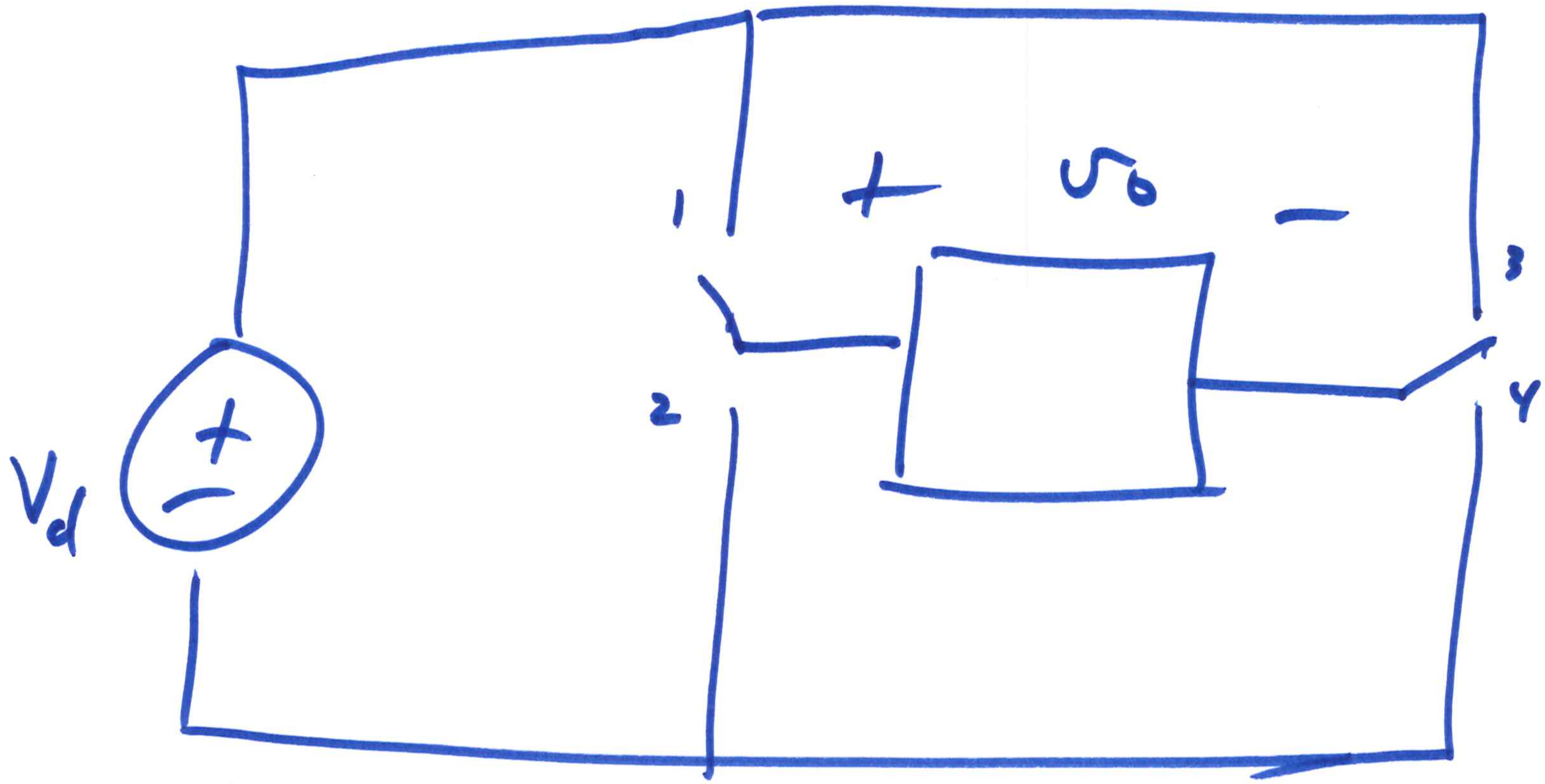
ECE 404-TD / 504-TD

ST: T&D APPLICATIONS OF VOLTAGE SOURCE CONVERTERS

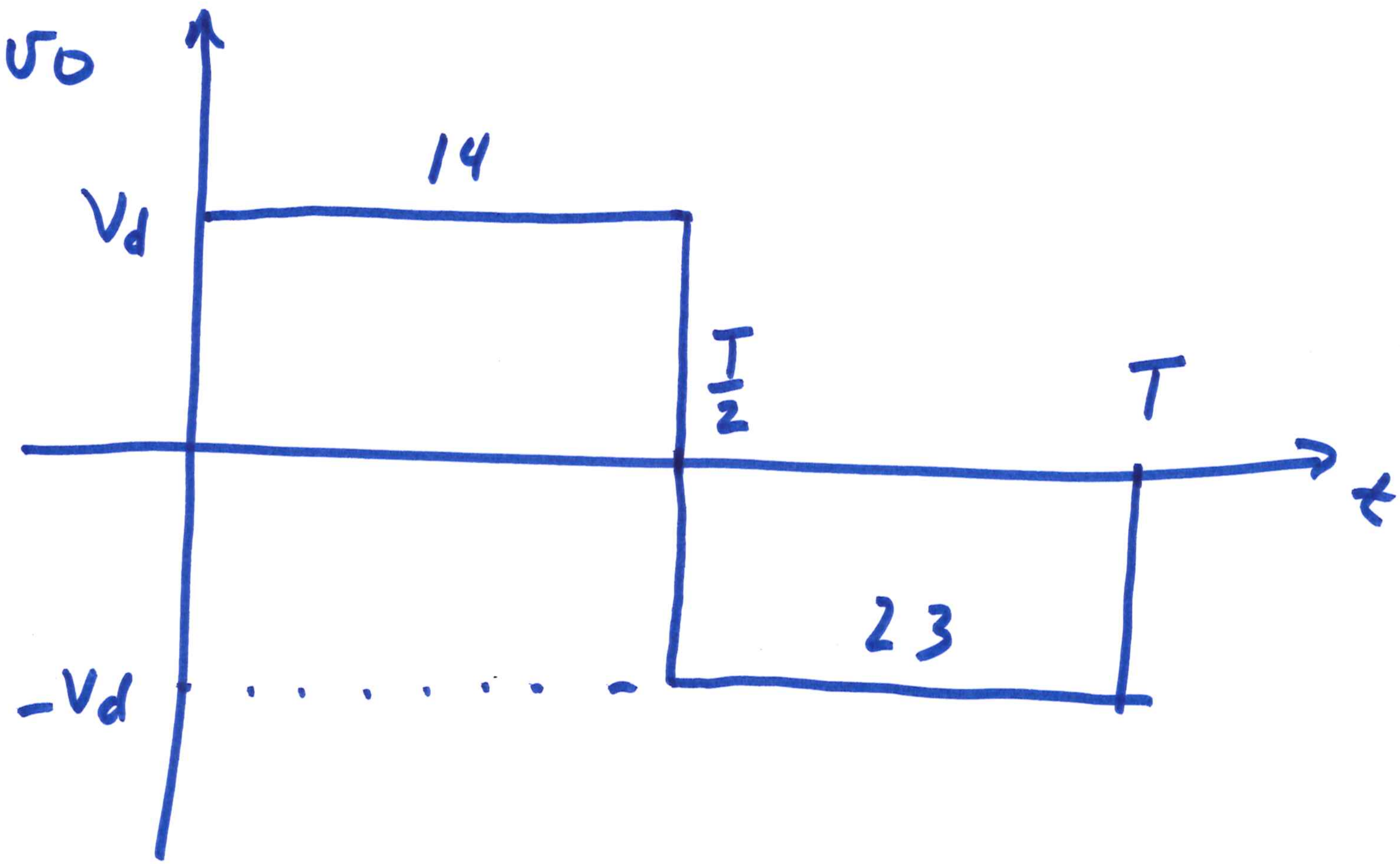
SESSION no. 10



$14 \rightarrow v_o = V_d$

$23 \rightarrow v_o = -V_d$

$13, 24 \rightarrow v_o = 0$



vo
Vd
14
T/2
T
t
23
-Vd

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$$\sqrt{2}\, V_d$$

$$V_d$$

$$\sqrt{\frac{1}{T}\int_0^T v_o^2(t)\, dt}$$

$$\sqrt{\frac{1}{T}\left[\int_0^{\frac{T}{2}} V_d^2\,dt + \int_{\frac{T}{2}}^{T} (-V_d)^2\,dt\right]}$$

$$\sqrt{\frac{1}{T}\int_0^{T} V_d^2\,dt}$$

$$\sqrt{\frac{1}{T} V_d^2 T}$$

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$$\sqrt{V_d^2}$$

$$\sqrt{V_d^2}$$

$$= +V_d$$

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$$\frac{1}{T} \qquad \frac{2\pi}{T}$$

