Project (part 1 small extension)

- Add new features in the dataset []
  - There are some of these metrics that have already been implemented, check the missing ones, and add
- I want to create other [new] graphics that are:
  - I want to graph which **[metric group]** several related metrics as defined in the table below, called groups: availability group, thermal groups ....
  - I want to graph with 2 axes [for all metrics]:
    - y-axis: the metric target;
      - I want two line (1 line to metric, other line to temperature)
    - x-axis: the time,
  - I want to graph with 3 axes [for all metrics]:
    - y-axis: the metric target;
    - x-axis: the time,
    - z-axis: temperature
- I need to review all the graphs one by one until satisfied, if I do not need to redo the graph
- Use only seaborn library
- As you are expert, I want you to give me suggestion to add other types of charts with different and also provide different statistical analyzes

Parameters to be used by equations [put as feature in dataset]

Features	Description
TimeStamp	is the time in seconds, where each sample will represent a second to the front. 1 sample: 1 seconds 2 sample: 2 seconds 3 sample: and so on
CPU frequency	$\boldsymbol{Freq} = N_{cores} \cdot F_{m_c} \cdot CPU_{usage}$
CPU temperature	$\boldsymbol{T_{(t)} = T_{\infty} + \frac{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}{h \cdot A_s} \cdot \left(1 - e^{-\frac{3600 \cdot h \cdot A_s}{m \cdot C} \cdot t}\right)}$
Range external Temperature	10 to 60 degree Celsis . has to generate numbers in this range, but it has a Uniform distribution
Range Room Temperature	20 to 30 degree Celsis. has to generate numbers in this range, but it has a Uniform distribution

*TimeStamp: will be the time used on the x-axis in the graphs. That's because I did the calculations and I discovered that I have this time. Adding a Time column makes the dataset a time series. (It's already a time series just was not explicit with time)

* Range Room Temperature: this feature will serve as input to the equations. Each line will have a new room temperature that will need to be read by the equation that needs this temperature

* Range external Temperature: this feature will serve as input to the equations. Each line will have a new room temperature that will need to be read by the equation that needs this temperature

Metrics for evaluation [put as feature in dataset]

<table>
<tr><th colspan="4">Availability Evaluation [metric group]</th></tr>
<tr><th>N</th><th>unit of measure
(common among metrics)</th><th>Metrics namely (features)</th><th>Equations</th></tr>
<tr><td>1</td><td rowspan="2">Availability (axis y)</td><td>Availability</td><td>

$$\boldsymbol{A} = \frac{\boldsymbol{MTTF_T \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}} - \frac{1}{T_\infty}\right)}}}{\boldsymbol{MTTF_T \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}} - \frac{1}{T_\infty}\right)} + MTTR}}$$

<table>
<tr><th>Symbol</th><th>Parameter</th><th>Magnitude</th></tr>
<tr><td>$MTTF_T$</td><td>Predicted Mean Time to Failure (Hours)</td><td>27800</td></tr>
<tr><td>E_a</td><td>Activation energy (eV)</td><td>0.642</td></tr>
<tr><td>K</td><td>Boltzmann constant (eV/k)</td><td>8.623×10^{-5}</td></tr>
<tr><td>T_∞</td><td>Room temperature (°C)</td><td>22</td></tr>
<tr><td>MTTR</td><td>Mean Time To Repair (Hours)</td><td>8</td></tr>
</table>
</td></tr>
<tr><td>2</td><td>Availability due to Electromigration</td><td>

$$\boldsymbol{A_{EM}} = \frac{\boldsymbol{MTTF_T \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}} - \frac{1}{T_\infty}\right)}}}{\boldsymbol{MTTF_T \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}} - \frac{1}{T_\infty}\right)} + MTTR}}$$

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<tr><td>$J_{\infty adv}$</td><td>Processor’s current density (A/cm^2)</td><td>2.5×10^5</td></tr>
<tr><td>J_∞</td><td>Room’s conditions current density (A/cm^2)</td><td>2×10^5</td></tr>
<tr><td>N</td><td>Empirical constant</td><td>2</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td rowspan="4">Availability (axis y)</td><td></td><td></td></tr>
<tr><td>3</td><td>Availability due to corrosion</td><td>

$$A_C = \frac{MTTF_T \cdot \left(\frac{RH_{\infty adv}}{RH_\infty}\right)^{-2.7} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}}{MTTF_T \cdot \left(\frac{RH_{\infty adv}}{RH_\infty}\right)^{-2.7} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)} + MTTR}$$

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<tr><td>$RH_{\infty adv}$</td><td>Relative humidity at unfavorable conditions (%)</td><td>85</td></tr>
<tr><td>RH_∞</td><td>Relative humidity at room's conditions (%)</td><td>60</td></tr>
</table>
</td></tr>
<tr><td>4</td><td>Availability due to time-dependent dielectric breakdown</td><td>

$$A_{TDDB} = \frac{MTTF_T \cdot e^{-\gamma(E_{\infty adv}-E_\infty)} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}}{MTTF_T \cdot e^{-\gamma(E_{\infty adv}-E_\infty)} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)} + MTTR}$$

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<tr><td>MTTR</td><td>Mean Time To Repair (Hours)</td><td>8</td></tr>
<tr><td>γ</td><td>Field acceleration parameter (cm/MV)</td><td>1</td></tr>
<tr><td>$E_{\infty adv}$</td><td>Externally applied electric field across the dielectric at unfavorable conditions (MV/cm)</td><td>4</td></tr>
<tr><td>E_∞</td><td>Externally applied electric field across the dielectric at room's conditions (MV/cm)</td><td>3.25</td></tr>
</table>
</td></tr>
<tr><td>5</td><td>Availability due to stress migration</td><td>

$$A_{SM} = \frac{MTTF_T \cdot \left(\left|\frac{T_{(f)} - T_{\infty adv}}{T_{(f)} - T_\infty}\right|\right)^{-2.5} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}}{MTTF_T \cdot \left(\left|\frac{T_{(f)} - T_{\infty adv}}{T_{(f)} - T_\infty}\right|\right)^{-2.5} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)} + MTTR}$$

