ECET 257 Power & RF Electronics

This course is a study of the application of circuit analysis techniques to amplifiers used in power and RF electronics, including bipolar junction transistors, field effect transistors, thyristors, RF amplifiers, phase lock loops, switching power supplies, and appropriate applications. Computer aided analysis of circuits is used.

Http://www.tech.purdue.edu/eet/courses/eet257/

What will you be able to do?

- RF Amplifiers
  - $f \leq 100$ MHz
- Power Electronic Switches
  - $I_{on} = 6\ A_p$ $V_{off} = \pm 56$ V $t_{on\ or\ off} < 30$ns
  - Buck power supply $I_{dc} = 1$ A $\pm 0.1\ V_{pp}$
  - Boost power supply   5 V_{dc} to 15 V_{dc} *not* transformer
- Switching & Linear Amplifier
  - $v_{load} \geq 40\ V_p$, 8 Ω, 100 Ω, protected, 1 % THD
  - Sound – room – loudspeaker – amplifier

What will this *cost*?

- How much more work was
  - ECET 207 than EET 107?
  - x 1.5

- ECET 257 requires x1.25 more work than ECET 207

Study !!

There is no substitute for *effective* work.

Purdue University

How to Study for ECET 257

~ 2 hours, five nights per week

Lectures on Monday, Wednesday, and Friday
Lab on Tuesday or Friday
Sim due Monday
Quiz on Friday

Monday

- Review all of your class notes
- Compare them to the web
- *Work* all calculations from lecture
- Highlight questions
- Re-read the text
  - *Work* all of the Practice problems (at the end of every Example in the text)
  - Highlight questions
- Work the Homework or do the manual calculations for the simulation

Tuesday

- Find answers to all of your questions, from Monday's lecture and from the text
- Work the Homework again
- Read the assignment for Wednesday
  - *Work* the Examples
  - Highlight questions
- Rough out the lab report

Wednesday

- Review all of your class notes
- Compare them to the web
- *Work* all calculations
- Highlight questions
- Re-read the text
  - *Work* all of the Practice problems (at the end of every Example in the text)
  - Highlight questions
- Work the Homework
- Complete the lab report

Thursday

- Find answers to all of your questions, from Wednesday's lecture and from the text
- Work the Homework *again*
- Read the assignment for Monday
  - *Work* the Examples
  - Highlight questions
- Work the Homework *again*
- Begin the Simulation due Monday
- Review for Quiz

Sunday

- Finish the Simulation
- *Catch up*

PURDUE UNIVERSITY — ELECTRICAL AND COMPUTER ENGINEERING TECHNOLOGY — ECET

ECET 257 **Consumer Power Electronics** **Fall 2010**

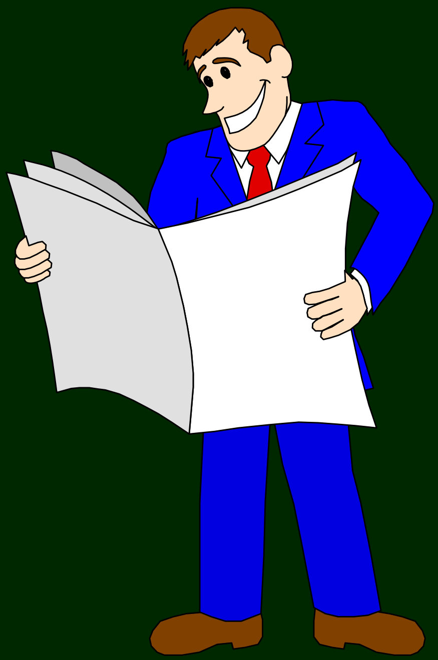
Course Information

Clicking on this icon will allow you to attend the class virtually; M-W-F 2:30-3:20.

Clicking on the same icon on a specific date, below, allows you to watch the recorded version of the class. If the class has not yet happened for the Fall 2010 semester, then you will be served that class from the Spring 2010 semester.

	Monday	Wednesday	Friday	Lab
Aug Week 1	**23** Intro Pwr read: text Chapter 3 assess: none	**25** Power Calculations read: text chapter 3 assess: 01-PowerCalc1	**27** Thyristors read: text p385-396 assess: 02-Power Calc2	Power Parameter Calculations
Aug/Sep 2	**30** DigitalCntrThy read: text 403-409 assess: 04-Thyristors	**1** Phase Angle Firing read :text p417-430 Only *audio* assess: Thyristors Sim	**3** Snubbing read: text p396-403 assess:05-PhaseAngleFired	Triac - Logic Control Screen Captures
3	**6** No Class **Labor Day**	**8** High Freq read: none assess: Phase Angle Fire Sim	**10** Problem Session read: none *no audio* assess: 03-HighFreqEffects	Triac - Analog Control
4	**13** **Exam 1**	**15** Low-Side BJT read: text p269-277 *no audio* assess: none	**17** LS MOS Analy read: text p278-286 assess: 06-LS BJT AnalyHS	High Frequency Considerations
5	**20** Highside Analy read: text p295-303 assess: 07-LS MOS Analy	**22** Heat Sinks read: text p176-181 assess: HS Switch Sim	**12**LS Switch Des read: text 269-304 assess: 09-Heat Sinks	Switch Analysis Example Layout Photo
Sep/Oct 6	**27** HS Switch Design read: textp295-303 assess: Low-side Design Sim	**29** MOS Drivers read: text 304-308 assess: 10-HS Design	**1** H-Bridges read: text 309-314 assess: 11-MOS Drivers	Switch Design
Oct 7	**4** **Exam 2**	**6** Buck Principles read: text p326-337 *no audio* assess: none	**8** LM3578 Buck read: National Semi data assess: 12a-Buck	MOS Driver Layout photo
8	**11** No Class **October Break**	**13** Problem Session read: none assess: Buck Sim	**15** Boost Principles read: text p344-352 assess: 12b-BuckIC	Buck Regulator

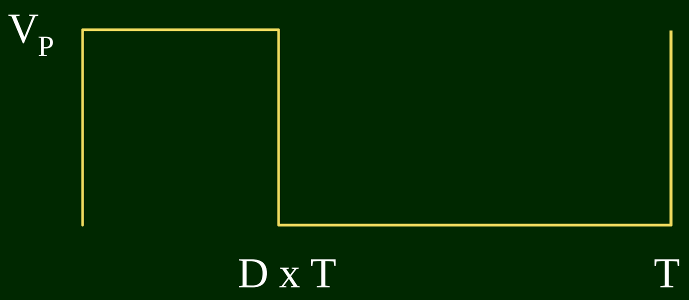
Syllabus



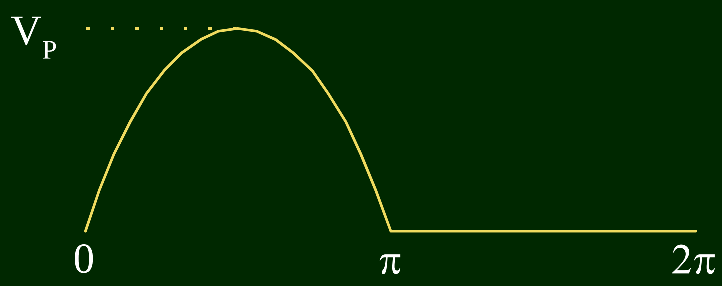
- It is a contract.
  - Read it!   Use it!
- 8. Professional conduct
- 9. Cheating
- Simulation*, HW, Quizzes,
- Labs*
- Grading Policy
- Standards: HW, Lab Reports

* *Must* pass Simulation & Lab to pass the course.