$$V_d \qquad > V_d$$

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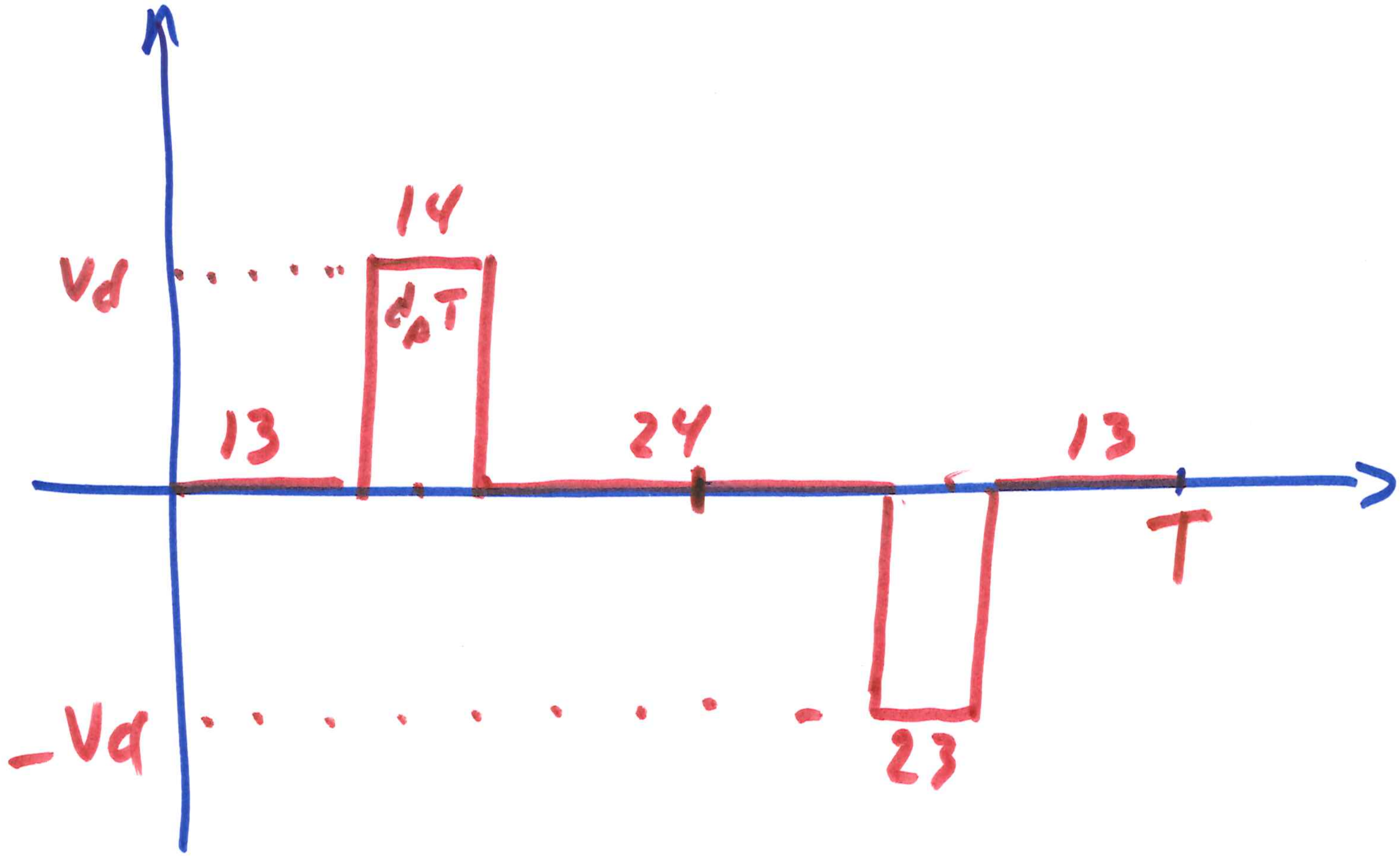
$$V_{o1} = \frac{4}{T}\int_0^{T/2} V_d \sin \omega t \, dt, \qquad \omega = \frac{2\pi}{T}$$

$$V_{o1} = \frac{4}{T}\frac{1}{\omega}\left[-V_d \cos \omega t\right]\Big|_0^{T/2}$$

$$V_{o1} = \frac{2}{\pi}\left(-(-1)-(-1)\right)V_d$$

$$V_o = \frac{4}{\pi}V_d$$

$$\frac{4}{\pi} = 1.28$$


14
Vd
$d_\Delta T$
13
24
13
T
-Vd
23

RMS:

$$\sqrt{\frac{1}{T/2}\int_0^{d_A T} V_d^2\,dt + 0}$$

$$\sqrt{\frac{1}{T/2} V_d^2 d_A T}$$

$$\sqrt{2 d_A V_d^2}$$

$V_d \sqrt{2} d_A$

$$S = \frac{\omega_e - \omega_m}{\omega_e}$$

LIKE s SMALL

$$S_h = \frac{h\omega_e - \omega_m}{h\omega_e}$$

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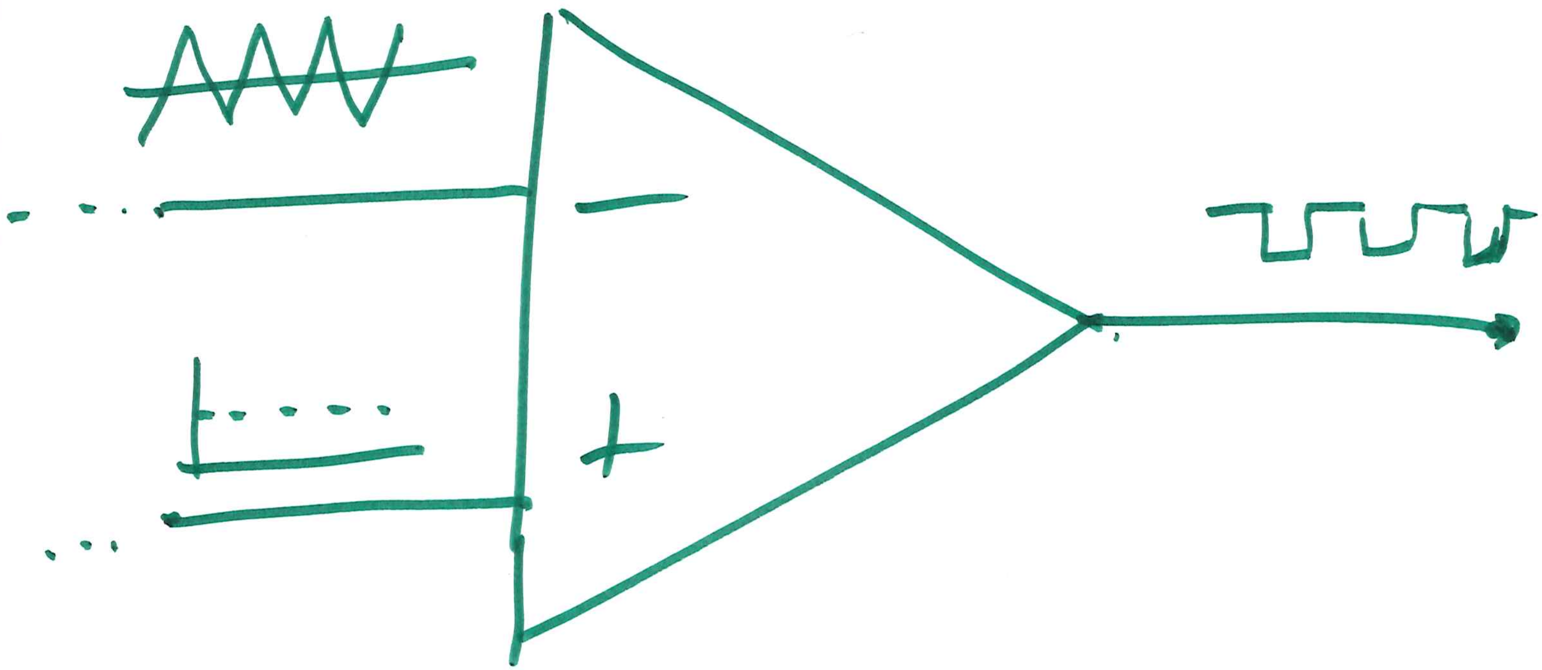

