MTBF Calculation of CBQ100 Series Quarter Size Converter

The MTBF, calculated in accordance with MIL-HDBK-217F DECEMBER 1991, are 447,128 hours@+25ºC, 282,819 hours@+50ºC and 191,993 hours@+70ºC for CBQ100 series dc/dc converters. This represents an average failure rate of 2.236492(+25ºC), 3.535819(+50ºC) and 5.208524(+70ºC) failures per million unit hours of operations. The assumptions are full load at +25ºC, +50ºC and +70ºC case temperature under ground benign (GB) environment condition. The detail MTBF calculation of CBQ100 series dc/dc converters are listed as following:

MTBF@+25ºC:

MICROCIRCUITS:

(1) Controller: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, $C_1=0.02$, $\pi_T=0.10$, $C_2=0.0034$, $\pi_E=0.5$, $\pi_Q=2.0$, $\pi_L=1.0$, N=1
$\lambda_p=(0.02\times0.10+0.0034\times0.5)2.0\times1.0\times1=0.0074$

(2) Timer: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, $C_1=0.01$, $\pi_T=0.10$, $C_2=0.0034$, $\pi_E=0.5$, $\pi_Q=2.0$, $\pi_L=1.0$, N=1
$\lambda_p=(0.01\times0.10+0.0034\times0.5)2.0\times1.0\times1=0.0054$

(3) Error Amplifier: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, $C_1=0.01$, $\pi_T=0.10$, $C_2=0.0012$, $\pi_E=0.5$, $\pi_Q=2.0$, $\pi_L=1.0$, N=2
$\lambda_p=(0.01\times0.10+0.0012\times0.5)2.0\times1.0\times2=0.0064$

(4) Comparator: $\lambda_p=(C_1\pi_T+C_2\pi_E)\pi_Q\pi_L N$, $C_1=0.01$, $\pi_T=0.10$, $C_2=0.0012$, $\pi_E=0.5$, $\pi_Q=2.0$, $\pi_L=1.0$, N=1
$\lambda_p=(0.01\times0.10+0.0012\times0.5)2.0\times1.0\times1=0.0032$

(5) Schmitt Trigger: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, $C_1=0.01$, $\pi_T=0.10$, $C_2=0.0016$, $\pi_E=0.5$, $\pi_Q=2.0$, $\pi_L=1.0$, N=1, $\lambda_p=(0.01\times0.10+0.0016\times0.5)2.0\times1.0\times1=0.0036$

(6) Photo-electronic: $\lambda_p=\lambda_b\ \pi_T\ \pi_Q\ \pi_E N$, $\lambda_b=0.017$, $\pi_T=1.0$, $\pi_Q=8.0$, $\pi_E=1.0$, N=2
$\lambda_p=0.017\times1.0\times8.0\times1.0\times2=0.272$

DISCRETE SEMICONDUCTORS:

(1) Synchronous Rectifier: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, $\lambda_b=0.012$, $\pi_T=1.0$, $\pi_A=1.5$, $\pi_Q=8.0$, $\pi_E=1.0$, N=4
$\lambda_p=0.012\times1.0\times1.5\times8.0\times1.0\times4=0.576$

(2) Switching Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, $\lambda_b=0.001$, $\pi_T=1.0$, $\pi_S=0.054$, $\pi_C=1.0$, $\pi_Q=8.0$, $\pi_E=1.0$, N=9 $\lambda_p=0.001\times1.0\times0.054\times1.0\times8.0\times1.0\times9=0.003888$

(3) Auxiliary Power Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, $\lambda_b=0.00074$, $\pi_T=1.0$, $\pi_A=0.7$, $\pi_R=0.65$, $\pi_S=0.29$, $\pi_Q=8.0$, $\pi_E=1.0$, N=1, $\lambda_p=0.00074\times1.0\times0.7\times0.65\times0.29\times8.0\times1.0\times1=0.000781144$

(4) MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, $\lambda_b=0.012$, $\pi_T=1.0$, $\pi_A=8.0$, $\pi_Q=8.0$, $\pi_E=1.0$, N=1
$\lambda_p=0.012\times1.0\times8.0\times8.0\times1.0\times1=0.768$

(6) Reset MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, $\lambda_b=0.012$, $\pi_T=1.0$, $\pi_A=0.7$, $\pi_Q=8.0$, $\pi_E=1.0$, N=1
$\lambda_p=0.012\times1.0\times0.7\times8.0\times1.0\times1=0.0672$

