APPLICATION NOTE

TELEDYNE RELAYS

Mean Time Between Failure
MTBF

Mean Cycles Between Failure
MCBF

MTBF applied to EMRs

MTBF is an expression of reliability that attempts to predict the life expectancy of a device in hours (Mean Time Between Failure). Any reliability expression for Electromechanical relays (EMRs) must be predicated on the number of cycles. Thus the EMR equivalent to MTBF is MCBF (Mean Cycles Between Failure).

MTBF calculation using available in house data from MOQ

For relays that are a part of an established reliability program, the empirical data of the MOQ (Maintenance of Qualification) plan can be used to calculate the MCBF. This is done by using the failure rate level of the relay in question. MCBF may be calculated using the predetermined number of unit cycles called out in the reliability expression and dividing that by the number of allowable failures.

$$\textbf{MCBF} = \frac{10{,}000}{X\%}$$

Once an MCBF level has been established, MTBF can be calculated by dividing the resulting MCBF by the number of cycles per hour

$$\textbf{MTBF} = \frac{\text{MCBF}}{\text{Cycles per hr}} \quad \text{or} \quad \frac{\left(\dfrac{\text{Unit operations}}{\text{Numbers of Failures}}\right)}{\text{Cycles per hr}}$$

Using the above formula, the following generic MCBF levels for Teledyne Relays established reliability relays is given:

For JAN
L Level = 333,333.33 cycles $\left(\dfrac{10{,}000}{.03}\right)$

M Level = 1,000,000.00 cycles $\left(\dfrac{10{,}000}{.01}\right)$

For ***T²R***®
A Level = 666,666.67 cycles $\left(\dfrac{10{,}000}{.015}\right)$

B Level = 1,333,333.33 cycles $\left(\dfrac{10{,}000}{.0075}\right)$

This can now be translated into generic MTBF data by applying a cycle rate to the numbers. MOQ is performed at a cycle rate of 20±2 cycles per minute or a nominal cycle rate of 1,200 cycles per hour. Plugging this into the MCBF numbers we get:

For JAN

L Level = $\dfrac{333{,}333.33 \text{ (cycles)}}{1{,}200 \text{ (cycles/hr)}}$ = 276.76 hrs

M Level = $\dfrac{1{,}000{,}000.00 \text{ (cycles)}}{1{,}200 \text{ (cycles/hr)}}$ = 833.33 hrs

For $\boldsymbol{T^2R}$®

A Level = $\dfrac{666{,}666.67 \text{ (cycles)}}{1{,}200 \text{ (cycles/hr)}}$ = 555.56 hrs

B Level = $\dfrac{1{,}333{,}333.33 \text{ (cycles)}}{1{,}200 \text{ (cycles/hr)}}$ = 1,111.11 hrs

When calculating MTBF for $\boldsymbol{T^2R}$® or JAN relays, the formula should be modified to include the actual cycle rate used in a specific application. It should be noted that the cycle rate is the critical factor in MTBF as it directly relates to how quickly the number of contact cycles is accumulated by a given relay. Using the MCBF for $\boldsymbol{T^2R}$® B level as an example, if we take the ± cycle rate tolerance (2 cycles per minute) into account this results in an MTBF window ranging from 1,010.10 hrs (22 cycles per minute) to 1,234.57 hrs (18 cycles per minute).

MTBF calculation Per MIL-HDBK-217

MIL-HDBK-217 provides a calculation to help “fine tune” a reliability prediction as it applies to a specific application. It consists of the following formula:

$\lambda_p = \lambda_b, \pi_L, \pi_C, \pi_{CYC}, \pi_F, \pi_Q, \pi_E$ Failures/10^6 hours.