Average, RMS, and Power



$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$



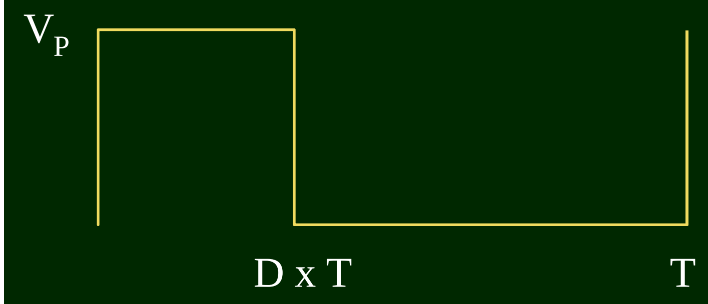
$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)dt\right)}$$

$$P = \frac{1}{2\pi}\left[\int_0^{\pi}(V_P \sin\theta)(I_P \sin\theta)d\theta + \int_{\pi}^{2\pi} 0 d\theta\right]$$

Overview

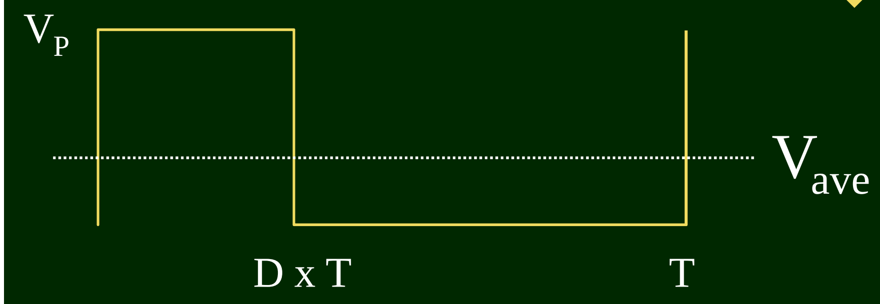
- Average
  - definition integrals
  - pulse half sine table
- Root Mean Squared
  - definition integrals
    table
- Power
  - definition
  - pulse half sine table

Average Value: definition

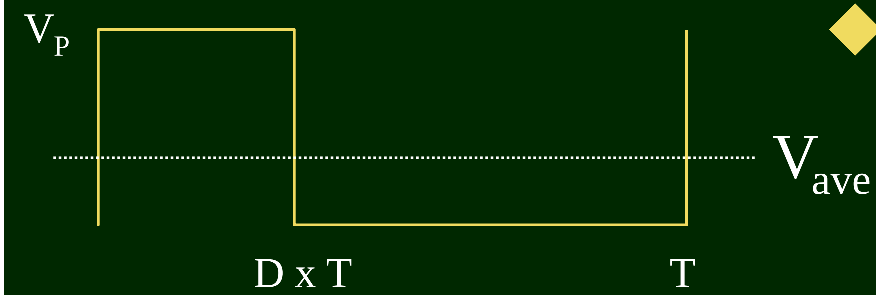


Average Value: definition

- average height
- area under the curve / length



Average Value: definition

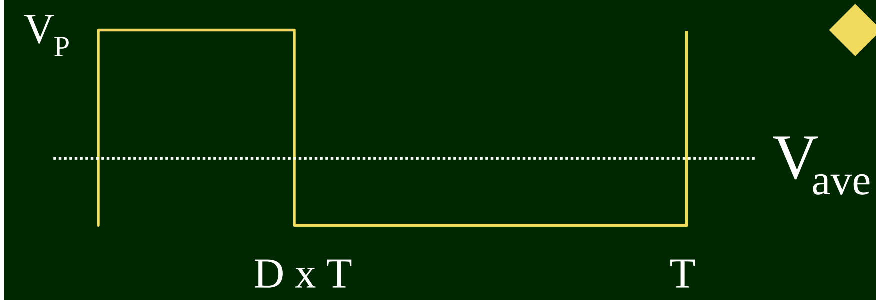


- average height
- area under the curve / length

$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

Average Value: definition

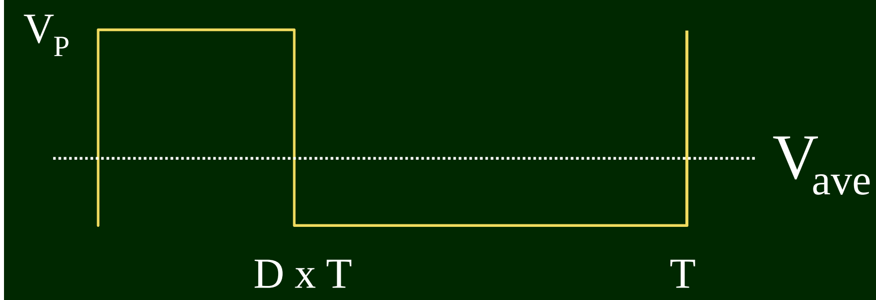
- average heigth
- area under the curve / length



$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

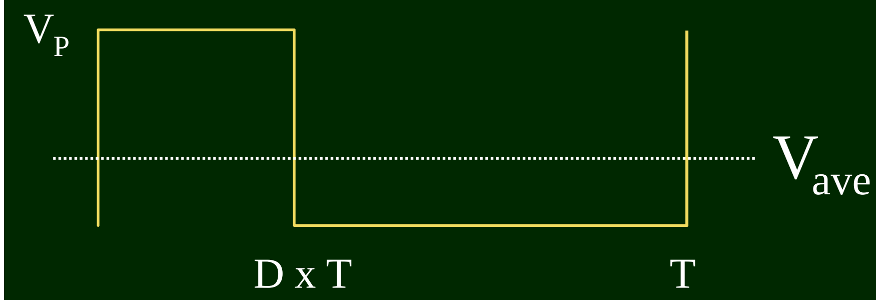
Average Value: pulse

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$



$$v(t) = \begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

Average Value: pulse

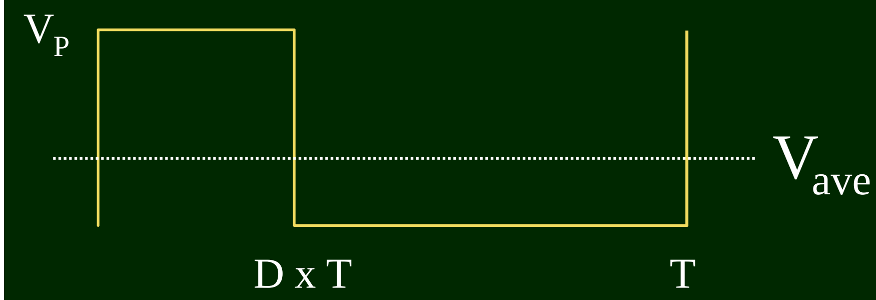


$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\left(\int_0^{DT} V_P\,dt + \int_{DT}^{T} 0\,dt\right)$$

Average Value: pulse



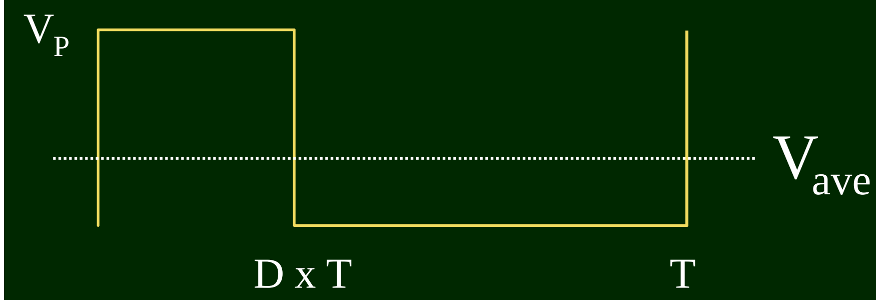
$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\left(\int_0^{DT} V_P\,dt + \int_{DT}^{T} 0\,dt\right)$$

$$= \frac{V_P}{T}\int_0^{DT} dt$$

Average Value: pulse



$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

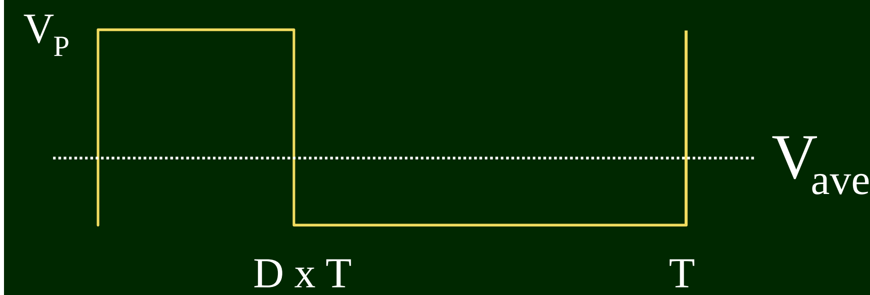
$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\left(\int_0^{DT} V_P\,dt + \int_{DT}^{T} 0\,dt\right)$$