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<tr><td>MTTR</td><td>Mean Time To Repair (Hours)</td><td>8</td></tr>
<tr><td>$T_{\infty adv}$</td><td>Temperature at adverse conditions (°C)</td><td>90</td></tr>
</table>
</td></tr>
</table>

<table>
<tr><td></td><td rowspan="5">Availability (axis y)</td><td></td><td></td></tr>
<tr><td>6</td><td>Availability due to thermal cycling</td><td>

$$A_{TC} = \frac{\boldsymbol{MTTF_T} \cdot \left(\left|\frac{\boldsymbol{T_{(f)} - T_{\infty adv}}}{\boldsymbol{T_{(f)} - T_{\infty}}}\right|\right)^{-q}}{\boldsymbol{MTTF_T} \cdot \left(\left|\frac{\boldsymbol{T_{(f)} - T_{\infty adv}}}{\boldsymbol{T_{(f)} - T_{\infty}}}\right|\right)^{-q} + \boldsymbol{MTTR}}$$

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<tr><td>T_∞</td><td>Room temperature (°C)</td><td>22</td></tr>
<tr><td>MTTR</td><td>Mean Time To Repair (Hours)</td><td>8</td></tr>
<tr><td>$T_{\infty adv}$</td><td>Temperature at adverse conditions (°C)</td><td>90</td></tr>
<tr><td>q</td><td>Coffin-Mason exponent</td><td>4</td></tr>
</table>
</td></tr>
<tr><td>7</td><td>Unified Reliability</td><td>

$$\boldsymbol{MTTF_{IC}} = \frac{MTTF_{TC} \cdot MTTF_{SM}}{MTTF_{TC} + MTTF_{SM}}$$

</td></tr>
<tr><td>8</td><td>External temperature impact</td><td>

$$TP_f = \frac{\left((A_{TI} \times h) \times \left(\frac{(3.413 \times P_{TI} \times (1-\eta_{TI}) \times \Delta t)}{(A_{TI} \times h)} + TP_E - TP_T\right) - P_{CSA}\right)}{(A_{TI} \times h)} + TP_T.$$

TP

TP_E = receives two types of values:
20 degrees (fixed value) or 10 to 60 degree Celsius.
has to generate numbers in this range
[Uniform distribution or other distribution that varies smoothly]

TP_T = receives two types of values []:
20 degrees (fixed value)
or 20 to 30 degree Celsius.
has to generate numbers in this range
[Uniform distribution or other distribution that varies smoothly]

<table>
<tr><td>A_{TI}</td><td>400,00</td></tr>
<tr><td>P_{TI}</td><td>125.742,40 W</td></tr>
<tr><td>TP_T</td><td>20° Celsius</td></tr>
<tr><td>TP_E</td><td>20° Celsius</td></tr>
<tr><td>h</td><td>1.73</td></tr>
<tr><td>η_{TI}</td><td>0,95</td></tr>
<tr><td>Δt</td><td>timestamp</td></tr>
</table>

$P_{TI} = P_{CSA} / 3.412141633$

I want two options to choose the fixed or variable temperature setting.
This is for all equations that use this type of temperature [room temperature or external temperature]

```
%Determination of the power required
Qr = ((Qred/COP) + Qdit)*3.413/(ne/100);
%Power required by processor (BTU)
Pcsa = Qr
```
</td></tr>
<tr><td>9</td><td>Unified Availability</td><td>

$$A_{TC} = \frac{\boldsymbol{MTTF_{IC}}}{\boldsymbol{MTTF_{IC} + MTTR}}$$

</td></tr>
<tr><td colspan="4">Evaluation Failures [metric group]</td></tr>
<tr><td>10</td><td></td><td>Change MTTF based in Temperature</td><td>

$$MTTF_R = MTTF_T \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}} - \frac{1}{T_\infty}\right)}$$

