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ECE342 HW 7 (Due Tuesday, October 31, 2006)

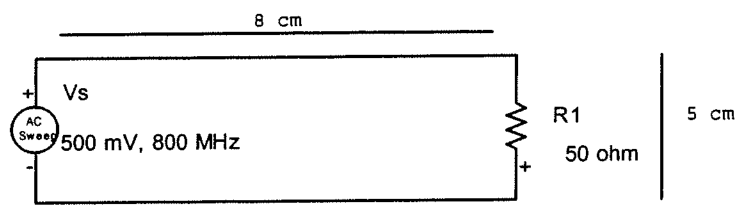
1. Problem 7.1.1 on page 494 of our textbook (2nd Ed) by Clayton Paul. (Comment: This problem shows the differences between the near field and the far field. Note when the distance away from the antenna becomes more than a wavelength, the amplitude of E_r becomes small compared to E_θ, and the ratio of E_θ to H_Φ approaches the plane wave value of $\eta_0 = 377$ ohms.)

2. Compute the radiation resistance of and the total average power radiated by the Hertzian dipole of Problem 1. (8.77 mΩ, 438.65 mW). (Comment: this problem shows that the Hertzian dipole is rather impractical, since rather large currents are necessary to radiate rather small power levels!)

3. Problem 7.1.8 on page 495 of our textbook (2nd edition) by Clayton Paul.

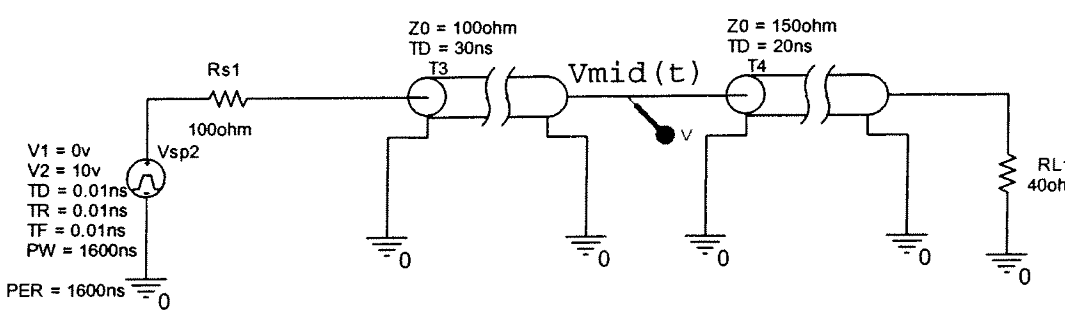
4. Problem 7.2.1 on page 495 of our textbook (2nd edition) by Clayton Paul.

5. Estimate the maximum far-field electric field strength at 3 meters generated by the following circuit. The wire radius is 0.5 mm. *Hint: use the "elemental loop" or "elemental magnetic dipole" antenna (Text Section 7.1.2) to model this circuit. (Answer: 101 dBμV/m)*



6. An antenna with the antenna factor shown in Fig. 7.17 on p. 458 of our textbook (2nd edition) is to be used to measure radiated emission. 50 feet of coaxial cable with a loss of 4 dB/100 feet connects the antenna to the spectrum analyzer. The measurement is at 150 MHz. If the spectrum analyzer gives a reading of 78 dBμV, what is the strength of the field in the vicinity of the antenna? *(Answer: 95 dBμV/m)*

7. Draw the voltage bounce diagrams for the two transmission lines below from t=0 to t=160ns. Then plot Vmid(t) and also the sending end and receiving end voltages for $0 < t < 160$ ns. Assume that the source is a 10 V step function, 10u(t) V. What dc steady-state voltage should both lines be approaching? Verify your results with a PSPICE simulation. Attach your PSPICE schematic and PROBE plots with each voltage step marked using the "Toggle Cursor" and "Mark Label" buttons.