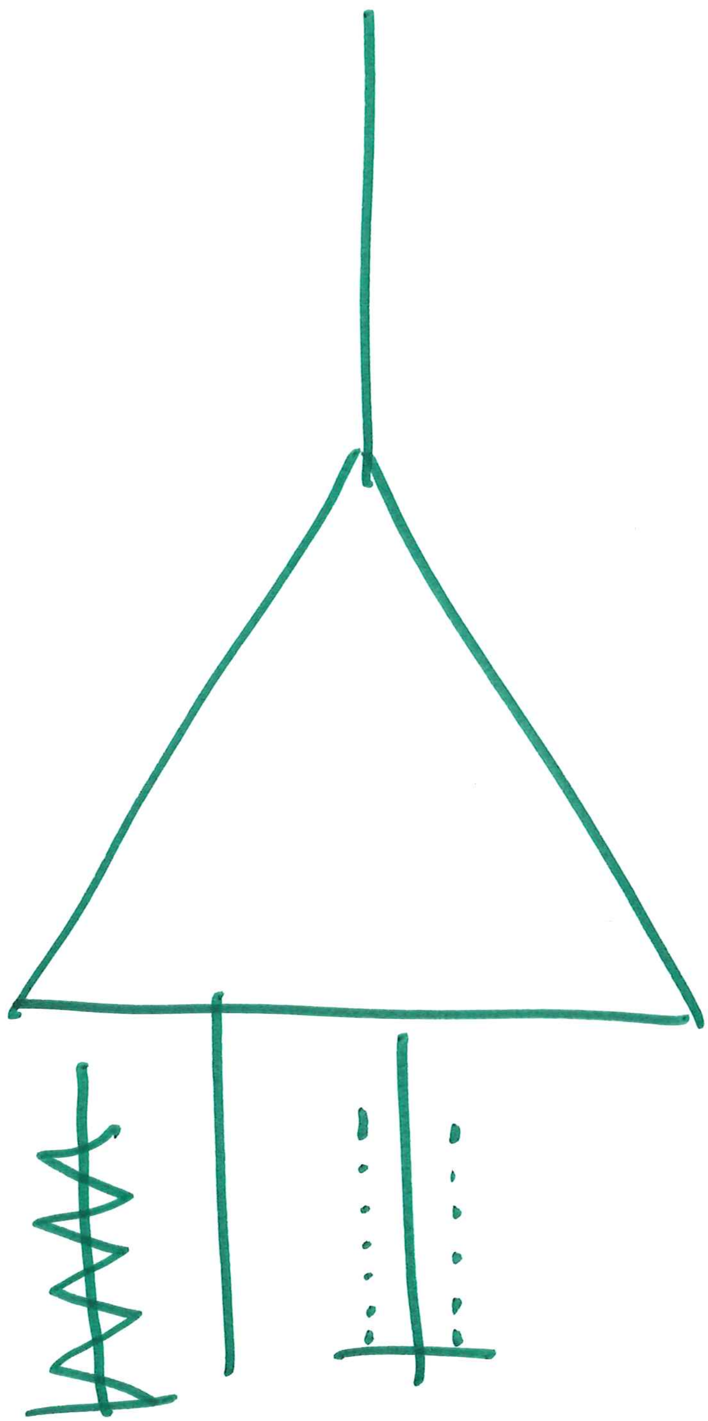

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