</td></tr>
</table>

<table>
<tr><td>11</td><td rowspan="4">MTTF</td><td>Time-dependent dielectric breakdown</td><td>$MTTF_{TDDB} = MTTF_T \cdot e^{-\gamma(E_{\infty adv}-E_\infty)} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}$</td></tr>
<tr><td>12</td><td>Stress Migration</td><td>$MTTF_{SM} = MTTF_T \cdot \left(\left|\frac{T_{(f)}-T_{\infty adv}}{T_{(f)}-T_\infty}\right|\right)^{-2.5} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}$</td></tr>
<tr><td>13</td><td>Corrosion</td><td>$MTTF_C = MTTF_T \cdot \left(\frac{RH_{\infty adv}}{RH_\infty}\right)^{-2.7} \cdot e^{\frac{E_a}{k}\left(\frac{1}{T_{(f)}}-\frac{1}{T_\infty}\right)}$</td></tr>
<tr><td>14</td><td>Thermal Cycling</td><td>$MTTF_{TC} = MTTF_T \cdot \left(\left|\frac{T_{(f)}-T_{\infty adv}}{T_{(f)}-T_\infty}\right|\right)^{-q}$</td></tr>
<tr><td colspan="4">Cooling Evaluation [metric group]</td></tr>
<tr><td>15</td><td rowspan="2">Btu/h</td><td>Thermal Load Released</td><td>$Q_{R_{ED}} = 3.413 \cdot [(I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f) \cdot (1 - n_T) + h \cdot A_s \cdot (T_\infty - T_d)] \cdot t_e$
<table>
<tr><th>Symbol</th><th>Parameter</th><th>Magnitude</th></tr>
<tr><td>T_∞</td><td>Room temperature (°C)</td><td>22</td></tr>
<tr><td>T_d</td><td>Desired Room Temperature (°C)</td><td>15</td></tr>
<tr><td>I</td><td>Electric current (A)</td><td>6</td></tr>
<tr><td>V</td><td>Voltage (V)</td><td>1</td></tr>
<tr><td>α</td><td>Activity factor</td><td>0.1</td></tr>
<tr><td>C_p</td><td>Capacitance (µF)</td><td>0.1</td></tr>
<tr><td>h</td><td>Convective coefficient (W/m^2K)</td><td>50</td></tr>
<tr><td>A_s</td><td>Motherboard surface area (m^2)</td><td>$60x10^{-4}$</td></tr>
<tr><td>n_t</td><td>IT system energy efficiency</td><td>0.7</td></tr>
<tr><td>t_e</td><td>Evaluation time (Hours)</td><td>1</td></tr>
<tr><td>f</td><td>Frequency (MHz)</td><td>Variable</td></tr>
</table></td></tr>
<tr><td>16</td><td>Energy Required</td><td>$Q_R = 3.413 \cdot \left(\frac{(3.792 + SEER) \cdot [(I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f) \cdot (1 - n_T)] + 3.792 \cdot [h \cdot A_s \cdot (T_\infty - T_d)]}{n_E \cdot SEER}\right) \cdot t_e$
<table>
<tr><th>Symbol</th><th>Parameter</th><th>Magnitude</th></tr>
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<tr><td>T_d</td><td>Desired Room Temperature (°C)</td><td>15</td></tr>
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A_s	Motherboard surface area (m^2)	$60x10^{-4}$
n_t	IT system energy efficiency	0.7
t_e	Evaluation time (Hours)	1
n_E	Efficiency of the electrical system	0.8
SEER	Seasonal Energy Efficiency Ratio	13
f	Frequency (MHz)	Variable

Energy Evaluation [metric group]			
17	W/h	Amount of energy dissipated	$\boldsymbol{Q_{D_{IT}}} = Q_D \cdot (1 - n_T)$
18		Energy demanded	$\boldsymbol{Q_D} = P_{total} \cdot t_e$
Individual metrics (not possible agruped)			
19	-	Power Usage Effectiveness	$\boldsymbol{PUE} = \frac{\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}}{\left(\frac{(\mathbf{3.792 + SEER}) \cdot \left[\left(\mathbf{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}\right) \cdot (\mathbf{1 - n_T})\right] + \mathbf{3.792} \cdot [\mathbf{h \cdot A_s \cdot (T_\infty - T_d)}]}{\mathbf{n_E \cdot SEER}}\right) \cdot \mathbf{t_e}}$
20	-	Data Center Infrastructure Efficiency	$\boldsymbol{DCiE} = \mathbf{100} \cdot \left(\frac{(\mathbf{3.792 + SEER}) \cdot \left[\left(\mathbf{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}\right) \cdot (\mathbf{1 - n_T})\right] + \mathbf{3.792} \cdot [\mathbf{h \cdot A_s \cdot (T_\infty - T_d)}]}{(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}) \cdot \mathbf{n_E \cdot SEER}}\right) \cdot \mathbf{t_e}$
21	**Usd($)**	Total Energy Cost	$\boldsymbol{Cost} = \left(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}\right) \cdot \boldsymbol{E_{cost}}$ price of 0.08 $/kW.h.
22	**m^3/s**	Required volume of Airflow	$\dot{\forall} = \frac{[(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}) \cdot (\mathbf{1} - \boldsymbol{n_T}) + \boldsymbol{h \cdot A_s \cdot (T_\infty - T_d)}] \cdot \boldsymbol{t_e}}{\mathbf{1.21} \cdot \left(\frac{\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}}{\boldsymbol{h \cdot A_s}} \cdot \left(\mathbf{1} - \boldsymbol{e}^{-\frac{\mathbf{3600} \cdot \boldsymbol{h \cdot A_s}}{\boldsymbol{m \cdot C}} \cdot \boldsymbol{t}}\right) + \frac{(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}) \cdot (\mathbf{1} - \boldsymbol{n_T})}{\boldsymbol{h \cdot A_s}}\right)}$
23	-	Thermal Accelerated Aging	$\boldsymbol{TAAF} = \boldsymbol{e}^{\frac{\boldsymbol{E_a}}{\boldsymbol{k}} \cdot \left(\frac{\mathbf{1}}{\boldsymbol{T_\infty} + \frac{(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}) \cdot (\mathbf{1} - \boldsymbol{n_T})}{\boldsymbol{h \cdot A_s}} + \mathbf{273}} - \frac{\mathbf{1}}{\boldsymbol{T_\infty} + \frac{\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}}{\boldsymbol{h \cdot A_s}} \cdot \left(\mathbf{1} - \boldsymbol{e}^{-\frac{\mathbf{3600} \cdot \boldsymbol{h \cdot A_s}}{\boldsymbol{m \cdot C}} \cdot \boldsymbol{t}}\right) + \mathbf{273}}\right)}$
24	kelvin	Temperature rise due to the dissipation of energy	$\boldsymbol{\Delta T_{de}} = \frac{Q_{D_{IT}}}{t_e \cdot h \cdot A_s} \quad Eq.(25)$
			$\boldsymbol{T_{aa}} = \boldsymbol{T_\infty} + \frac{(\boldsymbol{I \cdot V + \alpha \cdot C_p \cdot V^2 \cdot f}) \cdot (\mathbf{1} - \boldsymbol{n_T})}{\boldsymbol{h \cdot A_s}}$