SOLUTION ECE342 HW #7

Problem 1 (Text 7.1.1)

$dl := 1 \cdot 10^{-2}$ m $\quad I := 10e^{j \cdot 30 \cdot \frac{\pi}{180.}}$ A $\quad f := 100 \cdot 10^{6}$ Hz

$\lambda := 3 \cdot 10^{8} \cdot \frac{1}{f} \quad \lambda = 3$ m $\quad \beta := \frac{2 \cdot \pi}{\lambda} \quad \beta = 2.0944 \ \frac{r}{m}$

$\theta := 45 \cdot \frac{\pi}{180.} \quad \theta = 0.7854$ rad $\quad \eta := 377.0$

A. For a distance of 10 cm from the antenna: $r := 10 \cdot 10^{-2}$ m

$$H\phi := \frac{I \cdot dl}{4 \cdot \pi} \cdot \beta^{2} \cdot \sin(\theta) \cdot \left(\frac{j}{\beta \cdot r} + \frac{1}{\beta^{2} \cdot r^{2}} \right) \cdot e^{-j \cdot \beta \cdot r}$$

$H\phi = 0.49874 + 0.2859$ $H\phi mag := |H\phi|$ $\quad H\phi mag = 0.57491 \ \frac{A}{m}$

$H\phi ang := \arg(H\phi) \cdot \frac{180.}{\pi} \quad H\phi ang = 29.82902$ degrees

$$E_r := \frac{2 \cdot I \cdot dl}{4 \cdot \pi} \cdot \eta \cdot \beta^{2} \cdot \cos(\theta) \cdot \left(\frac{1}{\beta^{2} \cdot r^{2}} - j \cdot \frac{1}{\beta^{3} \cdot r^{3}} \right) \cdot e^{-j \cdot \beta \cdot r}$$

$E_r = 1.0295 \times 10^{3} - 1.7955i \times 10^{3}$

$E_{rmag} := |E_r| \quad E_{rmag} = 2.06971 \times 10^{3} \ \frac{V}{m}$

$E_{rang} := \arg(E_r) \cdot \frac{180.}{\pi} \quad E_{rang} = -60.17098$ degrees

$$E_\theta := \frac{I \cdot dl}{4 \cdot \pi} \cdot \eta \cdot \beta^{2} \cdot \sin(\theta) \cdot \left(\frac{j}{\beta \cdot r} + \frac{1}{\beta^{2} \cdot r^{2}} - \frac{j}{\beta^{3} \cdot r^{3}} \right) \cdot e^{-j \cdot \beta \cdot r}$$

$E_\theta = 501.02177 - 855.49658i$

$E_{\theta mag} := |E_\theta| \quad E_{\theta mag} = 991.41173 \ \frac{V}{m}$

$E_{\theta ang} := \arg(E_\theta) \cdot \frac{180}{\pi} \quad E_{\theta ang} = -59.64462$ degrees

$\frac{|E_\theta|}{|E_r|} = 0.47901 \quad \frac{|E_\theta|}{|H\phi|} = 1.72447 \times 10^{3}$

B. For a distance of 1 m from the antenna $r := 1.0$ m

$$H\phi := \frac{I\cdot dl}{4\cdot\pi}\cdot\beta^2\cdot\sin(\theta)\cdot\left(\frac{j}{\beta\cdot r}+\frac{1}{\beta^2\cdot r^2}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$H\phi = 0.01179 - 5.6269$ $H\phi mag := |H\phi|$ $H\phi mag = 0.01306$ $\frac{A}{m}$

$H\phi ang := \arg(H\phi)\cdot\frac{180.}{\pi}$ $H\phi ang = -25.52283$ degrees

$$E_r := \frac{2\cdot I\cdot dl}{4\cdot\pi}\cdot\eta\cdot\beta^2\cdot\cos(\theta)\cdot\left(\frac{1}{\beta^2\cdot r^2}-j\cdot\frac{1}{\beta^3\cdot r^3}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$E_r = -2.02576 - 4.24274i$

$E_{rmag} := |E_r|$ $E_{rmag} = 4.70155$ $\frac{V}{m}$

$E_{rang} := \arg(E_r)\cdot\frac{180.}{\pi}$ $E_{rang} = -115.52283$ degrees

$$E_\theta := \frac{I\cdot dl}{4\cdot\pi}\cdot\eta\cdot\beta^2\cdot\sin(\theta)\cdot\left(\frac{j}{\beta\cdot r}+\frac{1}{\beta^2\cdot r^2}-\frac{j}{\beta^3\cdot r^3}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$E_\theta = 3.43011 - 2.12137i$

$E_{\theta mag} := |E_\theta|$ $E_{\theta mag} = 4.03309$ $\frac{V}{m}$

$E_{\theta ang} := \arg(E_\theta)\cdot\frac{180}{\pi}$ $E_{\theta ang} = -31.73496$ degrees