MTBF = 10^6hrs/λ_p

Whereas:

λ_b = Base Failure Rate (temperature factor)
π_L = Load stress factor (load level and type)
π_C = Contact form factor (DPST, DPDT etc)
π_{CYC} = Cycling factor (cycle rate)
π_F = Application and construction factor (general relay load rating and armature type)
π_Q = Quality factor (mil-spec qualification level vs. non mil)
π_E = Environment factor (environment in which the relay is being used)

All of these factors have a numeric value associated with them that is to be chosen given a specific condition. These numeric values are obtained through the use of tables and/or calculation. Only λ_b, π_L and π_{CYC} allow for a calculated number that is then plugged into the formula. Even still, there are lists of standard values that can be used for these three factors. For example, λ_b, which is a temperature factor, has the temperature broken down into 5°C increments. Depending upon the rating of the relay and the projected ambient temperature, a standard value is offered. If, however, the projected temperature is something other than the standard temperatures listed, 37.5°C for example, there is a formula provided to obtain a number to represent the temperature value. The same is true for π_L and π_{CYC}.

When calculating for the π_L value, one of the formula factors is S. S is found by dividing the relays rated resistive load into the load value that is actually being switched, regardless of whether the actual load type is resistive or not.

In MIL-HDBK-217 the formula for solving λ_b and π_L, appears slightly different than the formulas presented in tables 1 and 2 later in this application note. In MIL-HDBK-217 part of the argument for λ_b and π_L is “exp”. “exp” in the MIL-HDBK-217 calculation is actually the Napierian number 2.7183 (**e**). In tables 1 and 2 **e** is used rather than “exp”.

π_{CYC} and π_Q are the only two factors in which a differentiation between mil spec and non mil spec, is made. In these two cases the user has discretion to decide into which category the subect relay will fall. As an example, ***T²R***® relays are not “mil spec” but are established reliability relays which encompass all mil requirements. Another example is a relay for space flight. Almost without exception, relays used in space flight applications start with a JAN relay of M level or better and expand the screening regimen. If π_{CYC} and π_Q were to be interpreted literally, spaceflight relays would be categorized as a lower reliability relay because they are not “mil spec”

π_F, or application and construction factor, have a number of conditions that could conceivably apply to an EMR. The Contact Rating portion that applies to the EMR is “0-5 Amp”. The Application Type portion will be “General Purpose”. For Construction Feature, “Armature (Long)” should be used for all non-magnetic latching relays. For all magnetic latching relays, the appropriate Construction Type is “Balanced Armature”.

MTBF levels obtained through calculation will differ greatly from the MTBF levels extracted from the established reliability statements as the claculation method takes into account varying load levels, operating conditions and armature styles.

Following are tables taken from MIL-HDBK-217, Revision F, Change Notice 2.

Base Failure Rate λ_b		
T_A (°C)	Rated Temperature	
	85°C [1]	125°C [2]
25	.0059	.0059
30	.0067	.0066
35	.0075	.0073
40	.0084	.0081
45	.0094	.0089
50	.010	.0098
55	.012	.011
60	.013	.012
65	.014	.013
70	.016	.014
75	.017	.015
80	.019	.017
85	.021	.018
90		.019
95		.021
100		.022
105		.024
110		.026
115		.027
120		.029
125		.031

1. $\lambda_b = .0059\ e\ (-.19 / 8.617 \times 10^{-5}\ [\{1 / T+273\} - \{1 / 298\}])$

2. $\lambda_b = .0059\ e\ (-.17 / 8.617 \times 10^{-5}\ [\{1 / T+273\} - \{1 / 298\}])$

T_A = Ambient Temperature (°C)

Table 1

Load Stress Factor $\mathbf{p}_L$			
S	Load Type		
	Resistive [1]	Inductive [2]	Lamp [3]
.05	1.00	1.02	1.06
.10	1.02	1.06	1.28
.20	1.06	1.28	7.72
.30	1.15	1.76	9.49
.40	1.28	2.72	54.6
.50	1.48	4.77	
.60	1.76	9.49	
.70	2.15	21.4	
.80	2.72		
.90	3.55		
1.00	4.77		

1. $\mathbf{p}L = \varepsilon\ (S\ /\ .8)^2$
2. $\mathbf{p}L = \varepsilon\ (S\ /\ .4)^2$
3. $\mathbf{p}L = \varepsilon\ (S\ /\ .2)^2$

S = Operating load current / Rated resistive load.