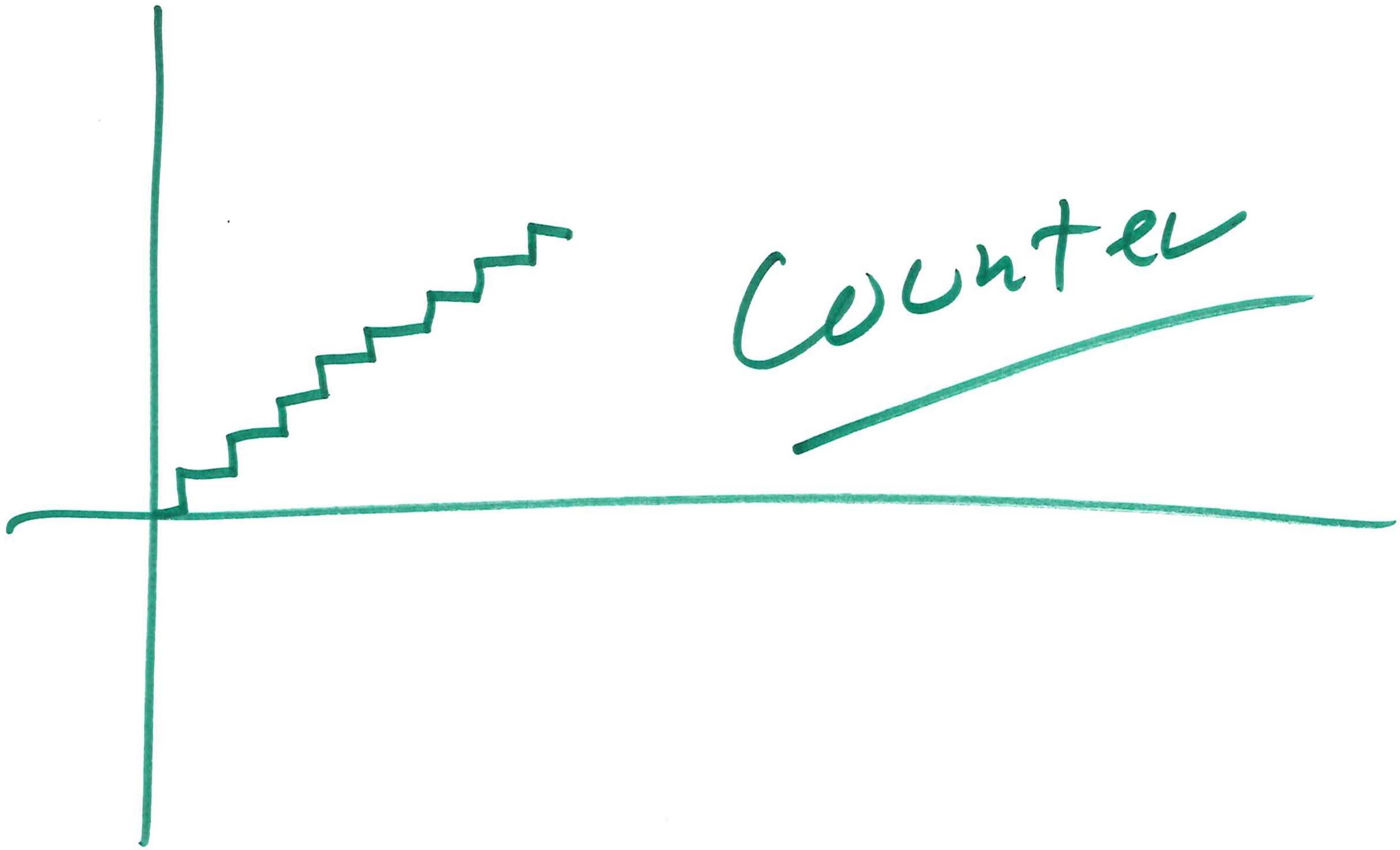


