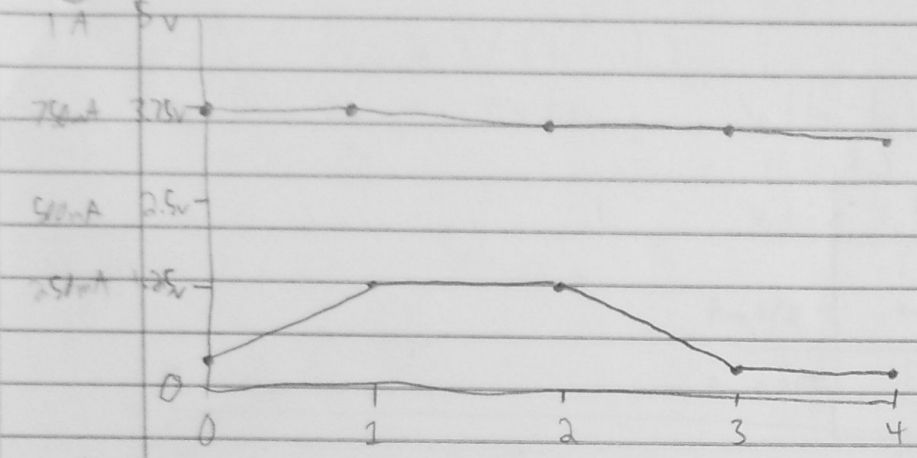
Battery Capacity

2/26/20



t	V	I
0	3.75	100 mA
1	3.75	250 mA
2	3.7	250 mA
3	3.7	100 mA
4	3.65	100 mA

$$\{\text{EPS Measurement}\}_i = \{\text{voltage, current, time}\}_i = \{v_i, i_i, t_i\}$$

- Given two measurements, we can get

$$V(t) = m_v \cdot t + b_v \;\therefore\; \left\{m_v = \frac{v_1 - v_0}{t_1 - t_0},\; b_v = v_0 - m_v \cdot t_0\right\}$$

$$I(t) = m_I \cdot t + b_I \;\therefore\; \left\{m_I = \frac{i_1 - i_0}{t_1 - t_0},\; b_I = i_0 - m_I \cdot t_0\right\}$$

$$P(t) = V(t) \cdot I(t) = (m_I \cdot m_v \cdot t^2) + (m_v \cdot t \cdot b_I) + (m_I \cdot t \cdot b_v) + (b_I \cdot b_v)$$

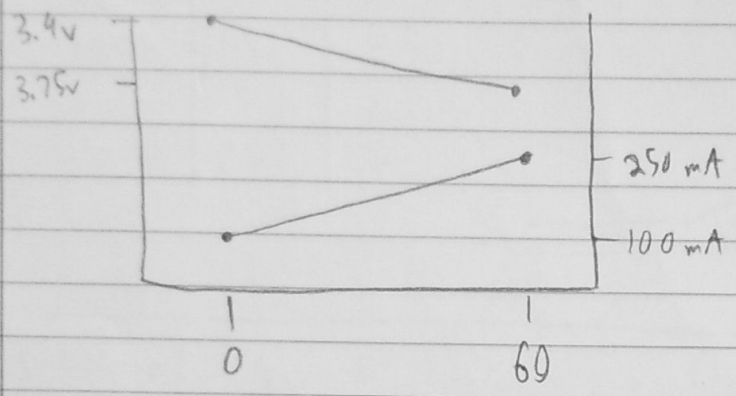
- measured between time t_0 & t_1, we can get the energy consumed by the system

$$E(t_0, t_1) = \int_{t_0}^{t_1} P(t) \cdot dt = \int_{t_0}^{t_1} \left(V(t) \cdot I(t)\right) dt$$

$$= \int_{t_0}^{t_1} \left(m_I m_v t^2\right) + \left(m_v b_I t\right) + \left(m_I b_v t\right) + \left(b_I b_v\right)\, dt$$

$$= \left[\frac{m_I m_v}{3} t^3 + \frac{m_v b_I + m_I b_v}{2} t^2 + b_I b_v t\right]_{t_0}^{t_1}$$

$$= \frac{m_I m_v}{3}\left(t_1^3 - t_0^3\right) + \frac{m_v b_I + m_I b_v}{2}\left(t_1^2 - t_0^2\right) + b_I b_v \left(t_1 - t_0\right)$$