<table>
<tr>
<td>25</td>
<td>Celsius</td>
<td>Actual Ambient Temperature</td>
<td></td>
<td>
<table>
<tr><th>Symbol</th><th>Parameter</th><th>Magnitude</th></tr>
<tr><td>T_∞</td><td>Room temperature (°C)</td><td>22</td></tr>
<tr><td>I</td><td>Electric current (A)</td><td>6</td></tr>
<tr><td>V</td><td>Voltage (V)</td><td>1</td></tr>
<tr><td>α</td><td>Activity factor</td><td>0.1</td></tr>
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SOME EXAMPLES OF GRAPHICS BASED ON MATLAB CODE. I WANT THIS AND GRAPHICS REPRESENTING EACH EQUATION (METRIC IN YELLOW). TEMPERATURE AND AVAILABILITIES

The following MATLAB code shows the procedure to obtain all the results and also the plots related to the evaluation of the processor's behavior:

```
%Determination of the Processor's Temperature
To = 22; %Room temperature (°C)
I = 6; %Electric current (A)
V = 1; %Voltage (V)
A = 0.1; %Activity factor
Cp = 0.1; %Capacitance (uF)
h = 50; %Convective coefficient (W/m2K)
As = 60e-4; %Motherboard surface area (m2)
m = 50e-3; %Mass (kg)
C = 900; %Specific heat (J/kgK)
f = [100:50:1000]; %Frequency (MHz)
t = 1000; %Time (Hours)

Tf = To + ((V*I+A*Cp*V*V.*f)/(h*As))*(1-exp(-t*3600*h*As/(m*C)));
%Processor's temperature (°C)

%Determination of the Inherent Availability
MTTFto = 27800; %Mean time to failure (Hours)
Ea = 0.642; %Activation energy (eV)
k = 8.623e-5; %Boltzmann constant (eV/K)

MTTFtf = MTTFto*exp((Ea/k).*((1./(Tf+273))-(1/(To+273)))); %Mean
time to failure taking temperature in account (Hours)
MTTR = 8; %Mean time to repair (Hours)

Ai = MTTFtf./(MTTFtf+MTTR); %Inherent Availability

%Determination of the Availability due to Electromigration
Jf = 2.5e5; %Processor's current density (A/cm2)
Jto = 2.0e5; %Room's conditions current density (A/cm2)
N = 2; %Empirical constant
```

```
MTTFem = MTTFto*((Jf/Jto)^-N)*exp((Ea/k).*((1./(Tf+273))-
(1/(To+273)))); %Mean time to faillure due to Electromigration
(Hours)
Aem = MTTFem./(MTTFem+MTTR); %Availability due to Electromigration

%Determination of the Availability due to Corrosion
RHf = 85; %Relative humidity at unfavorable conditions (%)
RHto = 60; %Relative humidity at room's conditions (%)
MTTFc = MTTFto*((RHf/RHto)^-2.7)*exp((Ea/k).*((1./(Tf+273))-
(1/(To+273)))); %Mean time to faillure due to Corrosion (Hours)
Ac = MTTFc./(MTTFc+MTTR); %Availability due to Corrosion

%Determination of the Availability due to Time-Dependent
Dielectric
%Breakdown
y = 1; %Assumed field acceleration parameter (cm/MV)
Ef = 4; %Externally applied electric field across the dielectric
at unfavorable conditions (MV/cm)
Eto = 3.25; %Externally applied electric field across the
dielectric at room's conditions (MV/cm)
MTTFtddb = MTTFto*(exp(-y*(Ef-Eto)))*exp((Ea/k).*((1./(Tf+273))-
(1/(To+273)))); %Mean time to faillure due to TDDB (Hours)
Atddb = MTTFtddb./(MTTFtddb+MTTR); %Availability due to TDDB

%Determination of the Availability due to Stress Migration
Ts = 90; %Temperature at adverse conditions
MTTFsm = MTTFto.*(((abs(Tf-Ts))/(abs(Tf-To))).^-
2.5)*exp((Ea/k).*((1./(Tf+273))-(1/(To+273)))); %Mean time to
faillure due to Stress Migration (Hours)
Asm = MTTFsm./(MTTFsm+MTTR); %Availability due to Stress Migration

%Determination of the Availability due to Thermal Cycling
q = 4; %Coffin-Manson exponent
MTTFtc = MTTFto.*(((abs(Tf-Ts))./(abs(Tf-To))).^-q); %Mean time to
faillure due to Thermal Cycling (Hours)
Atc = MTTFtc./(MTTFtc+MTTR); %Availability due to Thermal Cycling

%Determination of the Availability according to the Unified
Reliability
%Model
MTTFic = 1./((1./MTTFsm)+(1./MTTFtc)); %Mean time to faillure
according to the Unified Reliability Model
Aic = MTTFic./(MTTFic+MTTR); %Availability according to the
Unified Reliability

%Generation of the required plots
figure
subplot(2,1,1)
plot(Tf,f); %This plots Processor's Temperature (°C) vs Frequency
(MHz)
ylabel('Frequency (MHz)'); %This labels Y axis
xlabel('Temperature (°C)'); %This labels X axis
```

```
title('Processor´s temperature Vs Frequency')

subplot(2,1,2)
plot(Tf,Ai*100); %This plots Processor's Temperature (°C) vs
Availability (%)
hold on
plot(Tf,Aem*100); %This plots Processor's Temperature (°C) vs
Electromigration Availability (%)
plot(Tf,Ac*100); %This plots Processor's Temperature (°C) vs
Corrosion Availability (%)
plot(Tf,Atddb*100); %This plots Processor's Temperature (°C) vs
TDDB Availability (%)
plot(Tf,Asm*100); %This plots Processor's Temperature (°C) vs
Stress Migration Availability (%)
plot(Tf,Atc*100, 'k'); %This plots Processor's Temperature (°C) vs
Thermal Cycling Availability (%)
ylabel('Availability (%)'); %This labels Y axis
xlabel('Temperature (°C)'); %This labels X axis
title('Processor´s temperature Vs Availability')
legend('Inherent Availability', 'Electromigration Availability',
'Corrosion Availability', 'TDDB Availability', 'Stress Migration
Availability', 'Thermal Cycling Availability')
hold off

figure
plot(Tf,Aic*100); %This plots Processor's Temperature (°C) vs
Availability (%)
ylabel('Availability (%)'); %This labels Y axis
xlabel('Temperature (°C)'); %This labels X axis
title('Variation of the Availability according to the Unified
Model')
```