$$= \frac{V_P}{T}\int_0^{DT} dt$$

$$= \frac{V_P}{T}\left(t\Big|_0^{DT}\right)$$

Average Value: pulse



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

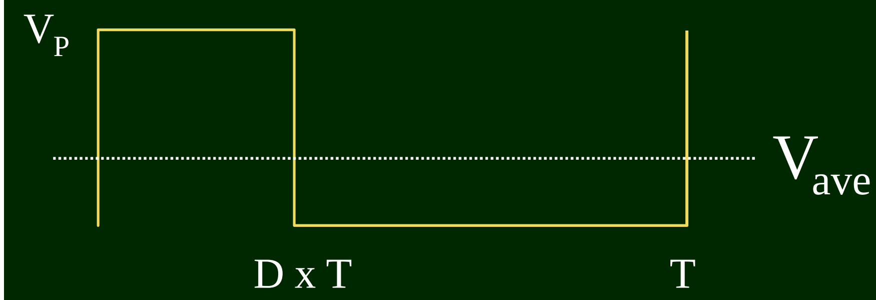
$$= \frac{1}{T}\left(\int_0^{DT} V_P\,dt + \int_{DT}^{T} 0\,dt\right)$$

$$= \frac{V_P}{T}\int_0^{DT} dt$$

$$= \frac{V_P}{T}\left(t\Big|_0^{DT} \right)$$

$$= \frac{V_P}{T}(DT - 0)$$

Average Value: pulse



$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

$$V_{ave}=\frac{1}{T}\int_0^T v(t)\,dt$$

$$=\frac{1}{T}\left(\int_0^{DT} V_P\,dt+\int_{DT}^{T} 0\,dt\right)$$

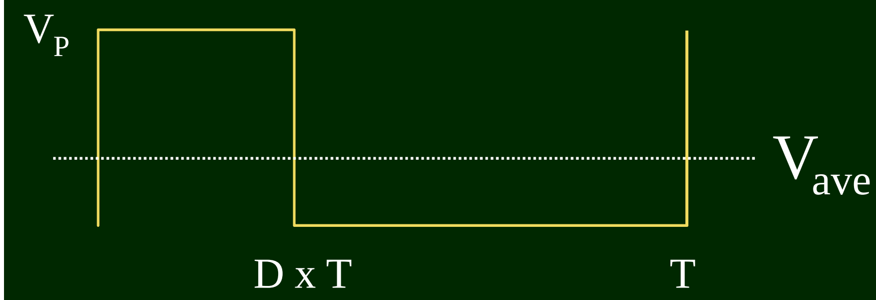
$$=\frac{V_P}{T}\int_0^{DT} dt$$

$$=\frac{V_P}{T}\left(t\Big|_0^{DT}\right)$$

$$=\frac{V_P}{T}(DT-0)$$

$$V_{ave}=DV_P$$

Average Value: pulse



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$V_{ave} = DV_P$$

$$T = 5\,\text{ms}$$

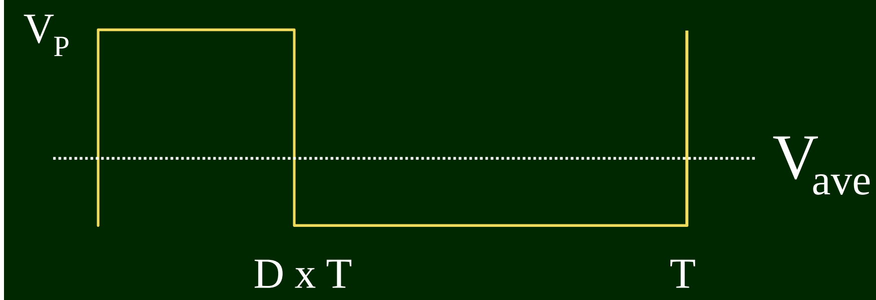
$$t_{\text{pulse width}} = 2\,\text{ms}$$

$$D = ?$$

$$V_p = 10\ V_p$$

$$V_{\text{ave}} = ?$$

Average Value: pulse



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \quad 0 < D < 1$$

$$V_{ave} = DV_P$$

$$T = 5\,\text{ms}$$

$$t_{\text{pulse width}} = 2\,\text{ms}$$

$$D = 0.4$$

$$V_p = 10\,\text{V}_p$$

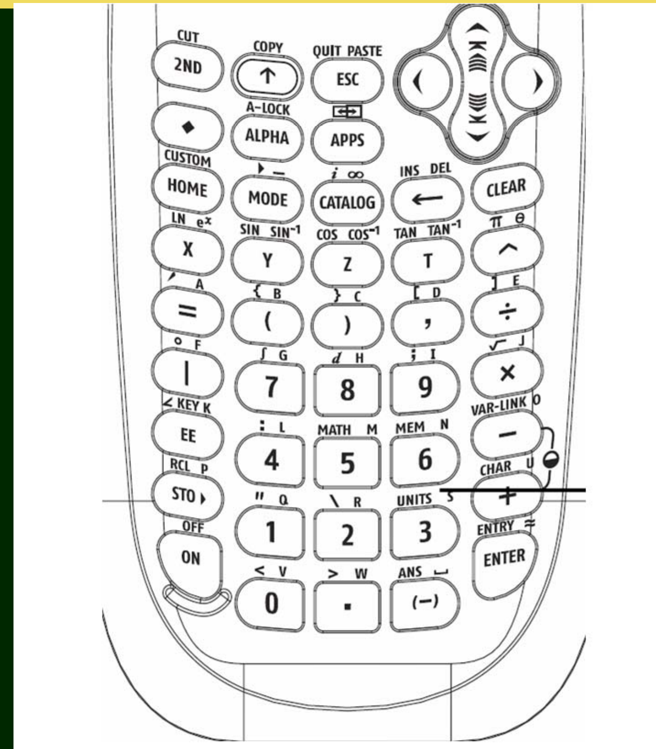
$$V_{ave} = 4\,\text{V}_p$$

Average Value: pulse

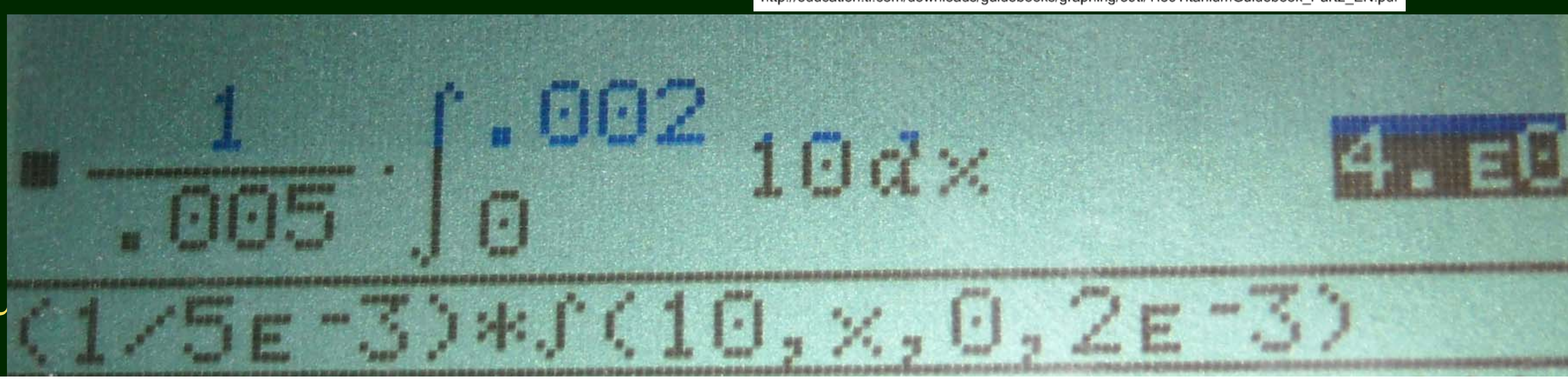
$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{1}{T}\left(\int_0^{DT} V_P\,dt + \int_{DT}^{T} 0\,dt\right)$$