(7) Zener Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, $\lambda_b=0.002$, $\pi_T=1.0$, $\pi_S=1$, $\pi_C=1.0$, $\pi_Q=8.0$, $\pi_E=1.0$, N=4
$\lambda_p=0.001\times1.0\times1\times1.0\times8.0\times1.0\times4=0.032$

(8) Small Signal Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, $\lambda_b=0.00074$, $\pi_T=1.0$, $\pi_A=0.7$, $\pi_R=0.65$, $\pi_S=0.11$, $\pi_Q=8.0$, $\pi_E=1.0$, N=7, $\lambda_p=0.00074\times1.0\times0.7\times0.65\times0.11\times8.0\times1.0\times7=0.002074072$

RESISTORS: $\lambda_p=\lambda_b\ \pi_R\pi_Q\ \pi_E N$ $\lambda_b=0.00070$, $\pi_R=1.0$, $\pi_Q=1.0$, $\pi_E=1.0$, N=58
$\lambda_p=0.00070\times1.0\times1.0\times1.0\times58=0.0406$

THERMISTOR: $\lambda_p=\lambda_b\pi_Q\ \pi_E N$ $\lambda_b=0.021$, $\pi_Q=15$, $\pi_E=1.0$, N=1 $\lambda_p=0.021\times15\times1.0\times1=0.315$

CAPACITORS:

(1) Input Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.00067, π_{CV}=4.08, π_Q=3, π_E=1.0, N=1
λ_p=0.00067×4.08×3×1.0×1=0.0082008

(2) Output Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.00018, π_{CV}=4.9148, π_Q=3, π_E=1.0, N=4
λ_p=0.00018×4.9148×3 ×1.0×4=0.010616

(3) Ceramic Chip Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.00012, π_{CV}=1.4, π_Q=3, π_E=1.0, N=22
λ_p=0.0003×1.4×3×1.0×27=0.03402

INDUCTIVE DEVICES:

(1) Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0023, π_Q=30, π_E=1.0, N=1
λ_p=0.0023×30×1.0×1=0.069

(2) Pulse Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0023, π_Q=5.0, π_E=1.0, N=1
λ_p=0.0023×5×1.0×1=0.0115

(3) Coils: $\lambda_p=\lambda_b \pi_C \pi_Q\ \pi_E N$, λ_b=0.00039, π_C=1.0, π_Q=20, π_E=1.0, N=4
λ_p=0.00039×1.0×20×1.0×4=0.0312

Total equipment failure rate:

λ_p=0.0077+0.0054+0.0064+0.0032+.0036+0.272+0.576+0.003888+0.000781144+0.768+0.0672 +0.032+0.002074072+0.0406+0.315+0.0082008+0.010616+0.03402+ 0.069+0.0115+ 0.0312 = 2.268380 Failures/10^6 hours.

MTBF=440,843 hours @+25ºC GB.

MTBF@+50ºC:

MICROCIRCUITS:

(1) Controller: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.02, π_T=0.71, C_2=0.0034, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.02×0.71+0.0034×0.5)2.0×1.0×1=0.0318

(2) Timer: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=0.71, C_2=0.0034, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.01×0.71+0.0034×0.5)2.0×1.0×1=0.0176

(3) Error Amplifiers: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=0.71, C_2=0.0012, π_E=0.5, π_Q=2.0, π_L=1.0, N=2, λ_p=(0.01×0.71+0.0012×0.5)2.0×1.0×2=0.0308

(4) Comparator: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=0.71, C_2=0.0012, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.01×0.71+0.0012×0.5)2.0×1.0×1=0.0154

(5) Schmitt Trigger: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=0.29, C_2=0.0016, π_E=0.5, π_Q=2.0, π_L=1.0, N=1, λ_p=(0.01×0.29+0.0016×0.5)2.0×1.0×1=0.0074

(6) Photo-electronic: $\lambda_p=\lambda_b\ \pi_T\ \pi_Q\ \pi_E N$, λ_b=0.017, π_T=2.1, π_Q=8.0, π_E=1.0, N=2
λ_p=0.017×2.1× 8.0×1.0×2=0.5712

DISCRETE SEMICONDUCTORS:

(1) Synchronous Rectifier: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=1.6, π_A=1.5, π_Q=8.0, π_E=1.0, N=4
λ_p=0.012×1.6×1.5×8.0×1.0×4=0.9216

(2) Switching Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, λ_b=0.001, π_T=2.2, π_S=0.054, π_C=1.0, π_Q=8.0, π_E=1.0, N=9, λ_p=0.001×2.2×0.054×1.0×8.0×1.0×9=0.0085536