The plots obtained are shown below:

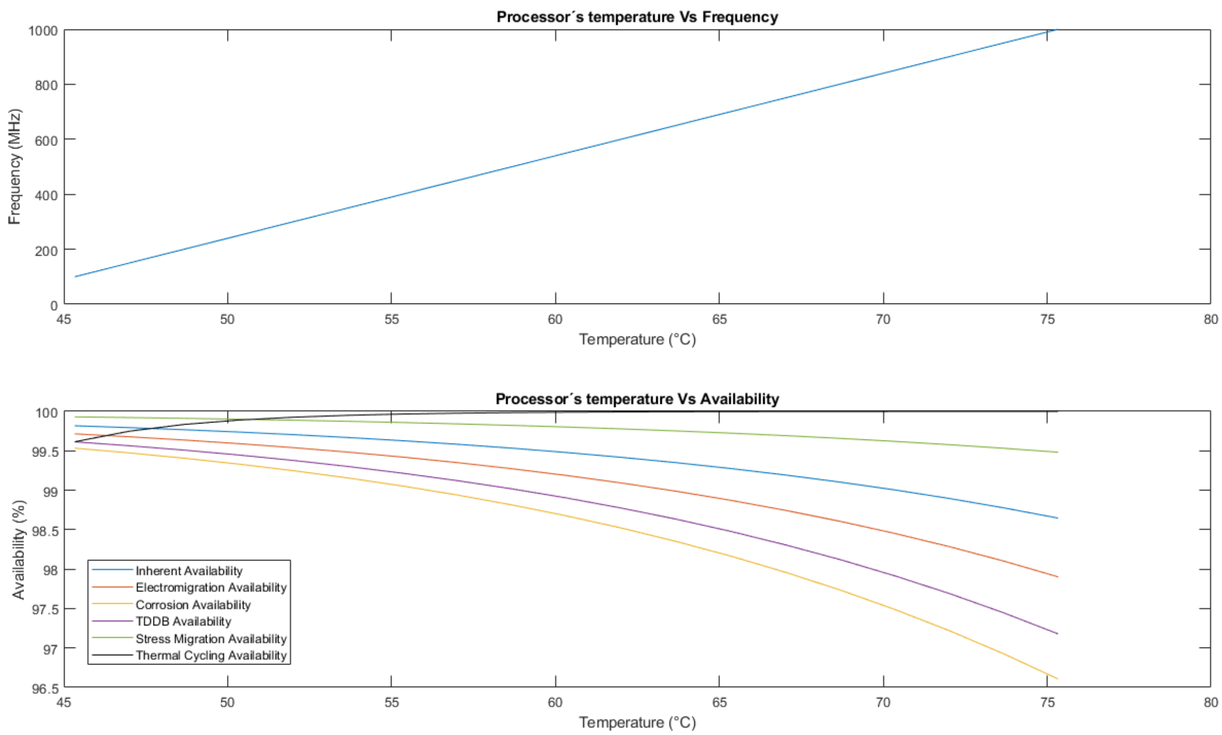

Figure 3. Processor’s behavior.

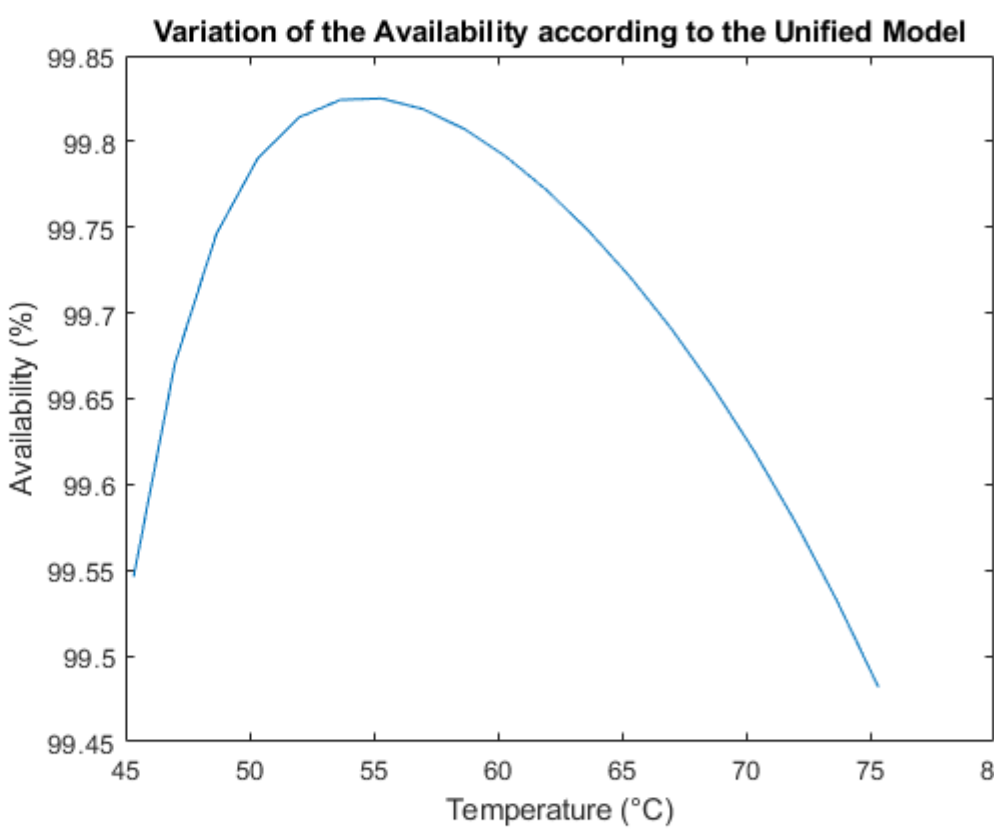

Figure 4. Variation of the Availability according to the unified model.