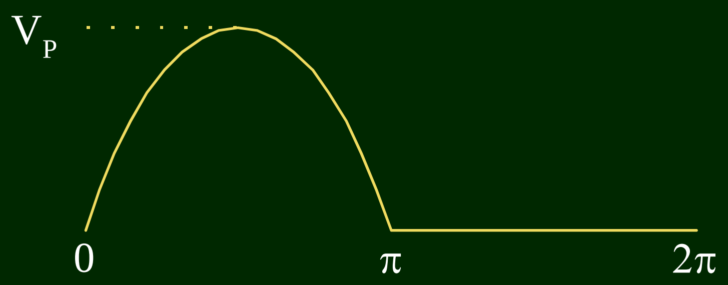
$$= \frac{1}{5\text{ms}}\left(\int_0^{2\text{ms}} 10\text{V}_P\,dt\right)$$



http://education.ti.com/downloads/guidebooks/graphing/89ti/TI89TitaniumGuidebook_Part2_EN.pdf

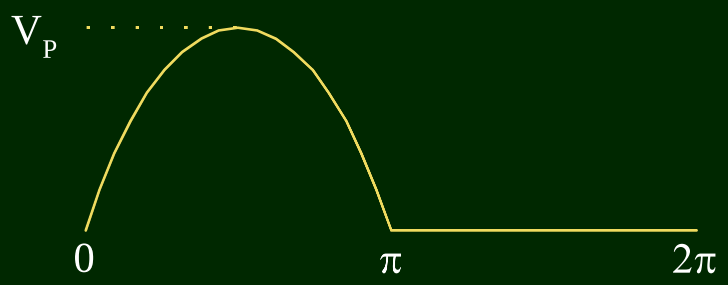


Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

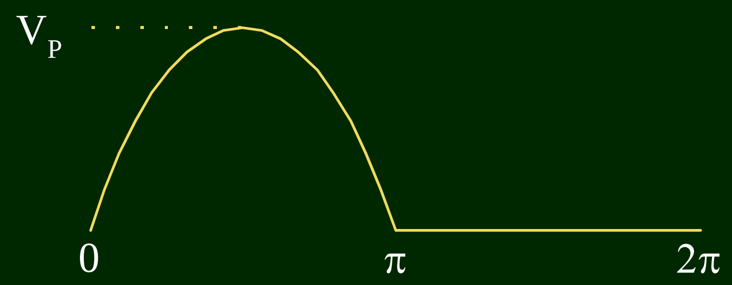
Average Value: half sine



$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

Average Value: half sine

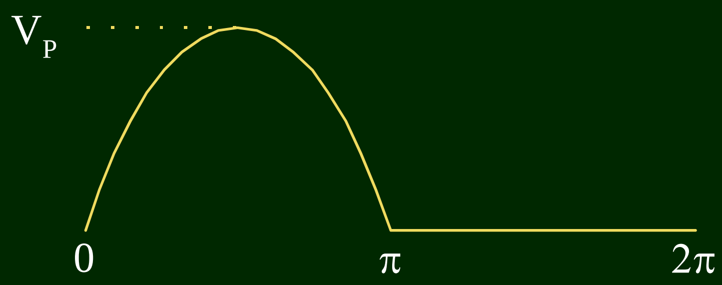


$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\vartheta\right)$$

Average Value: half sine



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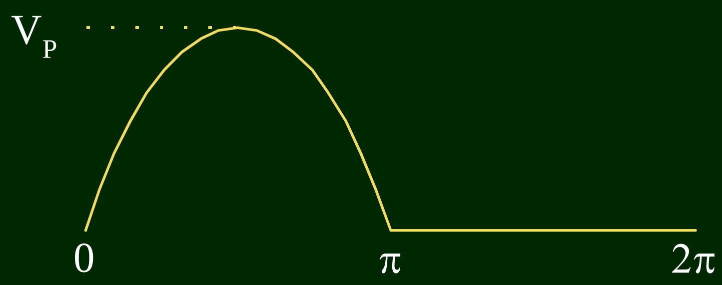
$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta d\theta + \int_{\pi}^{2\pi} 0 d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta d\theta$$

Average Value: half sine



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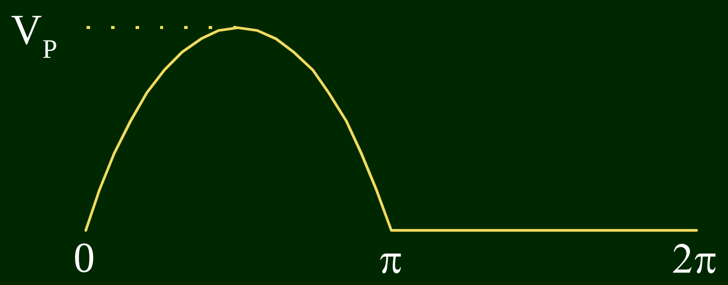
$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta \, d\theta + \int_{\pi}^{2\pi} 0 \, d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta \, d\theta$$

$$= \frac{V_P}{2\pi}\left(-\cos\theta\Big|_0^{\pi}\right)$$

Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

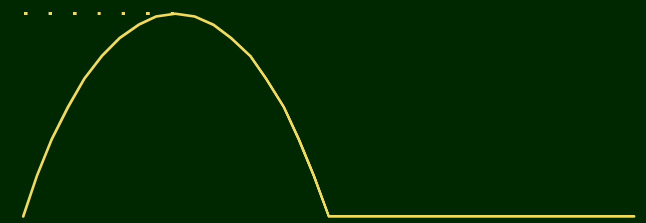
$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{V_P}{2\pi}\left(-\cos\theta\Big|_0^{\pi}\right)$$

$$= \frac{V_P}{2\pi}\left(-\cos\pi + \cos 0\right)$$

Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\vartheta\right)$$

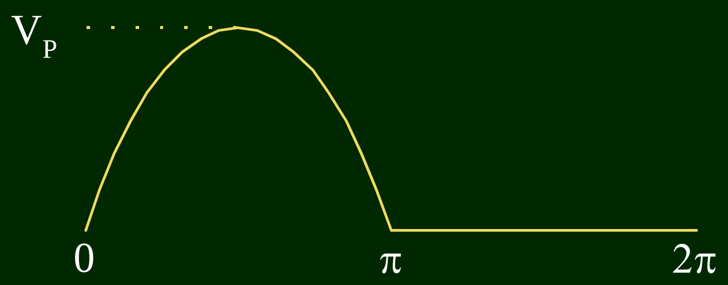
$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{V_P}{2\pi}\left(-\cos\theta\Big|_0^{\pi}\right)$$

$$= \frac{V_P}{2\pi}(-\cos\pi + \cos 0)$$

$$= \frac{V_P}{2\pi}(- -1 + 1)$$

Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta \, d\theta + \int_{\pi}^{2\pi} 0 \, d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta \, d\theta$$