$\frac{|E_\theta|}{|E_r|} = 0.85782$ $\frac{|E_\theta|}{|H\phi|} = 308.82348$

C. For a distance of 10 m from the antenna $r := 10.0$ m

$$H\phi := \frac{I\cdot dl}{4\cdot\pi}\cdot\beta^2\cdot\sin(\theta)\cdot\left(\frac{j}{\beta\cdot r}+\frac{1}{\beta^2\cdot r^2}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$H\phi = 1.17851 \times 10^{-3} - H\phi mag := |H\phi|^{5}$ $\qquad H\phi mag = 1.17985 \times 10^{-3}\ \frac{A}{m}$

$H\phi ang := \arg(H\phi)\cdot\frac{180.}{\pi}$ $\qquad H\phi ang = -2.7336$ degrees

$$E_r := \frac{2\cdot I\cdot dl}{4\cdot\pi}\cdot\eta\cdot\beta^2\cdot\cos(\theta)\cdot\left(\frac{1}{\beta^2\cdot r^2} - j\cdot\frac{1}{\beta^3\cdot r^3}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$E_r = -2.02576 \times 10^{-3} - 0.04243i$

$E_{rmag} := |E_r|$ $\qquad E_{rmag} = 0.04248\ \frac{V}{m}$

$E_{rang} := \arg(E_r)\cdot\frac{180.}{\pi}$ $\qquad E_{rang} = -92.7336$ degrees

$$E_\theta := \frac{I\cdot dl}{4\cdot\pi}\cdot\eta\cdot\beta^2\cdot\sin(\theta)\cdot\left(\frac{j}{\beta\cdot r} + \frac{1}{\beta^2\cdot r^2} - \frac{j}{\beta^3\cdot r^3}\right)\cdot e^{-j\cdot\beta\cdot r}$$

$E_\theta = 0.44329 - 0.02121i$

$E_{\theta mag} := |E_\theta|$ $\qquad E_{\theta mag} = 0.44379\ \frac{V}{m}$

$E_{\theta ang} := \arg(E_\theta)\cdot\frac{180}{\pi}$ $\qquad E_{\theta ang} = -2.73983$ degrees

$\frac{|E_\theta|}{|E_r|} = 10.44816$ $\qquad \frac{|E_\theta|}{|H\phi|} = 376.1425$

Note that as we move into the far field (r = 10 m), Er becomes small compared to Eθ and the ratio of |Eθ|/|Hϕ| approaches ηo = 377 ohms, thus the radiated spherical wave may be treated as "locally plane".

2. (Not in book) Find the radiation resistance and the total average power radiated by the Hertzian dipole in Problem 1.

$dl := 1\cdot10^{-2}\cdot m$ $\qquad \lambda := \frac{3\cdot10^{8}\cdot\frac{m}{s}}{100\cdot MHz}$ $\qquad \lambda = 3\,m$ $\qquad I := 10\cdot A$

$R_{rad} := 80\cdot\pi^2\cdot\Omega\cdot\left(\frac{dl}{\lambda}\right)^2$ $\qquad R_{rad} = 8.77298 \times 10^{-3}\,\Omega$

$P_{rad} := \frac{1}{2}\cdot I^2\cdot R_{rad}$ $\qquad P_{rad} = 0.43865\,W$

3. Problem 7.1.8 Text

$Aloop := \pi \cdot (5 \cdot cm)^2 \qquad Aloop = 7.85398 \times 10^{-3}\, m^2$

$\lambda := \dfrac{3 \cdot 10^8 \cdot \frac{m}{s}}{1 \cdot MHz} \qquad \lambda = 300\, m \qquad I := 3 \cdot A$ ***<u>Assume this is peak current, not RMS!</u>***

$R_{rad} := 31170\Omega \cdot \left(\dfrac{Aloop}{\lambda^2}\right)^2 \qquad R_{rad} = 2.37373 \times 10^{-10}\, \Omega$

$P_{rad} := \dfrac{1}{2} \cdot I^2 \cdot R_{rad}$

$P_{rad} = 1.06818 \times 10^{-9}\, W$

4. Problem 7.2.1 Text

$f := 300 \cdot MHz \qquad r := 100 \cdot m \qquad \theta := \dfrac{\pi}{2} \cdot rad \quad I := 100 \cdot mA \quad \lambda := \dfrac{3 \cdot 10^8 \cdot \frac{m}{s}}{f} \qquad \lambda = 1\, m$