(3) Auxiliary Power Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, λ_b=0.00074, π_T=1.7, π_A=0.7, π_R=0.65, π_S=0.29, π_Q=8.0, π_E=1.0, N=1, λ_p=0.00074×1.7×0.7×0.65×0.29×8.0×1.0×1=0.001327944

(4) MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=1.6, π_A=8.0, π_Q=8.0, π_E=1.0, N=1
λ_p=0.012×1.6×8.0×8.0×1.0×1=1.2288

(5) Reset MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=1.6, π_A=0.7, π_Q=8.0, π_E=1.0, N=1
λ_p=0.012×1.6×0.7×8.0×1.0×1=0.1075

(6) Zener Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, λ_b=0.002, π_T=1.6, π_S=1, π_C=1.0, π_Q=8.0, π_E=1.0, N=4
λ_p=0.001×1.6×1×1.0×8.0×1.0×4=0.0512

(7) Signal Process Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, λ_b=0.00074, π_T=1.7, π_A=0.7, π_R=0.65, π_S=0.11, π_Q=8.0, π_E=1.0, N=7, λ_p=0.00074×1.7×0.7×0.65×0.11×8.0×1.0×7=0.0035259224

RESISTORS: $\lambda_p=\lambda_b\ \pi_R\pi_Q\ \pi_E N$ λ_b=0.00084, π_R=1.0, π_Q=1.0, π_E=1.0, N=58
λ_p=0.00084×1.0×1.0×1.0×58=0.04872

THERMISTOR: $\lambda_p=\lambda_b\pi_Q\ \pi_E N$ λ_b=0.021, π_Q=15, π_E=1.0, N=1
λ_p=0.021×15×1.0×1=0.315

CAPACITORS:

(1) Input Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.0016, π_{CV}=4.08, π_Q=3, π_E=1.0, N=1
λ_p=0.0016×4.08×3×1.0×1=0.019584

(2) Output Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.000435, π_{CV}=4.9148, π_Q=3, π_E=1.0, N=4
λ_p=0.000435×4.9148×3×1.0×4=0.025655256

(3) Ceramic Chip Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.0003, π_{CV}=1.4, π_Q=3, π_E=1.0, N=27
λ_p=0.0003×1.4×3×1.0×27=0.03402

INDUCTIVE DEVICES:

(1) Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0027, π_Q=30, π_E=1.0, N=1
λ_p=0.0027×30×1.0×1=0.081

(2) Pulse Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0027, π_Q=5.0, π_E=1.0, N=1
λ_p=0.0027×5×1.0×1=0.0135

(3) Coils: $\lambda_p=\lambda_b\pi_C\pi_Q\ \pi_E N$, λ_b=0.00051, π_C=1.0, π_Q=20, π_E=1.0, N=4
λ_p=0.00051×1.0×20×1.0×4=0.0408

Total equipment failure rate:

λ_p=0.0318+0.0176+0.0308+0.0154+.0074+0.5712+0.9214+0.0085536+0.001327944+1.2288+0.1075 +0.0512+0.0035259224+0.04872+0.315+0.019584+0.025655256+003402+0.081+0.0135+0.0408 = 3.574787 Failures/10^6 hours.

MTBF=279,737 hours @+50ºC GB.

MTBF@+70ºC:

MICROCIRCUITS:

(1) Controller: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.02, π_T=2.8, C_2=0.0034, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.02×2.8+0.0034×0.5)2.0×1.0×1=0.1154

(2) Timer: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=2.8, C_2=0.0034, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.01×2.8+0.0034×0.5)2.0×1.0×1=0.0594

(3) Error Amplifiers: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=2.8, C_2=0.0012, π_E=0.5, π_Q=2.0, π_L=1.0, N=2, λ_p=(0.01×2.8+0.0012×0.5)2.0×1.0×2=0.1144

(4) Comparator: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=2.8, C_2=0.0012, π_E=0.5, π_Q=2.0, π_L=1.0, N=1
λ_p=(0.01×2.8+0.0012×0.5)2.0×1.0×1=0.0572

(5) Schmitt Trigger: $\lambda_p=(C_1\pi_T+C_2\pi_E)\ \pi_Q\pi_L N$, C_1=0.01, π_T=0.60, C_2=0.0016, π_E=0.5, π_Q=2.0, π_L=1.0, N=1, λ_p=(0.01×0.60+0.0016×0.5)2.0×1.0×1=0.0136

(6) Photo-electronic: $\lambda_p=\lambda_b\ \pi_T\ \pi_Q\ \pi_E N$, λ_b=0.017, π_T=3.4, π_Q=8.0, π_E=1.0, N=2
λ_p=0.017×3.4× 8.0×1.0×2=0.9248