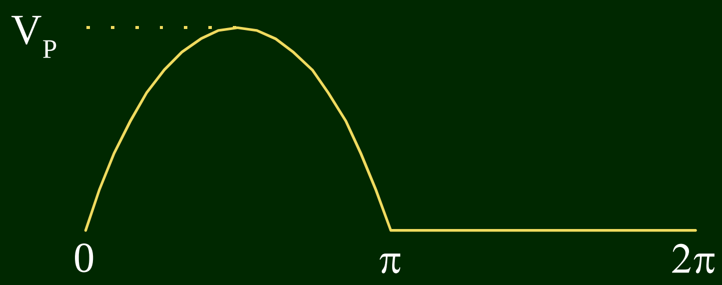
$$= \frac{V_P}{2\pi}\left(-\cos\theta\Big|_0^{\pi}\right)$$

$$= \frac{V_P}{2\pi}(-\cos\pi + \cos 0)$$

$$= \frac{V_P}{2\pi}(- -1 + 1)$$

$$= \frac{2V_P}{2\pi}$$

Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta\, d\theta$$

$$= \frac{V_P}{2\pi}\left(-\cos\theta\Big|_0^{\pi}\right)$$

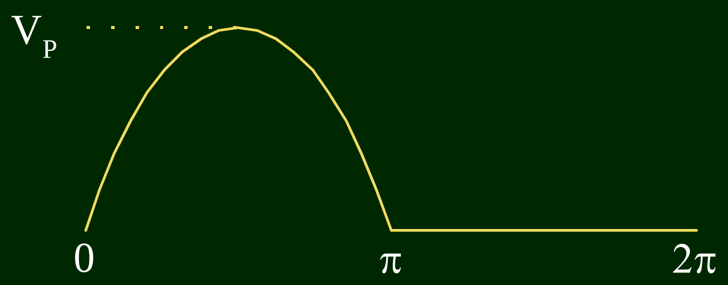
$$= \frac{V_P}{2\pi}(-\cos\pi + \cos 0)$$

$$= \frac{V_P}{2\pi}(- -1 + 1)$$

$$= \frac{2V_P}{2\pi}$$

$$V_{ave} = \frac{V_P}{\pi}$$

Average Value: half sine



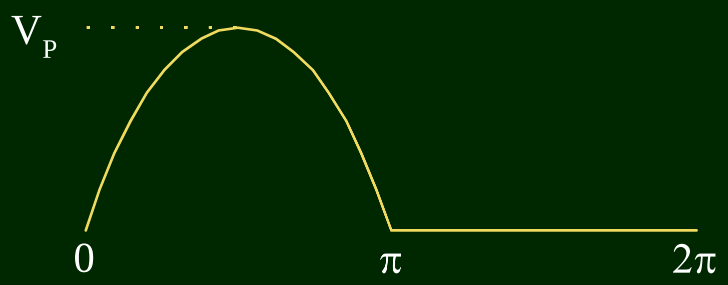
$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{V_P}{\pi}$$

$$V_p = 170\,V_p$$

$$V_{ave} = ?$$

Average Value: half sine



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$V_{ave} = \frac{V_P}{\pi}$$

$$V_p = 170\,V_p$$

$$V_{ave} = 54\,V_{dc}$$

Average Value: half sine

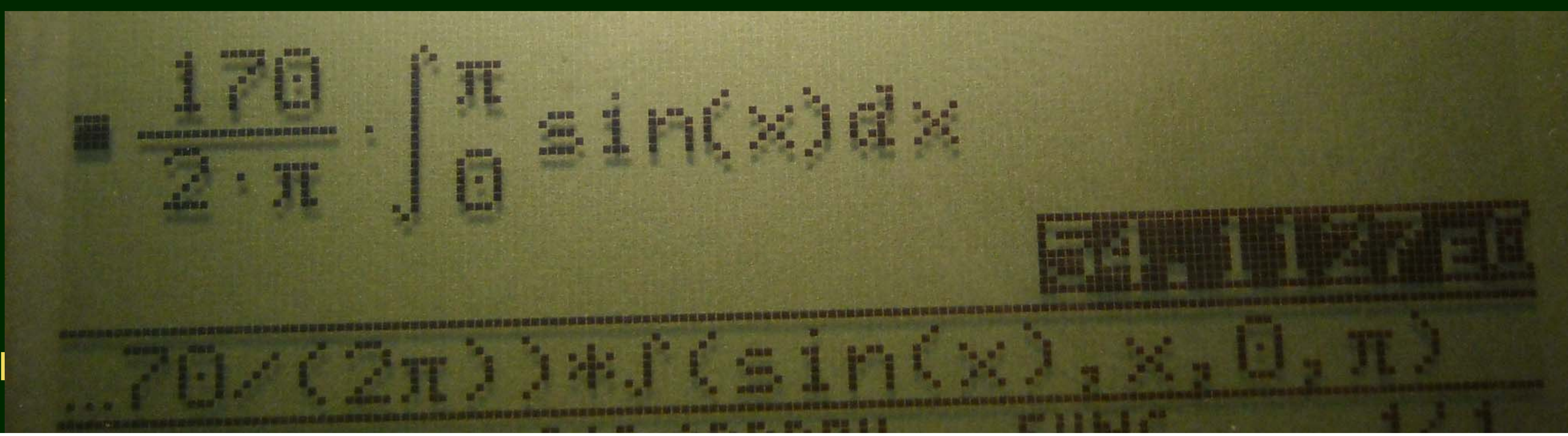
Set calculator to ***radians***.

$$V_{ave} = \frac{1}{T}\int_0^T v(t)\,dt$$

$$= \frac{V_P}{2\pi}\left(\int_0^{\pi} \sin\theta\, d\theta + \int_{\pi}^{2\pi} 0\, d\vartheta\right)$$

$$= \frac{V_P}{2\pi}\int_0^{\pi} \sin\theta\, d\theta$$

$$= (170/(2\pi)) * \int(\sin(X), X, 0, \pi)$$

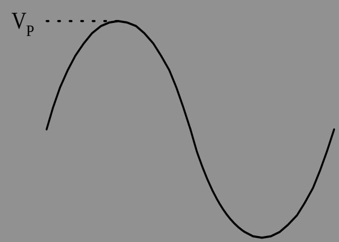


Average Value

Table 3-1

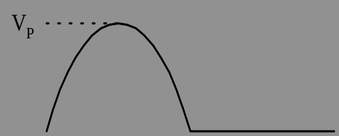
P 137

function	**average**



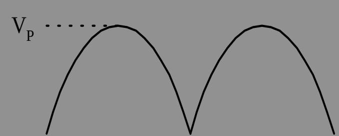
$$v(\theta) = V_P \sin\theta$$

average: 0



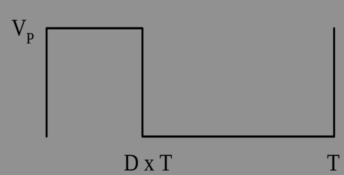
$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

average: $\dfrac{V_P}{\pi}$



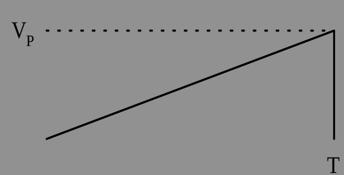
$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ -V_P \sin\theta & \pi < \theta < 2\pi \end{cases}$$

average: $\dfrac{2V_P}{\pi}$



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

average: DV_P



$$v(t) = \frac{V_P}{T} t$$

average: $\dfrac{V_P}{2}$

Overview

- Average
  - definition integrals
  - pulse half sine table
- Root Mean Squared
  - definition integrals
  - table
- Power
  - definition
  - pulse half sine table

Root Mean Squared: definition

- All signals of equal V_{RMS} => *same power*
- p => v^2 or i^2
- P_{ave} not p(t) => *integral of square*
- *square root* to get back to volts or amps
- root mean squared

