EE503 Example of measurement error due to noise in electronic instrumentation
filename EE503_noise.mcd
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Consider a tempurature meter with a range of 0C to 100C that has an output voltage of 0.1V to 1.1V and has an output noise density of 1mV/rtHz.

Estimate the probability that the tempurature accuracy is within 0.1C for the entire tempurature range of the instrument for update rates of 10/sec, 1/sec, and 0.1/sec

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(Assume the bandwith is equal to the update rate)

Problem variables:

$$B := \begin{pmatrix} 0.1 \\ 1 \\ 10 \end{pmatrix} \qquad N_0 := \left(10^{-3}\right)^2 \frac{V^2}{Hz}$$ noise density

calculate total noise power:

$$Sn := N_0 \cdot B \qquad Sn = \begin{pmatrix} 1 \times 10^{-7} \\ 1 \times 10^{-6} \\ 1 \times 10^{-5} \end{pmatrix} V^2 = \sigma^2$$

find the rms noise voltage

$$\sigma := \sqrt{Sn} \qquad \sigma = \begin{pmatrix} 3.162 \times 10^{-4} \\ 1 \times 10^{-3} \\ 3.162 \times 10^{-3} \end{pmatrix}$$ Vrms

Mean voltage is the desired signal and varies from 100 mV to 1.1 V

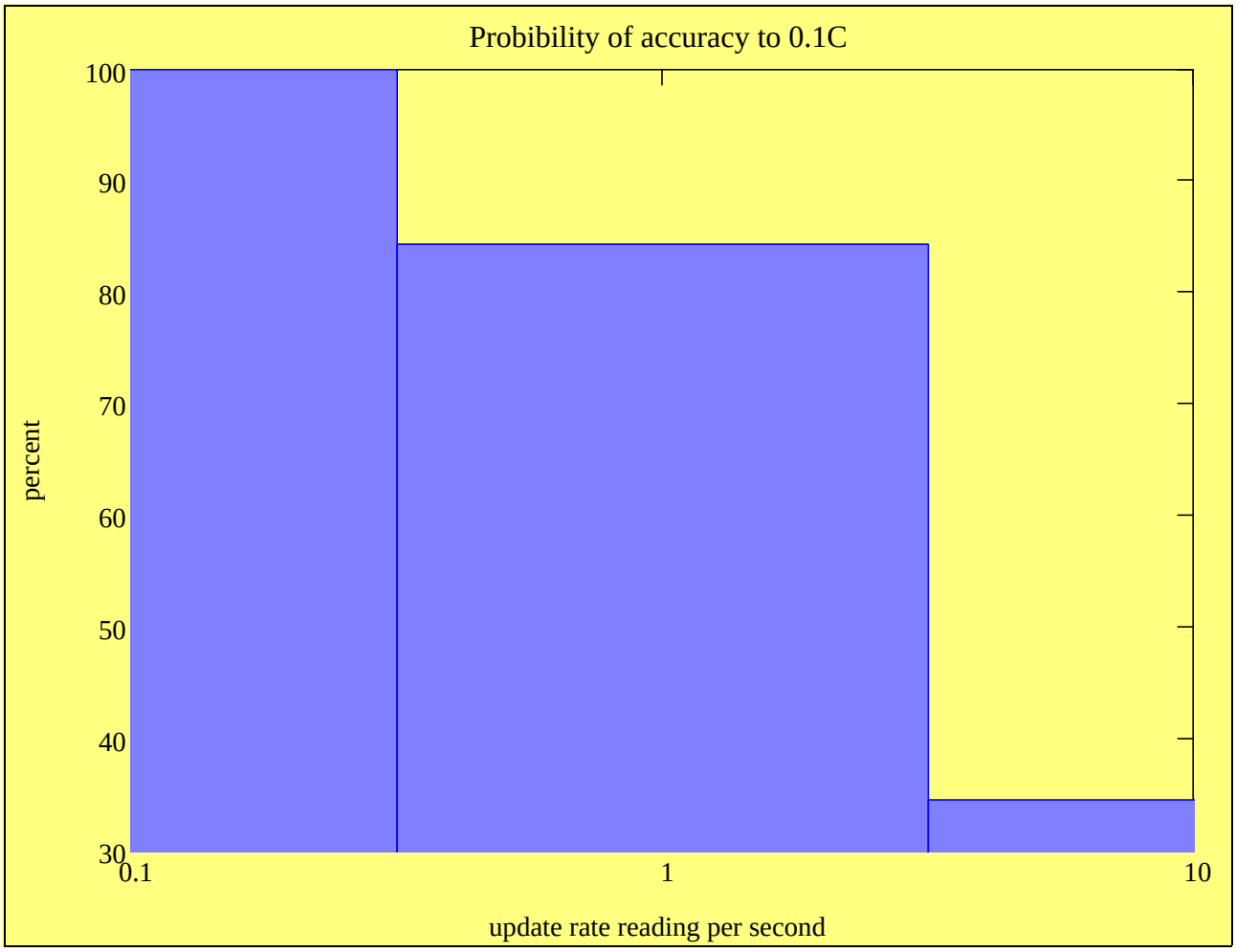
+/-1 degree C corresponds to: $dC := \frac{1.1 - 0.1}{100}$ $dC = 0.01 \frac{Volts}{degreeC}$

Error allowed for 0.1C: $Ev := dC \cdot 0.1$ $Ev = 1 \times 10^{-3}$ Volts

now find the probility of being within +/- 0.1 degrees C:

$P := erf\left(\frac{Ev}{\sigma}\right) \cdot 100$ $P = \begin{pmatrix} 99.999 \\ 84.27 \\ 34.528 \end{pmatrix}$

range variable for element extraction: $k := 0 .. 2$



Another way.....