DISCRETE SEMICONDUCTORS:

(1) Synchronous Rectifier: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=2.3, π_A=1.5, π_Q=8.0, π_E=1.0, N=4
λ_p=0.012×2.3×1.5×8.0×1.0×4=1.3248

(2) Switching Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, λ_b=0.001, π_T=3.9, π_S=0.054, π_C=1.0, π_Q=8.0, π_E=1.0, N=9, λ_p=0.001×3.9×0.054×1.0×8.0×1.0×9=0.0151632

(3) Auxiliary Power Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, λ_b=0.00074, π_T=2.5, π_A=0.7, π_R=0.65, π_S=0.29, π_Q=8.0, π_E=1.0, N=1, λ_p=0.00074×2.5×0.7×0.65×0.29×8.0×1.0×1=0.00195286

(4) MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=2.3, π_A=8.0, π_Q=8.0, π_E=1.0, N=1
λ_p=0.012×2.3×8.0×8.0×1.0×1=1.7664

(5) Reset MOSFET: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_Q\ \pi_E N$, λ_b=0.012, π_T=2.3, π_A=0.7, π_Q=8.0, π_E=1.0, N=1
λ_p=0.012×2.3×0.7×8.0×1.0×1=0.15453125

(6) Zener Diodes: $\lambda_p=\lambda_b\ \pi_T\ \pi_S\ \pi_C\ \pi_Q\ \pi_E N$, λ_b=0.002, π_T=2.3, π_S=1, π_C=1.0, π_Q=8.0, π_E=1.0, N=4
λ_p=0.001×2.3×1×1.0×8.0×1.0×4=0.0736

(7) Small Signal Transistors: $\lambda_p=\lambda_b\ \pi_T\ \pi_A\ \pi_R\ \pi_S\ \pi_Q\ \pi_E N$, λ_b=0.00074, π_T=2.5, π_A=0.7, π_R=0.65, π_S=0.11, π_Q=8.0, π_E=1.0, N=7, λ_p=0.00074×2.5×0.7×0.65×0.11×8.0×1.0×7=0.00518518

RESISTORS: $\lambda_p=\lambda_b\ \pi_R\pi_Q\ \pi_E N$ λ_b=0.0010, π_R=1.0, π_Q=1.0, π_E=1.0, N=58
λ_p=0.0010×1.0×1.0×1.0×58=0.058

THERMISTOR: $\lambda_p=\lambda_b\pi_Q\ \pi_E N$ λ_b=0.021, π_Q=15, π_E=1.0, N=1
λ_p=0.021×15×1.0×1=0.315

CAPACITORS:

(1) Input Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.0033, π_{CV}=4.08, π_Q=3, π_E=1.0, N=1
λ_p=0.0016×4.08×3×1.0×1=0.040392

(2) Output Ceramic Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.000758, π_{CV}=4.9148, π_Q=3, π_E=1.0, N=4
λ_p=0.000758×4.9148×3 ×1.0×4=0.044705

(3) Ceramic Chip Capacitors: $\lambda_p=\lambda_b\ \pi_{CV}\ \pi_Q\ \pi_E N$, λ_b=0.00061, π_{CV}=1.4, π_Q=3, π_E=1.0, N=27
λ_p=0.00061×1.4×3×1.0×27=0.069174

INDUCTIVE DEVICES:

(1) Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0040, π_Q=30, π_E=1.0, N=1
λ_p=0.0040×30×1.0×1=0.12

(2) Pulse Transformer: $\lambda_p=\lambda_b\ \pi_Q\ \pi_E N$, λ_b=0.0040, π_Q=5.0, π_E=1.0, N=1
λ_p=0.0040×5×1.0×1=0.02

(3) Coils: $\lambda_p=\lambda_b\pi_C\pi_Q\ \pi_E N$, λ_b=0.00076, π_C=1.0, π_Q=20, π_E=1.0, N=4
λ_p=0.00076×1.0×20×1.0×4=0.0608

Total equipment failure rate:

λ_p=0.1154+0.0594+0.1144+0.0572+0.0136+0.9248+1.3248+0.0151632+0.00195286+1.7664 +0.15453125+0.0736+0.00518518+0.058+0.315+0.040392+0.044705+0.069174+0.12+ 0.02+0.0608 = 5.354503 Failures/10^6 hours.

MTBF=186,758 hours @+70ºC GB.

The component temperatures determine their reliability! Most important factor to obtaining the reliability of the dc-dc converter lies entirely in the hands of control of temperature rise. Designing to provide the best possible temperature control will give the greatest field MTBF.