Root Mean Squared: definition

$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)dt\right)}$$

Root Mean Squared: definition

$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)\,dt\right)}$$

root

Root Mean Squared: definition

$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)\,dt\right)}$$

root

mean

Root Mean Squared: definition

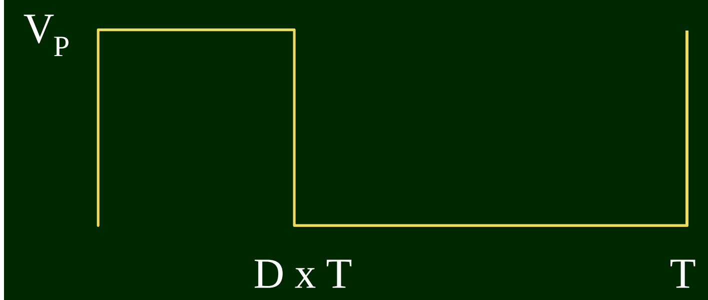
$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)\,dt\right)}$$

root

mean

squared

Root Mean Squared: pulse



$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int v^2(t)\,dt\right)}$$

$$V_{RMS} = \sqrt{\frac{1}{T}\left(\int_0^{DT} V_P{}^2\,dt + \int_{DT}^{T} 0\,dt\right)}$$

$$= \sqrt{\frac{V_P{}^2}{T}\left(\int_0^{DT} dt\right)}$$

$$= \frac{V_P}{\sqrt{T}}\sqrt{(t)\Big|_0^{DT}}$$

$$= \frac{V_P}{\sqrt{T}}\sqrt{(DT)-(0)}$$

$$= \frac{V_P}{\sqrt{T}}\sqrt{DT}$$

$$V_{RMS} = \sqrt{D} \times V_P$$

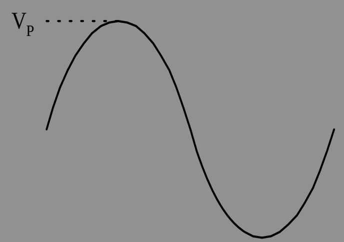
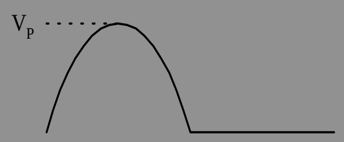
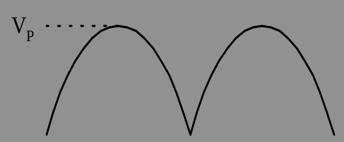
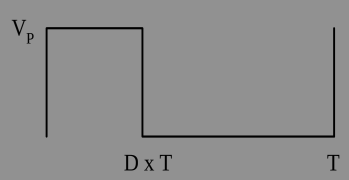
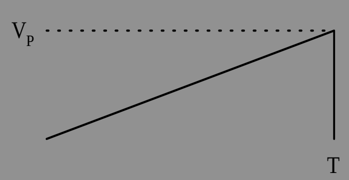
	function	average	RMS
	$v(\theta) = V_P \sin\theta$	0	$\frac{V_P}{\sqrt{2}}$
	$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$	$\frac{V_P}{\pi}$	$\frac{V_P}{2}$
	$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ -V_P \sin\theta & \pi < \theta < 2\pi \end{cases}$	$\frac{2V_P}{\pi}$	$\frac{V_P}{\sqrt{2}}$
	$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \quad 0 < D < 1$	DV_P	$\sqrt{D} \times V_P$
	$v(t) = \frac{V_P}{T} t$	$\frac{V_P}{2}$	$\frac{V_P}{\sqrt{3}}$

Table 3-1

p137

Overview

- Average
  - definition integrals
  - pulse half sine table
- Root Mean Squared
  - definition integrals
  - table
- Power
  - definition
  - pulse half sine table

Power: definition

- p(t)
  - instantaneous power
  - v(t) x i(t)
- P_{ave}
  - average p(t)

Power: definition

p(t)

instantaneous power

v(t) x i(t)

P_{ave}

average p(t)

$$= \frac{1}{T}\int_0^T v(t) \times i(t)\, dt$$

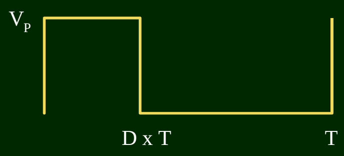
Power: definition

- p(t)
  - instantaneous power
  - v(t) x i(t)
- P_{ave}
  - average p(t)

$$= \frac{1}{T}\int_0^T v(t) \times i(t)\, dt$$

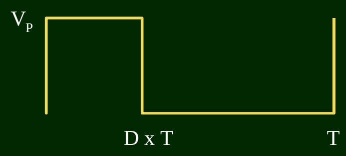
$$\neq V_{RMS} I_{RMS}$$

Power: pulse into a resistor

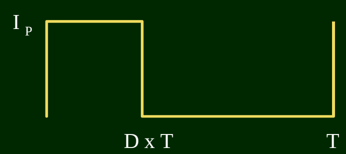


$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

Power: pulse into a resistor

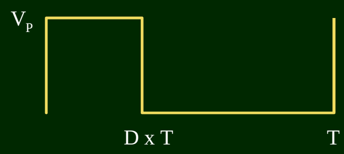


$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

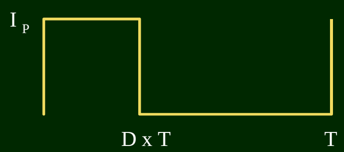


$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

Power: pulse into a resistor



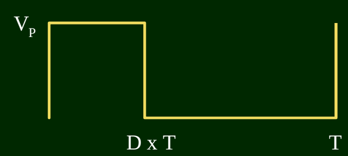
$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



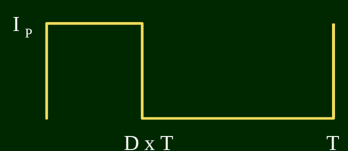
$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

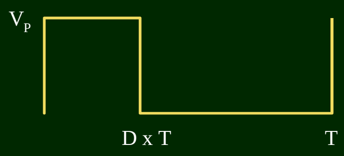


$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

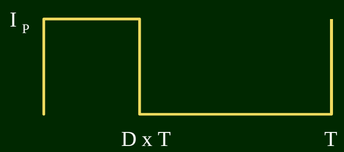
$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



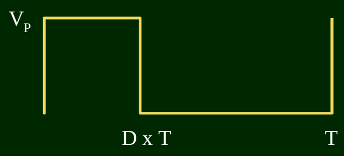
$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

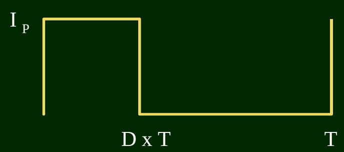
$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

$$= \frac{1}{T}\int_0^{DT} V_P I_P dt$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

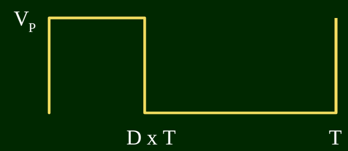
$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

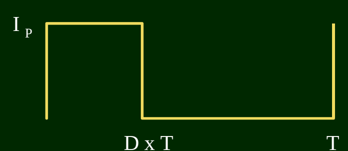
$$= \frac{1}{T}\int_0^{DT} V_P I_P dt$$

$$= \frac{V_P I_P}{T}\int_0^{DT} dt$$

Power: pulse into a resistor



$$v(t)=\begin{cases}V_P & 0<t<DT\\ 0 & DT<t<T\end{cases}\qquad 0<D<1$$



$$i(t)=\begin{cases}I_P & 0<t<DT\\ 0 & DT<t<T\end{cases}\qquad 0<D<1$$

$$P=p_{ave}=ave\left[v(t)\times i(t)\right]$$

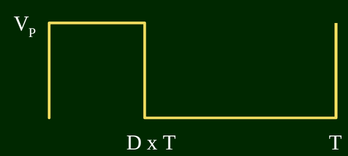
$$P=\frac{1}{T}\left[\int_0^{DT}V_P I_P\,dt+\int_{DT}^{T}0\,dt\right]$$

$$=\frac{1}{T}\int_0^{DT}V_P I_P\,dt$$

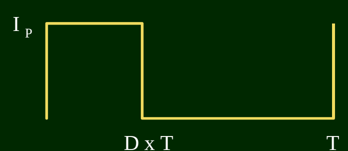
$$=\frac{V_P I_P}{T}\int_0^{DT}dt$$

$$=\frac{V_P I_P}{T}\left[t\Big|_0^{DT}\right]$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