The following MATLAB code shows the procedure to obtain all the results and also the plots related to the evaluation of the Actual Ambient Temperature, the Thermal Load Released and the Energy Required:

```
%Determination of the Processor's power demanded
I = 6; %Electric current (A)
V = 1; %Voltage (V)
A = 0.1; %Activity factor
Cp = 0.1; %Capacitance (uF)
f = [500:50:1500]; %Frequency (MHz)
te = 1; %Evaluation period of time (Hours)
nt = 70; %IT system energy efficiency (%)
ne = 80; %Efficiency of the electrical system (%)
h = 50; %Convective coefficient (W/m2K)
As = 60e-4; %Motherboard surface area (m2)
To = 22; %Surrounding's temperature (°C)
Td = 15; %Desired temperature (°C)
SEER = 13; %Seasonal Energy Efficiency Ration
COP = SEER/3.792; %Coefficient of Performance
t = 1000; %Time (Hours)
m = 50e-3; %Mass (kg)
C = 900; %Specific heat (J/kgK)

%Determination of the actual ambient temperature
Pf = V*I+A*Cp*V*V.*f; %Processor's power demanded (W)
Qd = Pf*te; %Energy demanded in the period "t" (W.h)
Qdit = Qd*(1-(nt/100)); %Energy dissipated by the device (W.h)
DTde = Qdit/(te*h*As); %Temperature rise due to the dissipation of energy (K)
Taa = To + DTde; %Actual ambient temperature (°C)

%Determination of the thermal load released by the device
Qred = As*h*(Taa - Td)*te*3.413; %Thermal load released by the device (BTU)

%Determination of the power required
Qr = ((Qred/COP) + Qdit)*3.413/(ne/100); %Power required by processor (BTU)

%Determination of the Power Usage Effectiveness
PUE = Pf./(Qr./(te*3.413)); %Power Usage Effectiveness

%Determination of the Data Center Infrastructure Efficiency
DCiE = 100./PUE; %Data Center Intrastructure Efficiency

%Determination of the Total Cost
Ecost = 0.08; %Energy cost $ per kWh
Cost = PUE.*(Qr./(te*1000*3.413)).*Ecost;
```

```
%Required airflow to remove heat
Tf = To + ((V*I+A*Cp*V*V.*f)/(h*As))*(1-exp(-t*3600*h*As/(m*C)));
%Processor's temperature (°C)
Mreq = (Qred/(te*3.413))./(1.21.*(Tf-Taa));

%Determination of the thermal accelerated aging
Ea = 0.642; %Activation energy (eV)
k = 8.623e-5; %Boltzmann constant (eV/K)
TAAF = exp((Ea/k).*((1./(Taa+273))-(1./(Tf+273)))); %Thermal
accelerated aging

%Generation of the required plots
figure
subplot(2,2,1)
plot(f,Qr); %This plots Power required by processor (BTU) vs
Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Power required by processor (BTU)'); %This labels Y axis
title('Power required by processor Vs Frequency')

subplot(2,1,2)
plot(f,Taa); %This plots Actual ambient temperature (°C) vs
Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('External temperature (°C)'); %This labels Y axis
title('External temeprature Vs Frequency')

subplot(2,2,2)
plot(f,Qred); %This plots Thermal load released by the device
(Btu) vs Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Thermal load released (BTU)'); %This labels Y axis
title('Thermal load Vs Frequency')

figure
subplot(3,1,1)
plot(f,PUE); %This plots Power Usage Effectiveness vs Frequency
(MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Power Usage Effectiveness'); %This labels Y axis
title('Power Usage Effectiveness Vs Frequency')

subplot(3,1,2)
plot(f,DCiE); %This plots the Data Center Infrastructure
Efficiency vs Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Data Center Infrastructure Efficiency'); %This labels Y
axis
title('Data Center Infrastructure Efficiency Vs Frequency')

subplot(3,1,3)
plot(f,Cost); %This plots the Total Cost vs Frequency (MHz)
```

```
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Total Cost ($)'); %This labels Y axis
title('Total Cost Vs Frequency')

figure
plot(f,Mreq); %This plots the Required Airflow vs Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Required airflow (m3/s)'); %This labels Y axis
title('Required airflow (m3/s) Vs Frequency')

figure
plot(f,TAAF); %This plots the Thermal Accelerated Aging vs
Frequency (MHz)
xlabel('Frequency (MHz)'); %This labels X axis
ylabel('Thermal Accelerated Aging'); %This labels Y axis
title('Thermal Accelerated Aging Vs Frequency')
```

The plots obtained are shown below:

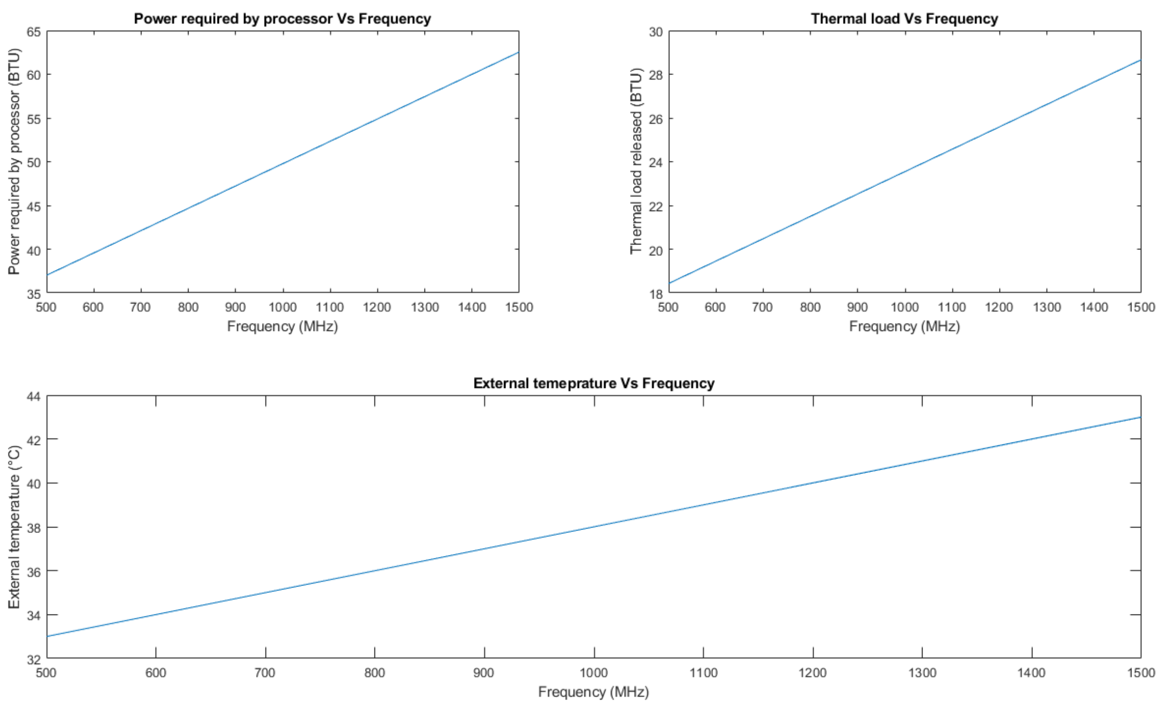

Figure 5. Thermal Impact of the Processor.

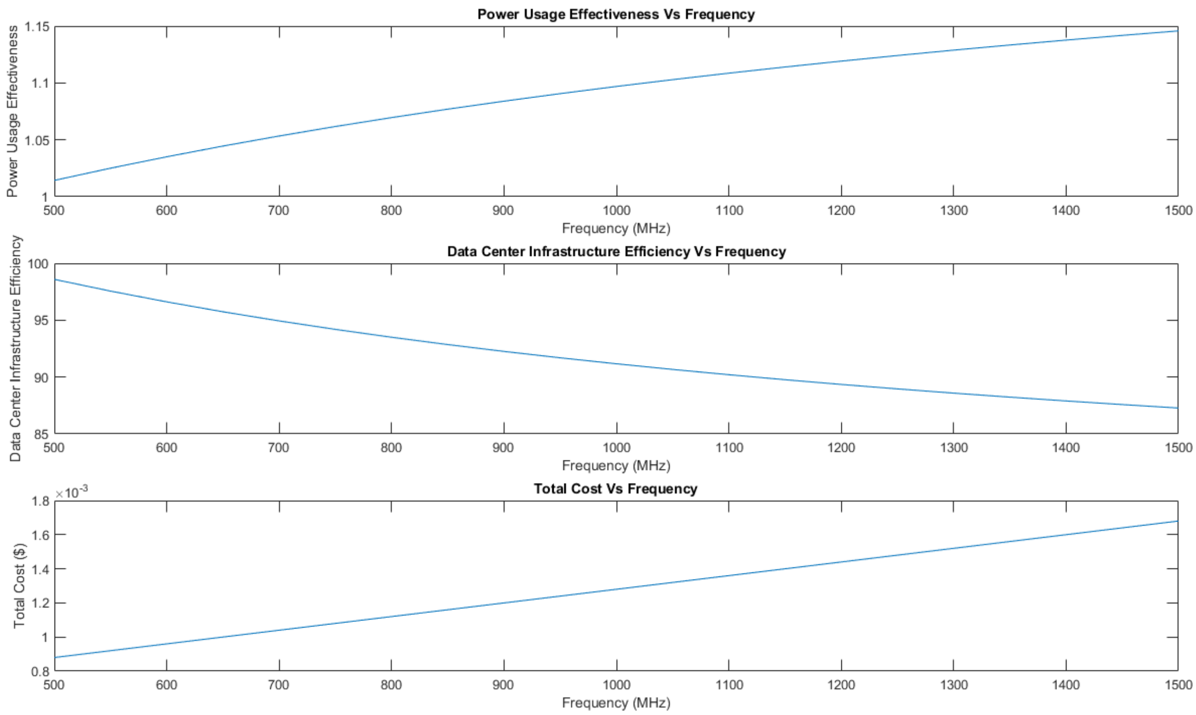

Figure 6. Variation of the Energy Effectiveness, Efficiency and Cost.