$len := \dfrac{\lambda}{2}$

We assume F(θ) = 1, since θ = 90 degrees (we are broadside to antenna)

$$E_{max} := \left| \frac{j \cdot 377 \cdot \Omega \cdot I \cdot e^{-j \cdot \frac{2 \cdot \pi}{\lambda} \cdot r}}{2 \cdot \pi \cdot r} \cdot \frac{\cos\left(\frac{2\pi \cdot len}{\lambda} \cdot \cos(\theta)\right) - \cos\left(\pi \cdot \frac{len}{\lambda}\right)}{\sin(\theta)} \right|$$

$E_{max} := 0.06 \cdot \dfrac{V}{m}$

$H_{max} := \dfrac{E_{max}}{377 \cdot \Omega} \qquad H_{max} = 1.59151 \times 10^{-4}\, \dfrac{A}{m}$

$R_{rad} := 73 \cdot \Omega \qquad P_{rad} := \dfrac{1}{2} \cdot I^2 \cdot R_{rad} \qquad P_{rad} = 0.365\, W$

Power Density at $r := 100\, m \qquad Pdens := \dfrac{P_{rad}}{4 \cdot \pi \cdot r^2} \qquad Pdens := \dfrac{1}{2}\, Re(H_{max} \cdot E_{max})$

$Pdens = 4.77454 \times 10^{-6}\, \dfrac{kg}{s^3}$ = 4.775 uW/m2

5. (Not in the book)

Using the $E_{FARFIELD}$ equation for the elemental magnetic dipole Text (Equation 7.9a

$\omega := 2\cdot\pi\cdot 800\cdot MHz$ $\quad \mu_0 := 4\cdot\pi\cdot 10^{-7}\cdot\frac{F}{m}$ $\quad A_c := 8\cdot cm\cdot 5\cdot cm$ $\quad I := \frac{0.5\cdot V}{50\cdot\Omega}$ $\quad I = 0.01\,A$

$\theta := \frac{\pi}{2}$ $\quad r := 3\cdot m$ $\quad A_c = 4\times 10^{-3}\,m^2$

$$\beta := \frac{2\cdot\pi\cdot rad}{\left(\frac{3\cdot 10^8\cdot\frac{m}{s}}{800\cdot MHz}\right)} \qquad \beta = 16.75516\frac{1}{m} \qquad \sin(\theta) = 1$$

(Observation point is Broadside to antenna in order to observe max field.)

$$E_{FARFIELD} := \left|\frac{\omega\cdot\mu_0\cdot(A_c\cdot I)\cdot\beta}{4\cdot\pi}\cdot\sin(\theta)\cdot\frac{e^{-j\cdot\beta\cdot r}}{r}\right| \qquad E_{FARFIELD} := 0.112\cdot\frac{V}{m}$$

$$E_{FARFIELD\_dB\mu V} := 20\cdot\log\left(\frac{E_{FARFIELD}}{10^{-6}\cdot\frac{V}{m}}\right)$$

$$E_{FARFIELD\_dB\mu V} = 100.98436$$

6. (Not in book) Antenna Factor is 15 dB at 150 MHz from text Fig. 7.17.

$$AF = \frac{E}{Voltage\_Antenna} \qquad \frac{1}{m}$$

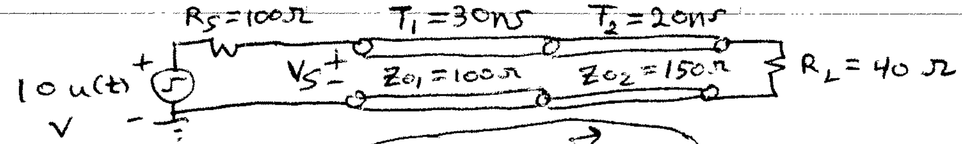
=> in dB $\quad AF_{dB} = EdB\mu V\_per\_meter - Voltage\_AntennadB\mu V$

$AF_{dB} := 15.0\ \ dB$ $\quad CableLoss := \frac{50}{100}\cdot 4\ \ dB$ $\quad CableLoss = 2\ \ dB$