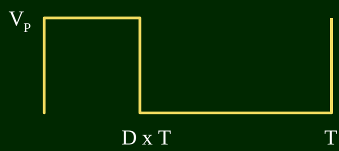
$$= \frac{1}{T}\int_0^{DT} V_P I_P dt$$

$$= \frac{V_P I_P}{T}\int_0^{DT} dt$$

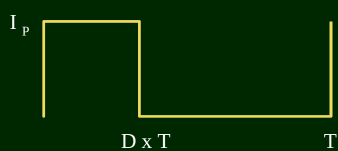
$$= \frac{V_P I_P}{T}\left[t \Big|_0^{DT} \right]$$

$$= \frac{V_P I_P}{T}\left[DT - 0\right]$$

Power: pulse into a resistor



$$v(t)=\begin{cases} V_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$



$$i(t)=\begin{cases} I_P & 0<t<DT \\ 0 & DT<t<T \end{cases} \qquad 0<D<1$$

$$P = p_{ave} = ave\left[v(t)\times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

$$= \frac{1}{T}\int_0^{DT} V_P I_P dt$$

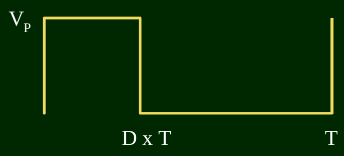
$$= \frac{V_P I_P}{T}\int_0^{DT} dt$$

$$= \frac{V_P I_P}{T}\left[t\Big|_0^{DT}\right]$$

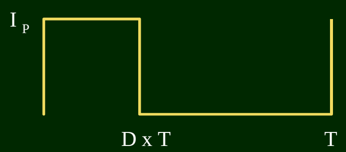
$$= \frac{V_P I_P}{T}\left[DT-0\right]$$

$$P = DV_P I_P$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$P = p_{ave} = ave[v(t) \times i(t)]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P dt + \int_{DT}^{T} 0 dt\right]$$

$$P = D V_P I_P$$

$$T = 12\mu s$$

$$t_{\text{pulse width}} = 8\mu s$$

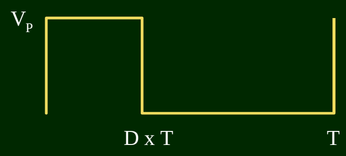
$$D = ?$$

$$V_p = 28 \text{Vp} \qquad R_{load} = 8\Omega$$

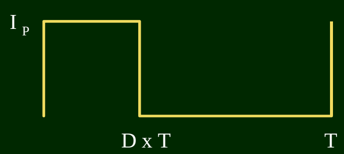
$$I_p = ?$$

$$P_{ave} = ?$$

Power: pulse into a resistor



$$v(t) = \begin{cases} V_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$



$$i(t) = \begin{cases} I_P & 0 < t < DT \\ 0 & DT < t < T \end{cases} \qquad 0 < D < 1$$

$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P \, dt + \int_{DT}^{T} 0 \, dt\right]$$

$$P = D V_P I_P$$

$$T = 12 \mu s$$

$$t_{\text{pulse width}} = 8 \mu s$$

$$D = 0.67$$

$$V_p = 28 \text{Vp} \qquad R_{load} = 8 \Omega$$

$$I_p = 3.5 \text{A}_p$$

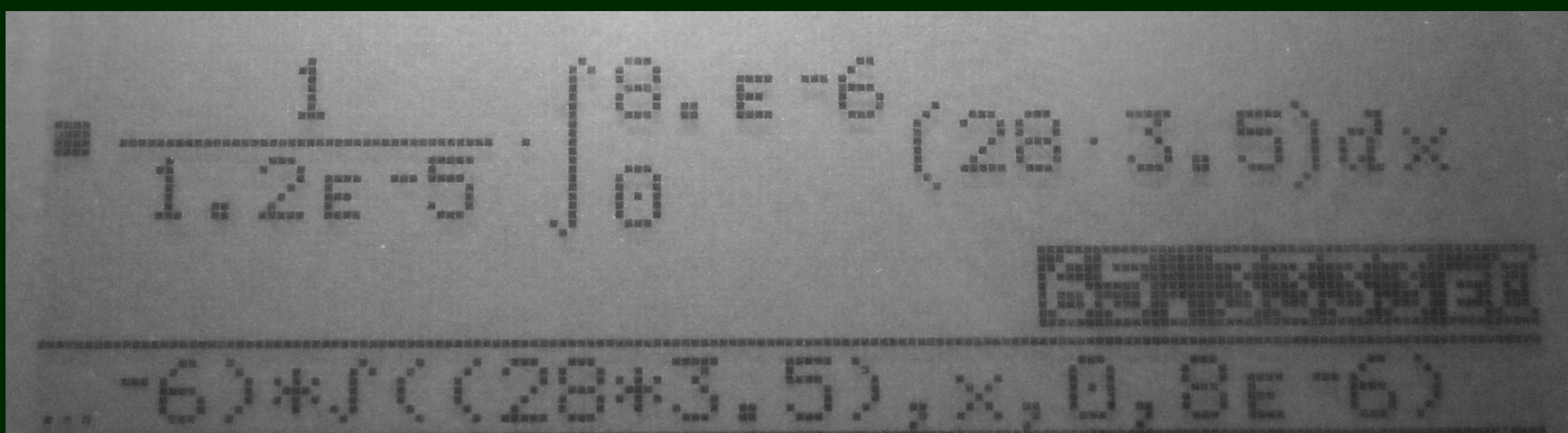
$$P_{ave} = 65.66 \text{W}$$

Power: pulse into a resistor

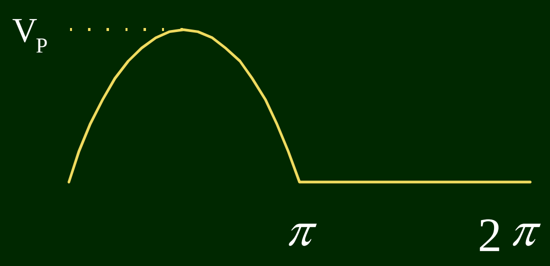
$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

$$P = \frac{1}{T}\left[\int_0^{DT} V_P I_P \, dt + \int_{DT}^{T} 0 \, dt\right]$$

$$P = \frac{1}{12\,\mu s}\left[\int_0^{8\,\mu s} \left(28\,\mathrm{V_P} \times 3.5\,\mathrm{A_p}\right) dt\right]$$

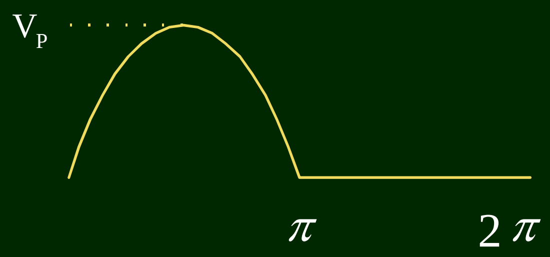


Power: half sine into a resistor

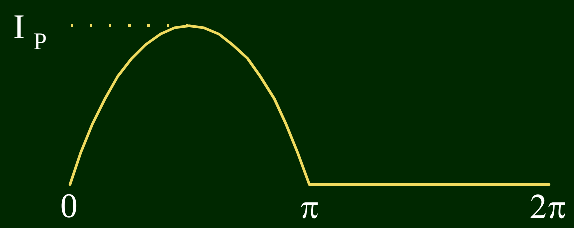


$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

Power: half sine into a resistor



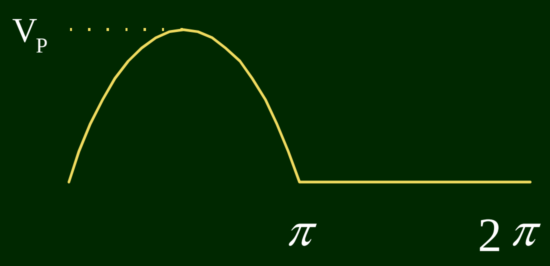
$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$



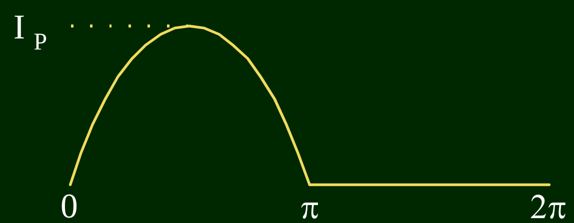
$$i(\theta) = \begin{cases} I_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