$P(0) = 0.39\ W$

$P(60) = 0.9375\ W$

$\Delta P = 0.5475\ W$

$\Delta t = 60\ s$

$m_p = 0.009125$, $b_p = 0.39$

$P = m_p t + 0.39$

$\int P\,dt = \frac{m_p}{2} t^2 + 0.39t$

$16.425 + 23.4$

$= 39.825$

$\text{Error} = \frac{39.825 - 40.05}{40.05} = -0.56\%$

$V = -0.0025t + 3.4$

$I = 0.0025t + 0.1$

$\int V\,dt = -0.00125t^2 + 3.4t$

$\int I\,dt = 0.00125t^2 + 0.1t$

$\int V\,dt = -4.5 + 234 = 224.5$

$\int I\,dt = 4.5 + 6 = 10.5$

$\frac{\int V \cdot \int I}{60} = \frac{2409.75}{60} = 40.162$

$\text{Error} = \frac{40.1625 - 40.05}{40.05} = +0.28\%$

$\Delta i = i_1 - i_0$

$\Delta v = v_1 - v_0$

$\Delta t = t_1 - t_0$

$20.4 \times 3600 = 73,440$

$m_v = (v_1 - v_0) / (t_1 - t_0)$

$b_v = v_0 - m_v t_0 = \frac{v_0 (t_1 - t_0)}{(t_1 - t_0)} - \frac{(v_1 - v_0) t_0}{t_1 - t_0}$

$= \frac{v_0 t_1 - v_0 t_0 - v_1 t_0 + v_0 t_0}{t_1 - t_0}$

$= \frac{v_0 t_1 - v_1 t_0}{t_1 - t_0}$

v	3.9 → 3.75	$\Delta v = -0.15$	, $m_v = -0.03$	, $b_v = 3.9$
I	0.1 → 0.25	$\Delta I = 0.15$	, $m_I = 0.03$	, $b_I = 0.1$
t	0 → 5	$\Delta t = 5$		

$E = \frac{-0.0009}{3}(5^3 - 0^3) + \frac{-0.03 \cdot 0.1 + 0.03 \cdot 3.9}{2}(5^2 - 0^2) + 0.34(5 - 0)$

$= 125 \cdot -0.0003 + \frac{-0.003 + 0.117}{2} \cdot 25 + 1.95$

$= -0.0375 + 1.425 + 1.95 = 3.3375$ J

V	3.9 → 3.75	$\Delta V = -0.15$	, $m_V = -0.0025$	, $b_V = 3.9$
I	0.1 → 0.25	$\Delta I = 0.15$	, $m_I = 0.0025$	, $b_I = 0.1$
t	0 → 60	$\Delta t = 60$		

$E = \frac{-0.0000625}{3}(60^3) + \frac{-0.00025 + 0.00975}{2} \cdot (60^2) + 0.39 \cdot 60$

$E = -0.45 + 17.1 + 23.4 = 40.05$ J

V	3.9 → 3.75	$\Delta V = -0.15$	, $mv = -0.0025$	, $bv = 3.93$
I	0.1 → 0.25	$\Delta i = +0.15$	, $mi = +0.0025$	, $bi = 0.07$
t	12 → 72	$\Delta t = 60$		

$E = \frac{-0.0000625}{3}(72^3 - 12^3) + \frac{-0.000175 + 0.009825}{2}(72^2 - 12^2) + 0.2751(60)$

$E = -0.774 + 24.318 + 16.506 = 40.05$ J

3/16/20

$(27 - 15)^3 = 12^3 = 1728$

$27^3 - 15^3 = 19{,}683 - 3{,}375 = 16{,}488$

$m_v = dv / dt$
$b_v = v_0$
$m_i = di / dt$
$b_i = i_0$

$$E = \frac{m_v m_i}{3} dt^3 + \frac{m_v b_i + m_i b_v}{2} dt^2 + b_i b_v \cdot dt$$

$$= \frac{1}{3} \frac{dv}{dt} \cdot \frac{di}{dt} dt^3 + \frac{1}{2} \cdot \frac{dv \cdot i_0}{dt} + \frac{di \cdot v_0}{dt} dt^2 + b_i b_v \cdot dt$$

$$= \left(\frac{dv \cdot di}{3} + \frac{dv \cdot i_0 + di \cdot v_0}{2} + v_0 \cdot i_0 \right) dt$$

$dv = -0.15$
$di = +0.15$
$v_0 = 3.9$
$i_0 = 0.1$
$dt = 60$

$$E = \left(\frac{-0.0225}{3} + \frac{0.585 - 0.015}{2} + 0.39 \right) 60$$

$$= (-0.0075 + 0.285 + 0.39)\, 60$$

$$= 40.05 \text{ J}$$