Problem variables:

number of points: $k := 1 .. 100$

noise density: $N_0 := \left(10^{-3}\right)^2 \quad \frac{V^2}{Hz}$

Noise bandwith range: $B_k := .1 \cdot k \quad Hz$

calculate total noise power:

$Sn := N_0 \cdot B \qquad Sn = V_n{}^2 = \sigma^2$

find the rms noise voltage:

$\sigma := \sqrt{Sn} \qquad Vrms$

Mean voltage is the desired signal and varies from 100 mV to 1.1 V

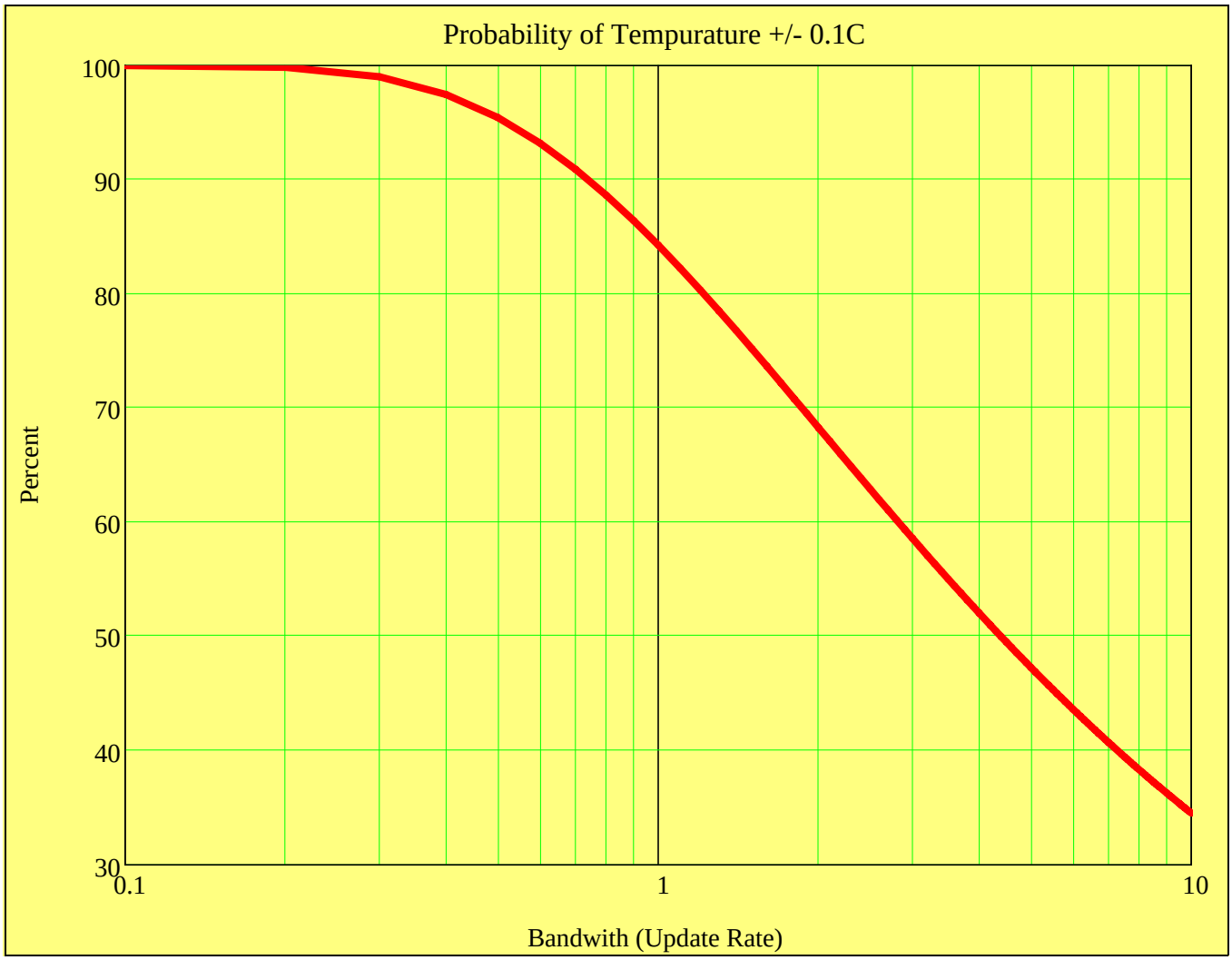
Calculate the voltage limit for the required +/- 0.1 accuracy. This is independent of the actual tempurature since the transfer function is linear:

+/-1 degree C corresponds to: $dC := \frac{1.1 - 0.1}{100} \quad dC = 0.01 \ \frac{Volts}{C}$

Error voltage allowed for 0.1C: $ErV := dC \cdot 0.1 \qquad ErV = 1 \times 10^{-3} \quad Volts$

now find the probility:

$P := erf\left(\frac{ErV}{\sigma}\right) \cdot 100$


Probability of Tempurature +/- 0.1C
100
90
80
70
60
50
40
30
Percent
0.1
1
10
Bandwith (Update Rate)