rate multiplier, temperature:

$$\pi_{TE} = e^{\left(\frac{-Ea_{nonop}}{0.00008617}\left(\frac{1}{T_{AE}+273}-\frac{1}{298}\right)\right)}$$

$Ea_{nonop}$ = *Activation energy, nonoperating. Function of relay type (see Table 2)*

$\lambda_{TCB}$ = Base failure rate, temperature cycling (see Table 2)

$\pi_{CR}$ = Failure rate multiplier, cycling rate:

$$\pi_{CR} = \frac{CR}{CR_1}$$

$CR_1$ = *Constant. Function of relay type (see Table 2)*

$\pi_{DT}$ = Failure rate multiplier, delta temperature:

$$\pi_{DT} = \left(\frac{T_{AO}+T_R-T_{AE}}{DT_1}\right)^2$$

$DT_1$ = *Constant. Function of relay type (see Table 2)*

$\lambda_{IND}$ = Failure rate, induced (see Table 2)

*Table 2: Relay Parameters*

| Part Type | $\lambda_{OB}$ | $\lambda_{EB}$ | $\lambda_{TCB}$ | $\lambda_{IND}$ | $\beta$ | $DC_{1op}$ | $Ea_{op}$ | $T_{Rdefault}$ | $DC_{1nonop}$ | $Ea_{nonop}$ | $CR_1$ | $DT_1$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| General Purpose | 0.0063446 | 0.1432385 | 0.0109744 | 0.0247443 | 0 | 0.51 | 1.1 | 0 | 0.49 | 1.1 | 500 | 22.55 |
| Reed | 0.0067468 | 0.0198698 | 0.0095525 | 0.0076172 | 0 | 0.51 | 1.1 | 0 | 0.49 | 1.1 | 500 | 22.55 |
| Solid State | 0.0000514 | 0.0015014 | 0.0000596 | 0.0002885 | 0 | 0.51 | 1.1 | 0 | 0.49 | 1.1 | 500 | 22.55 |
| Thermal | 0.0325570 | 4.8930327 | 0.0814692 | 0.4014993 | 0 | 0.51 | 1.1 | 0 | 0.49 | 1.1 | 500 | 22.55 |
| Time Delay | 0.0130515 | 0.7657106 | 0.0185094 | 0.0788699 | 0 | 0.51 | 1.1 | 0 | 0.49 | 1.1 | 500 | 22.55 |

As with the Switch model, the environment-type and equipment-dependent default values for DC, $T_{AO}$, $T_{AE}$ and CR were previously presented in Reference 1.

## Example Calculation

What is the predicted failure rate of a pressure switch manufactured in 2006. The pressure switch operates in a "Ground, Mobile, Heavy-wheeled" vehicle with an assumed operating temperature of 55°C, a dormant temperature of 14°C and a relative humidity of 40%. The actual temperature rise of the switch is unknown. The operating profile of the equipment is typical of military ground equipment, with a duty cycle of 45% and a cycling rate of 263 cycles per year.

$$\lambda_P = \pi_G(\lambda_{OB}\pi_{DCO}\pi_{TO} + \lambda_{EB}\pi_{DCN}\pi_{TE} + \lambda_{TCB}\pi_{CR}\pi_{DT}) + \lambda_{IND}$$

The failure rate equation for a switch [Reference 5] is:

$$\pi_G = e^{(-\beta(Y-1993))} = 1.0$$

where,

$\beta$ = 0 (from Table 1) and
Y = 2006 (given)

$$\pi_{DCO} = \frac{DC}{DC_{1op}} = 0.8333$$

$\lambda_{OB}$ = 0.1199 (from Table 1)
DC = 0.45 (given as 45%)

$$\pi_{TO} = e^{\left(\frac{-Ea_{op}}{0.00008617}\left(\frac{1}{T_{AO}+T_R+273} - \frac{1}{298}\right)\right)} = 35.23$$

$DC_{1op}$ = 0.54 (from Table 1)
$Ea_{op}$ = 1.0 (from Table 1)
$T_{AO}$ = 55 (given)

$$\pi_{DCN} = \frac{1-DC}{DC_{1nonop}} = 1.196$$

$\lambda_{EB}$ = 9.575 (from Table 1)
DC = 0.45 (given as 45%)

$$\pi_{TE} = e^{\left(\frac{-Ea_{nonop}}{0.00008617}\left(\frac{1}{T_{AE}+273} - \frac{1}{298}\right)\right)} = 0.2248$$

$DC_{1nonop}$ = 0.46 (from Table 1)

$Ea_{nonop}$ = 1.0 (from Table 1)
$T_{AE}$ = 14 (given)

$$\pi_{CR} = \frac{CR}{CR_1} = 0.5058$$

$\lambda_{TCB}$ = 0.3924 (from Table 1)
CR = 263 (given)

$$\pi_{DT} = \left(\frac{T_{AO}+T_R-T_{AE}}{DT_1}\right)^2 = 2.2196$$

$CR_1$ = 520 (from Table 1)
$T_{AO}$ = 55 (given)
$T_{Rdefault}$ = 0 (from Table 1)
$T_{AE}$ = 14 (given)
$DT_1$ = 27.52 (from Table 1)

$\lambda_{IND}$ = 0.3609 (from Table 1)

$$\lambda_P = (1.0)\big[(0.1199)(0.8333)(35.23) + (9.575)(1.196)(0.2248) + (0.3924)(0.5058)(2.2196)\big] + (0.3609)$$

**$\lambda_P$ = 6.8957 f/$10^6$ calendar hours**

## Next Issue

The next issue of the RIAC Journal (2nd Quarter 2008) will present the 217Plus™ connector and resistor failure rate models.

## References:


1: "An Introduction to the RIAC 217Plus™ Component Failure Rate Models", Journal of the Reliability Information Analysis Center, First Quarter 2007
2: "The 217Plus™ Capacitor and Diode Failure Rate Models", Journal of the Reliability Information Analysis Center, Second Quarter 2007
3: "The 217Plus™ Integrated Circuit and Inductor Failure Rate Models", Journal of the Reliability Information Analysis Center, Third Quarter 2007
4: "The 217Plus™ Transformer and Optoelectronic Device Failure Rate Models", Journal of the Reliability Information Analysis Center, Fourth Quarter 2007
5: Denson, W.K., "Handbook of 217Plus™ Reliability Prediction Models", Reliability Information Analysis Center (RIAC), 26 May 2006, ISBN 1-933904-02-X
6: "An Overview of the 217Plus™ System Reliability Assessment Methodology", Journal of the Reliability Information Analysis Center, Fourth Quarter 2006


*References 1, 2, 3, 4 and 6 available for free download from the RIAC website at http://theRIAC.org*