ECE 404 / 504

T & D Applications of Voltage Sourced Converters

Lesson 10

We can get variable voltage DC from –Vd to +Vd using two power poles in a bidirectional buck converter.

We will now get AC using this same set of ideas.

Peak value is Vd; negative peak is –Vd.

The rms value is Vd.

The amplitude of the fundamental frequency is 4Vd/pi.

What have I been able to do so far?

*Set the frequency

* I can get an amplitude; One and only one amplitude so far.

*Set the phase.

Let's go back and look at improving this amplitude. I'd like to be able to set it to something I like.

Peak value is V_d; negative peak is $-V_d$.

The rms value is (depends on duty cycle): $Vd*sqrt(2*d_A)$

The amplitude of the fundamental frequency is (depends on duty cycle). Use an FFT to get the numbers.

What do harmonics do ~~for~~ to us?

*Heat

*Torques…

How can we get the ac pulses that we saw?

*Use two levels dc and compare to a triangle wave.

*Make two buck converter controls and subtract the results.

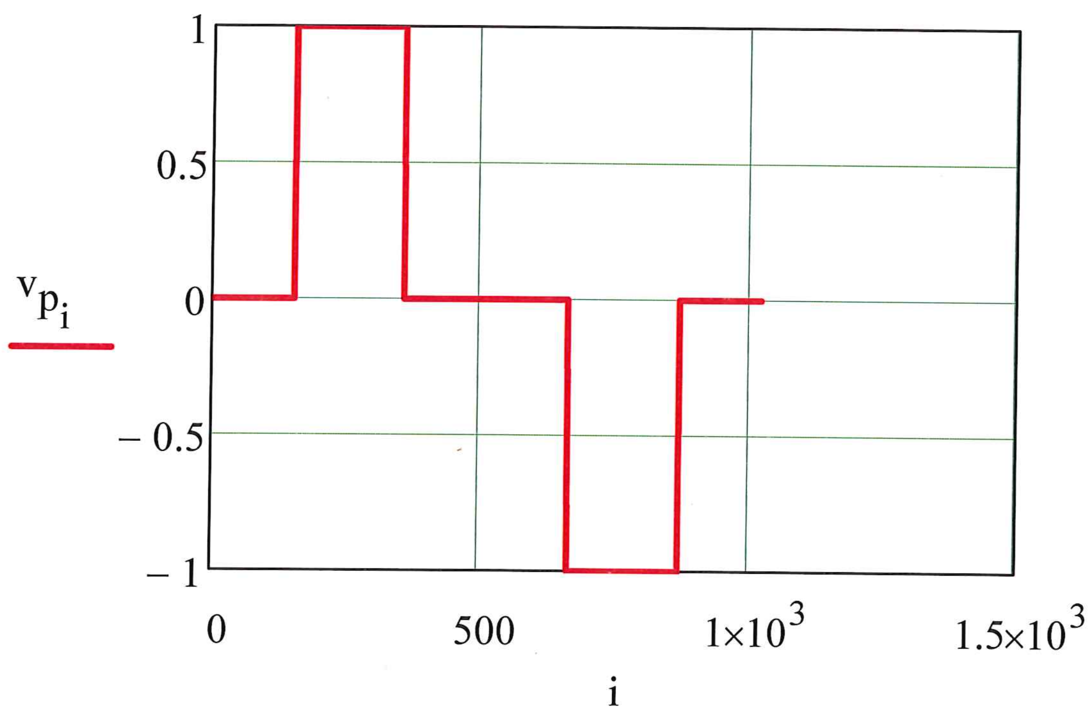
Next: Three phase waveforms

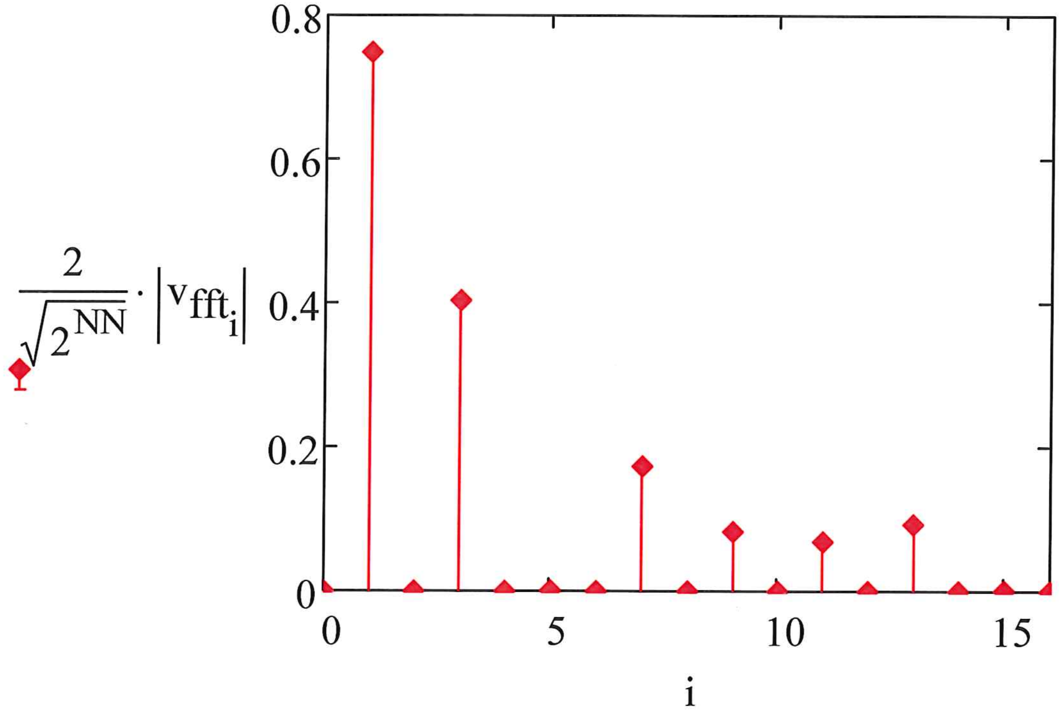
Harmonics in an AC Pulse Width Modulated Waveform: FFT Example

$d_A := 0.8 \quad NN := 10 \quad pts := 2^{NN} \quad i := 0, 1 .. pts - 1$

$$v_{p_i} := \begin{cases} 1 & \text{if } \dfrac{1 - \frac{d_A}{2}}{4} \cdot pts \le i < \left(\dfrac{1 + \frac{d_A}{2}}{4}\right) \cdot pts \\ (-1) & \text{if } \dfrac{3 - \frac{d_A}{2}}{4} \cdot pts \le i < \dfrac{3 + \frac{d_A}{2}}{4} \cdot pts \\ 0 & \text{otherwise} \end{cases}$$

$v_{fft} := fft(v_p)$





0.8
0.6
0.4
0.2
0
$\frac{2}{\sqrt{2^{NN}}} \cdot \left| v_{fft_i} \right|$
0
5
10
15
i