Power: half sine into a resistor

$$P = p_{ave} = ave\left[v(t) \times i(t)\right]$$

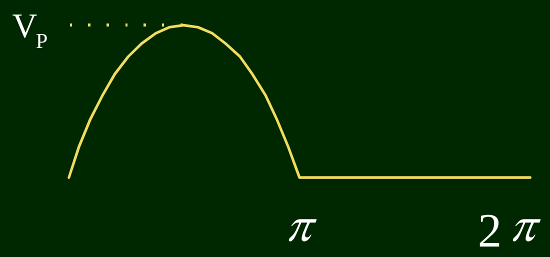


$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

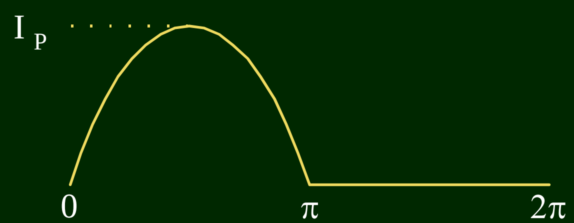


$$i(\theta) = \begin{cases} I_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

Power: half sine into a resistor



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$



$$i(\theta) = \begin{cases} I_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

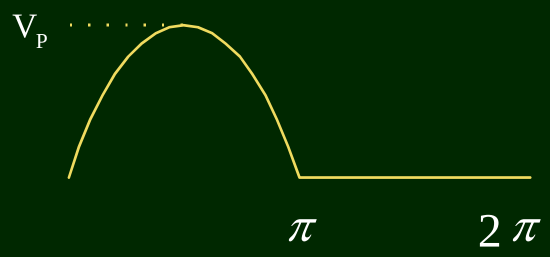
$$P = p_{ave} = ave[v(t) \times i(t)]$$

$$P = \frac{1}{2\pi}\left[\int_0^{\pi} (V_P \sin\theta)(I_P \sin\theta)d\theta + \int_{\pi}^{2\pi} 0 d\theta\right]$$

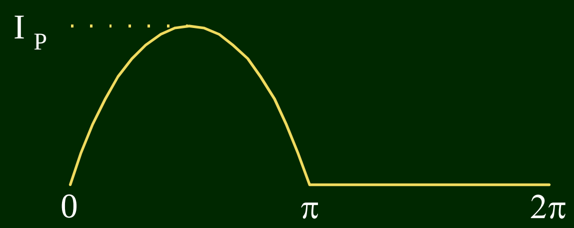
$V_p = 170\mathrm{V_p}$ $\quad$ $R_{load} = 20\Omega$

$I_p = ?$

Power: half sine into a resistor



$$v(\theta) = \begin{cases} V_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$



$$i(\theta) = \begin{cases} I_P \sin\theta & 0 < \theta < \pi \\ 0 & \pi < \theta < 2\pi \end{cases}$$

$$P = p_{ave} = ave[v(t) \times i(t)]$$

$$P = \frac{1}{2\pi}\left[\int_0^{\pi} (V_P \sin\theta)(I_P \sin\theta)\, d\theta + \int_{\pi}^{2\pi} 0\, d\theta\right]$$

$$V_p = 170\,\mathrm{V_p} \qquad \mathrm{R_{load}} = 20\Omega$$

$$I_p = 8.5\,\mathrm{A_p}$$

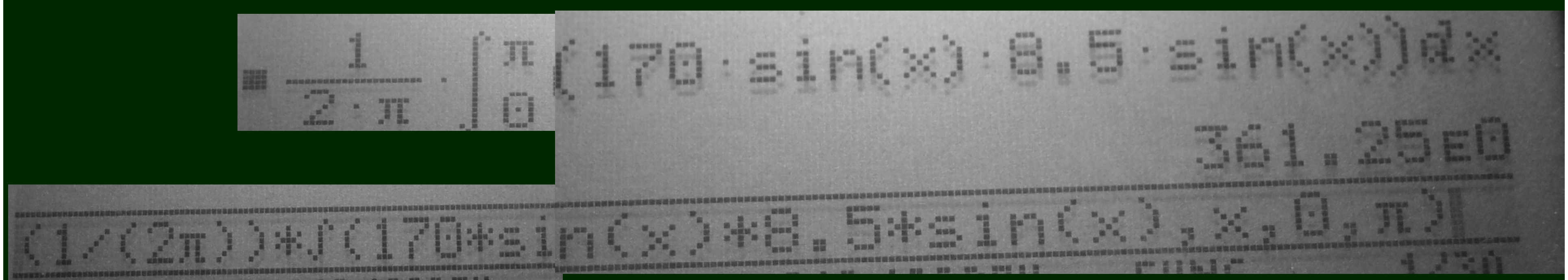
$$P = \frac{1}{2\pi}\left[\int_0^{\pi} (170\,\mathrm{V_P} \sin\theta)(8.5\,\mathrm{A_p} \sin\theta)\, d\theta\right]$$

$$P = ?$$

Power: half sine into a resistor

$$P = \frac{1}{2\pi}\left[\int_0^{\pi}\left(170\,\mathrm{V_P}\sin\theta\right)\left(8.5\,\mathrm{A_p}\sin\theta\right)d\theta\right]$$

$$P = (1/(2\pi))*\int(170*\sin(X)*8.5*\sin(X), X, 0, \pi)$$



Power for common waves

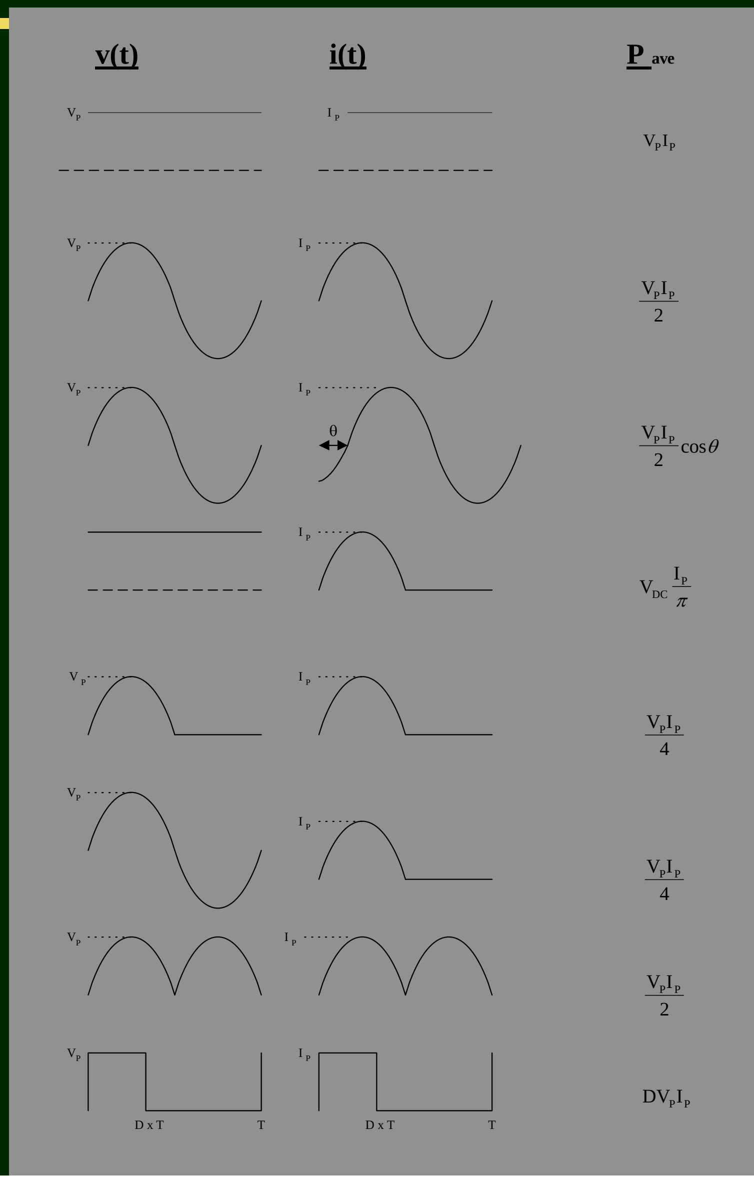


Table 3-2

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Overview

- Average
  - definition integrals
  - pulse half sine table
- Root Mean Squared
  - definition integrals
  - pulse half sine table
- Power
  - definition
  - pulse half sine table