Introduction

Product Reliability is defined as the probability that a device will perform its required function, subjected to stated conditions, for a specific period of time. Product Reliability is quantified as MTBF (Mean Time Between Failures) for repairable product and MTTF (Mean Time To Failure) for non-repairable product.

The Bathtub Curve

Figure 1 shows the reliability "bathtub curve" which models instantaneous failure rate vs. time, which we would see if we were to wait long enough and keep good records for a given lot of devices. This curve is modeled mathematically by the exponential function $P(t) = e^{-t/MTBF}$.
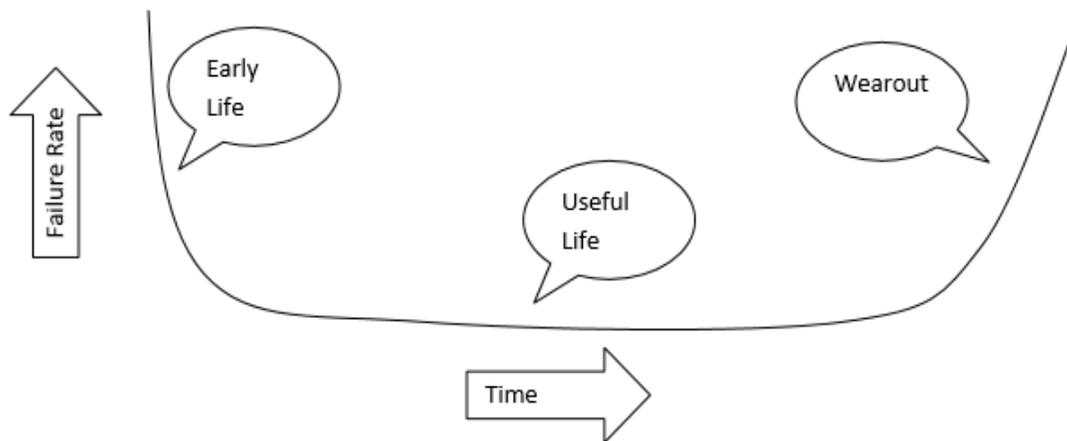

Figure 1. Reliability Bathtub Curve

The life of a population of devices can be divided into three distinct periods:

Early Life

If we follow the slope from the leftmost start to where it begins to flatten out this can be considered the first period. The first period is characterized by a decreasing failure rate. It is what occurs during the "early life" of a population of units. The weaker units fail leaving a population that is more robust.

Useful Life

The next period is the flat bottom portion of the graph. It is called the "useful life" period. Failures occur in lesser numbers during this time. It is difficult to predict which failure mode will occur, but the rate of failures is predictable. Notice the constant slope.

Wearout

The third period begins at the point where the slope begins to increase and extends to the rightmost end of the graph. This is what happens when units become old and begin to fail at an increasing rate. It is called the "wearout" period.

Understanding MTBF and MTTF Numbers

Reliability is quantified as MTBF for repairable product and MTTF for non-repairable product. In reliability calculations, a suspension occurs when a destructive test or observation has been completed without observing a failure. MTBF calculations do not consider suspensions whereas MTTF does. MTTF is the number of total hours of service of all devices divided by the number of devices.

RoboteQ MTTF Calculations

RoboteQ motor controllers are replaced if they fail. Therefore, we prefer to use Mean Time to Failure (MTTF) calculations.

Controllers Shipped Since 2012

Year	Quantity Shipped
2012	1,245
2013	2,987
2014	3,733
2015	6,147
2016	7,771
2017	12,270
Total	**34,153**

Field population at the end of 2016: 34,153 pcs

Estimated average working window: One year = 8,760 hours

Total Pcs x Hour of Service:

Starting year	Years in Svc	Hours in Svc	Pcs	Pcs x Hr of Svc
2012	6	52560	1245	65437200
2013	5	43800	2987	130830600
2014	4	35040	3733	130804320
2015	3	26280	6147	161543160
2016	2	17520	7771	136147920
2017	1	8760	12270	107485200
			Total Time in Service:	**732248400**

Total time in service assuming controllers are in use 50% of the time:
732248400 / 2 = **366,124,200 Hours**

Long Term Failures from 2012-2017: 95

MTTF = T/N *where T = total time and N = number of units under test*

MTTF = 366124200 / 95 = 3,853,939 hours = 440 years

Probability of survival P for time t is $P(t) = e^{-t/MTTF}$

Probability of survival for 5 years = $P(5) = e^{-5/440} = e^{-0.0113} = 98.9\%$
Probability of survival for 10 years = $P(10) = e^{-10/440} = e^{-0.0227} = 97.6\%$
Probability of survival for 15 years = $P(15) = e^{-15/440} = e^{-0.0341} = 96.6\%$

It can be expected that a RoboteQ motor controller will have a 96.6 percent probability of being operation after 15 years of continuous operation.

Assumptions Made in Counting Field Failures for MTTF Calculation

1. Each controller in the population has been put in service and has operated continuously for one year.
2. We do not know for sure the number of hours each controller in the field has actually been on in a working condition. It has been assumed that controllers spend a significant amount of time OFF. This can be for a variety of reasons including recharging batteries or a machine that is not in use. For the sake of the calculations above it was assumed that all controllers were in operation at for 50% of the time (i.e. 12 hours per day for 365 days).
3. We believe that one year is a conservative estimate which will lower the calculated MTTF but will give a more conservative number.
4. Failures considered are long term as reported by our customers (Useful Life section of the Bathtub Curve). All failures are recorded and an RMA is issued. Early failures at arrival or at very early stages of use are not taken into account.