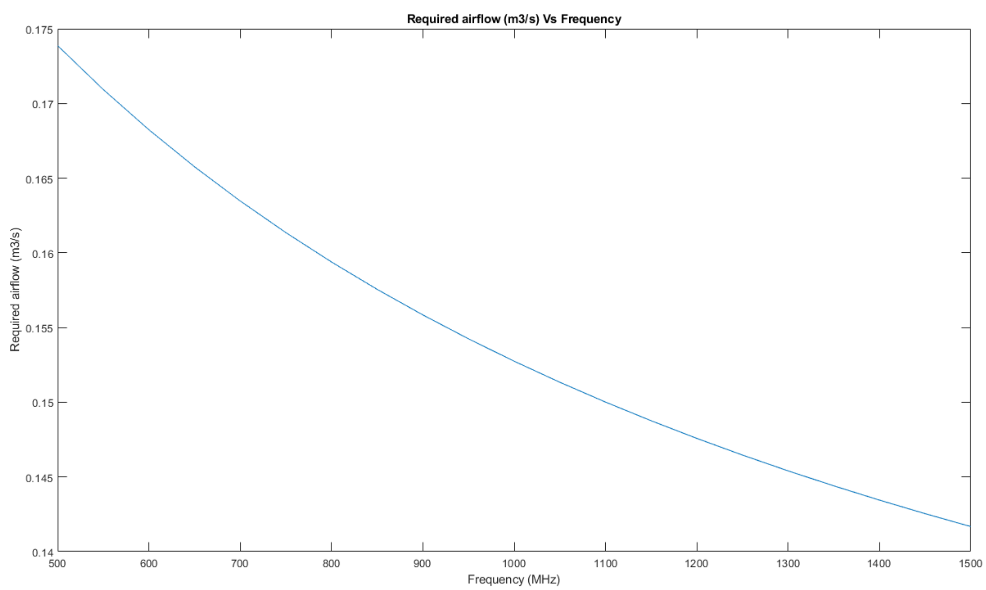

Figure 7. Variation of the Required Airflow to Dissipate the Heat released by the Processor.

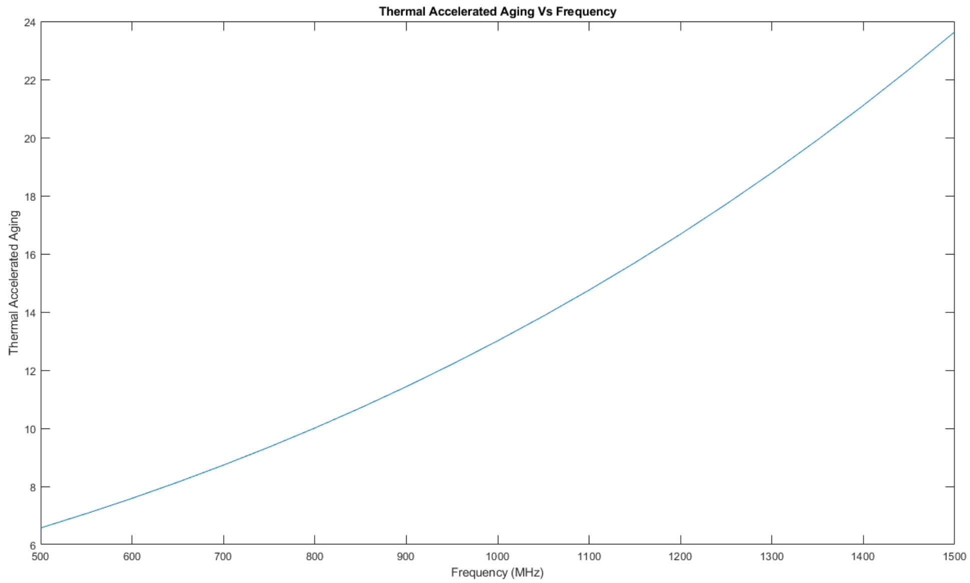

Figure 8. Variation of the Thermal Acceleration Aging

MATLAB CODE

The following MATLAB code shows the procedure to obtain all the results and also the plots related to the CPU utilization frequency as a function of the Percentage of CPU usage and the CPU maximum frequency.

```
%%%Equation for the CPU frequency based on CPU consumption
Nc = 8; %Number of cores
APf = 2.3; %Average CPU per physical (GHz)
APs = Nc*APf; %Average CPU per physical system (GHz)
Cu = [71.88, 3.51599, 0.18044, 26.46, 41.74, 36.66, 8.35, 10.656,
25.91999, 2.594, 8.35, 12.488, 14.282, 0.12836, 15.3799, 8.094, 12,
0.1049, 28.56]; %CPU utilization (%)  …. here is for you to read all my
samples
t = [1:1:19]; %Time (Hours)

ACu = APs*Cu/100; %Average CPU utilization frequency (GHz)

figure
plot(t, ACu);
xlabel('Time (Hours)'); %This labels X axis
ylabel('Frequency (GHz)'); %This labels Y axis
title('Average CPU Frequency Vs Time')
```

The plot obtained is shown below:

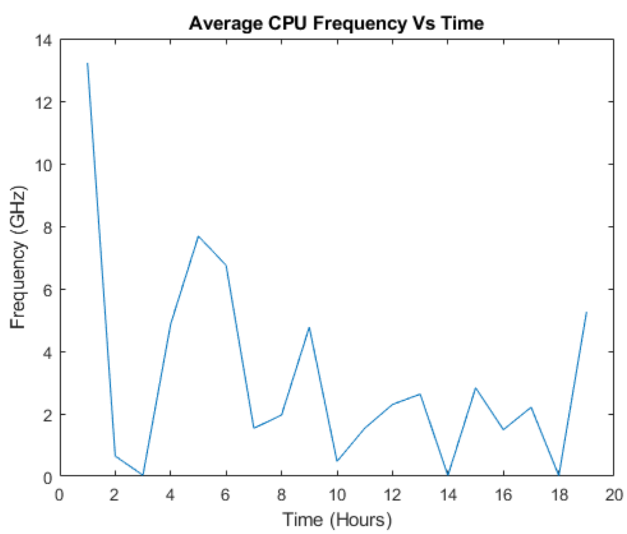

Figure 9. Variation of the CPU utilization frequency as a function of time.