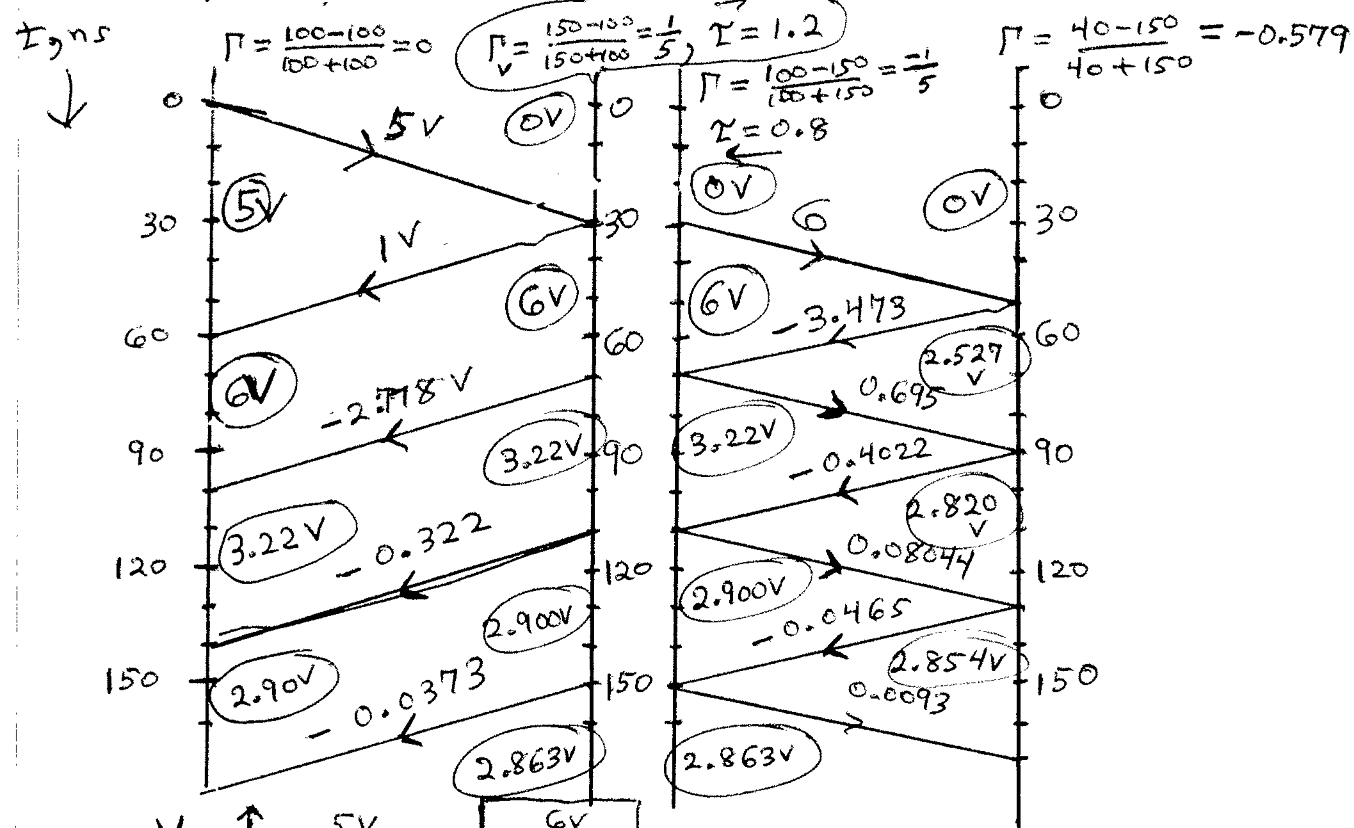
$Voltage\_Antenna := 78$ dBμV

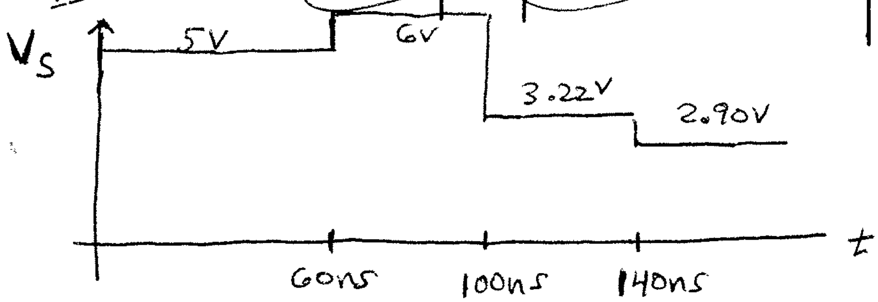
$$EdB\mu V\_per\_meter := AF_{dB} + CableLoss + Voltage\_Antenna$$