For single devices which switch two different loads, evaluate $\mathbf{p}_L$ for each possible load combination and use the worst case (largest $\mathbf{p}_L$).

Table 2

Contact Form Factor $\mathbf{p}_C$	
Contact Form	$\mathbf{p}_C$
SPST	1.00
DPST	1.50
SPDT	1.75
3PST	2.00
4PST	2.50
DPDT	3.00
3PDT	4.25
4PDT	5.50
8PDT	8.00

Table 3

Cycling Factor $\mathbf{p}_{CYC}$	
Cycle Rate (cycles per hour)	$\mathbf{p}_{CYC}$ (Mil Spec)
$\geq$ 1.0	Cycles per hour / 10
<1.0	0.1
Cycle Rate (cycles per hour)	$\mathbf{p}_{CYC}$ (Commercial Quality)
>1,000	(Cycles per hour / 10)^2
10 - 1,000	Cycles per hour / 10
<10	1.0
Note: Values of $\mathbf{p}_{CYC}$ for cycling rates beyond the basic design limitations are not valid. Design specifications should be consulted prior to evaluation of $\mathbf{p}_{CYC}$.	

Table 4

Quality Factor $\mathbf{p}_Q$	
Quality	$\mathbf{p}_Q$
R	.10
P	.30
X	.45
U	.60
M	1.0
L	1.5
Mil Spec, Non established reliability	1.5
Comercial	2.9

Table 5

Environment Factor π_E	
Environment	π_E
G_B	1.0
G_F	2.0
G_M	15
N_S	8.0
N_U	27
A_{IC}	7.0
A_{IF}	9.0
A_{UC}	11
A_{UF}	12
A_{RW}	46
S_F	.50
M_F	25
M_L	66
C_L	N/A
G_B	Ground benign
G_F	Ground fixed
G_M	Ground mobile
N_S	Naval sheltered
N_U	Naval unsheltered
A_{IC}	Aircraft inhabited cargo
A_{IF}	Aircraft uninhabited cargo
A_{UC}	Aircraft inhabited fighter
A_{UF}	Aircraft uninhabited fighter
A_{RW}	Aircaft rotary wing
S_F	Spaceflight
M_F	Missile flight
M_L	Missile launch
C_L	Cannon launch

Table 6

Application and Construction Factor p_F (see note at the end of the table)			
Contact Rating	Application Type	Construction Type	p_F
Signal Current (low mv and low ma)	Dry circuit	Armature (long)	4
		Dry Reed	6
		Mercury Wetted	1
		Magnetic Latching	4
		Balanced Armature	7
		Solenoid	7
0-5 Amp	*General Purpose*	*Armature Long*	*3*
		Balanced Armature	5
		Solenoid	6
	Sensitive (0-100mW)	Armature (Long and Short)	5
		Mercury Wetted	2
		Magnetic Latching	6
		Meter Movement	100
		Balanced Armature	10
	Polarized	Armature Short	10
		Meter Movement	100
	Vibrating Reed	Dry Reed	6
		Mercury Wetted	1
	High Speed	Armature (Balanced and Short)	25
		Dry Reed	6
	Thermal Time Delay	Bimetal	10
	Electronic Time Delay, Non Thermal		9
	Latching Magnetic	Dry Reed	10
		Mercury Wetted	5
		Balanced Armature	*5*
5-20 Amp	High Voltage	Vacuum (Glass)	20
		Vacuum (Ceraic)	5
	Medium Power	Armature (Long and Short)	3
		Mercury Wetted	1
		Magnetic Latching	2
		Balanced Armature	2
		Solenoid	2
25-600 Amp	Contactors High Current	Armature (Short)	7
		Mechanical Latching	12
		Balanced Armature	10
		Solenoid	5
Note: While all condition for p_F have been included in this table, only the conditions noted in italics apply to Teledyne Relays' Electromechanical relays.			

Table 7