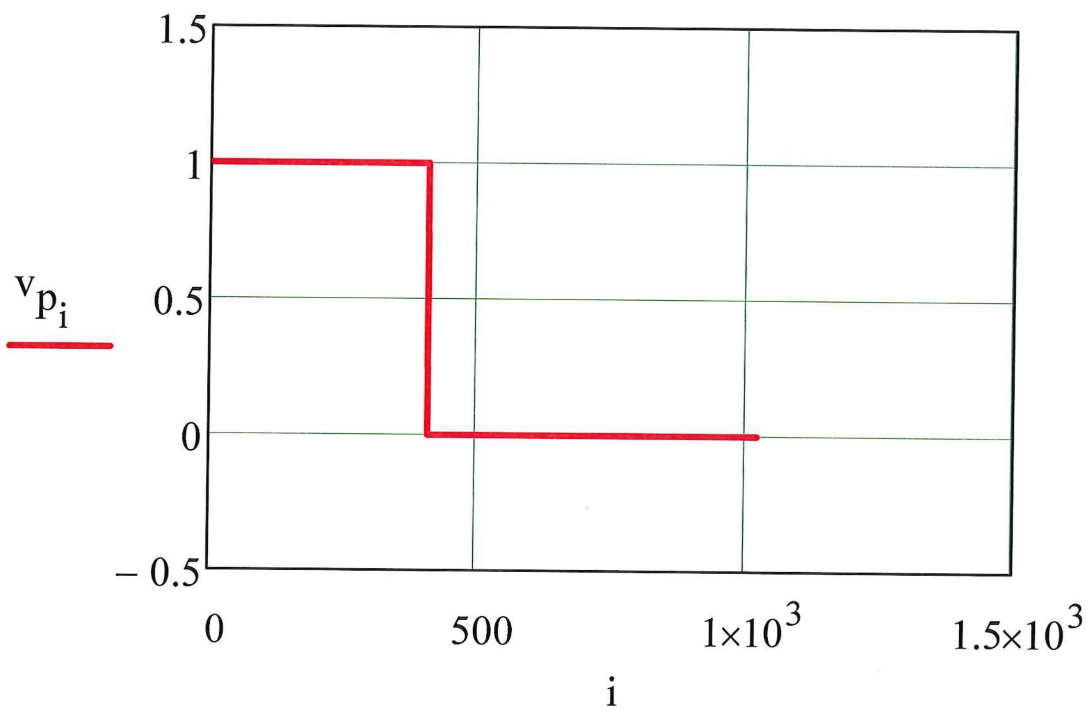
FFT Example

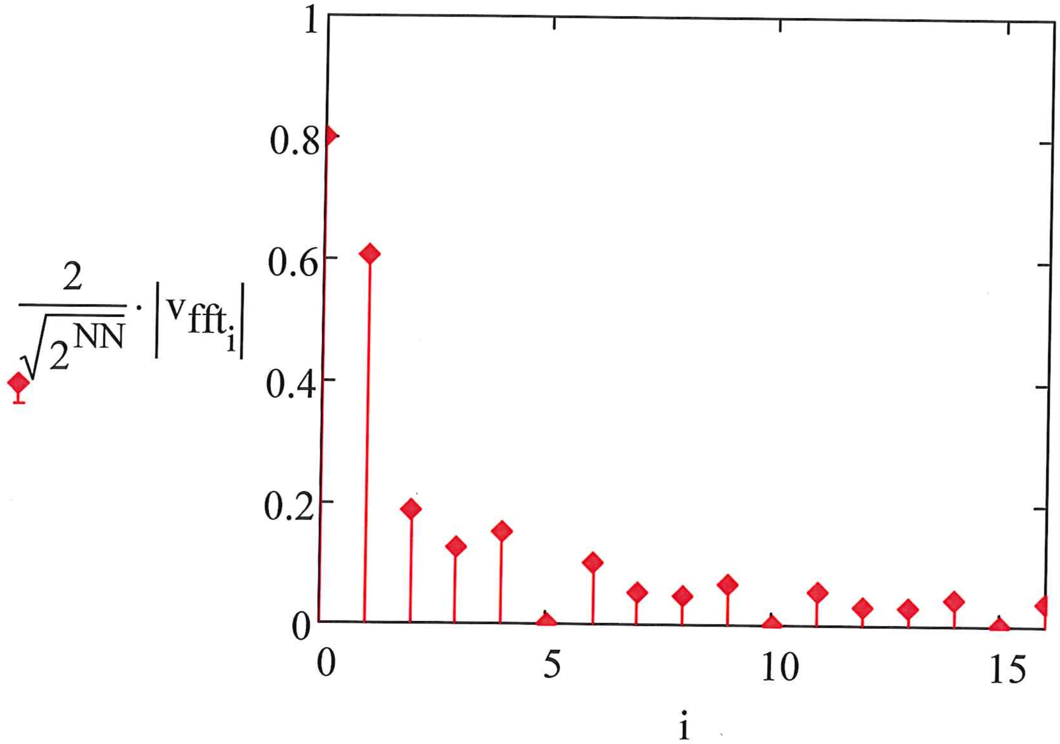
$d_A := 0.4$

$NN := 10$ $\qquad pts := 2^{NN}$ $\qquad i := 0, 1 .. pts - 1$

$$v_{p_i} := \begin{cases} 1 & \text{if } 0 \le i < d_A \cdot pts \\ 0 & \text{otherwise} \end{cases}$$

$$v_{fft} := \text{fft}(v_p)$$




1
0.8
0.6
0.4
0.2
0
$\frac{2}{\sqrt{2^{NN}}} \cdot \left| v_{fft_i} \right|$
0
5
10
15
i

$$v_{fft_1} = 3.012 + 9.211i$$

$$\left|v_{fft_1}\right| = 9.691$$

$$\arg\left(v_{fft}\right) = 71.895 \cdot deg$$

$$\frac{\left|v_{fft_1}\right|}{8} = 1.211$$

$$\frac{4}{\pi} = 1.273$$