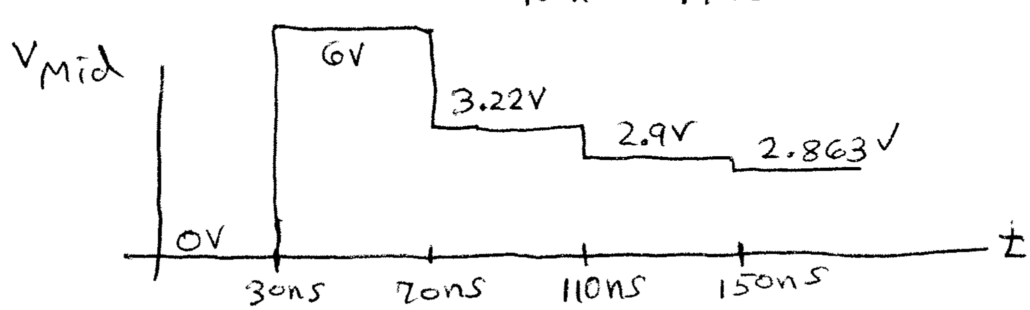
$$EdB\mu V\_per\_meter = 95\ \ \frac{dB\mu V}{m}$$

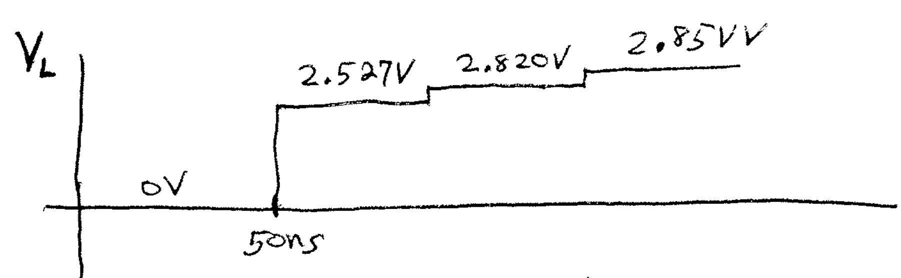


$$V^+ = 10\left(\frac{Z_{01}}{R_S+Z_{01}}\right) = 10\left(\frac{100}{100+100}\right) = 5V$$

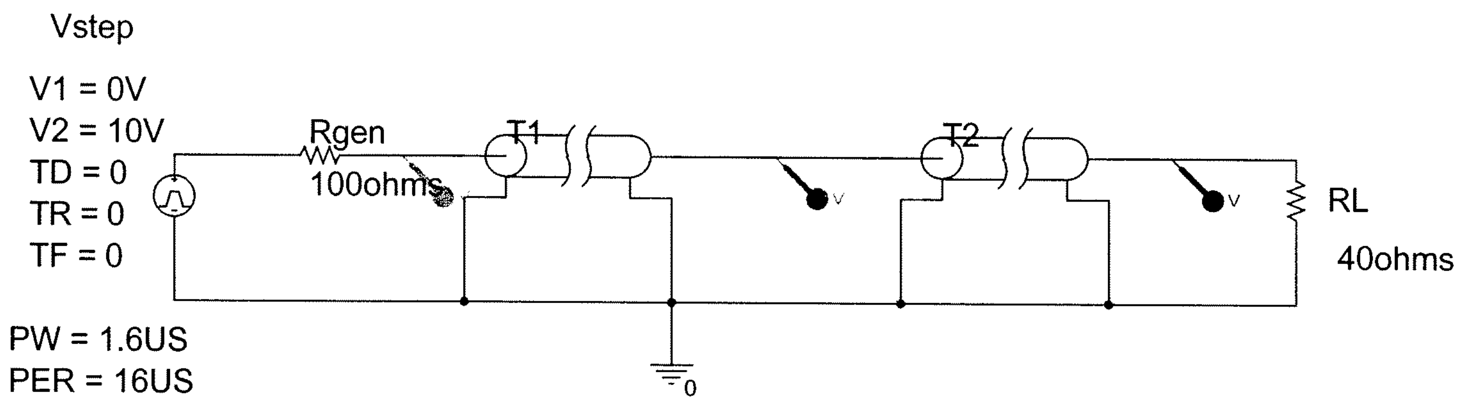








Check: $V_{SS} = 10\left(\frac{R_L}{R_S+R_L}\right) = 10\left(\frac{40}{100+40}\right) = \boxed{2.857V}$



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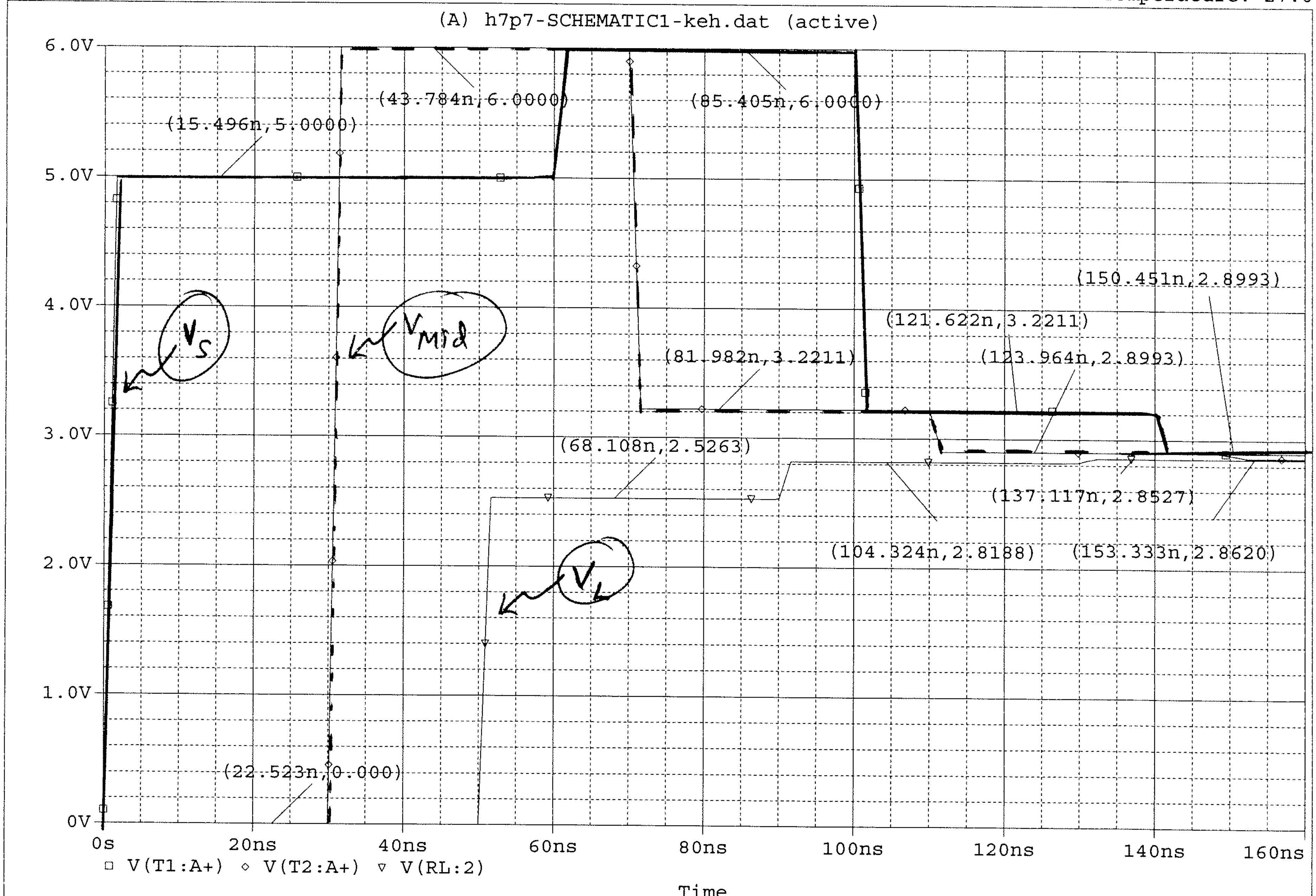

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