IEEE 802.3af DTE Power via MDI
System Considerations - Normal Powering Mode

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Objectives

- Specifying PSE output current parameters at normal powering mode
  - Support that PSE output current is 350mA average max.
  - Define current waveform parameters to support dynamic load changes
  - Specifying PSE-PD power limitations

Strategy

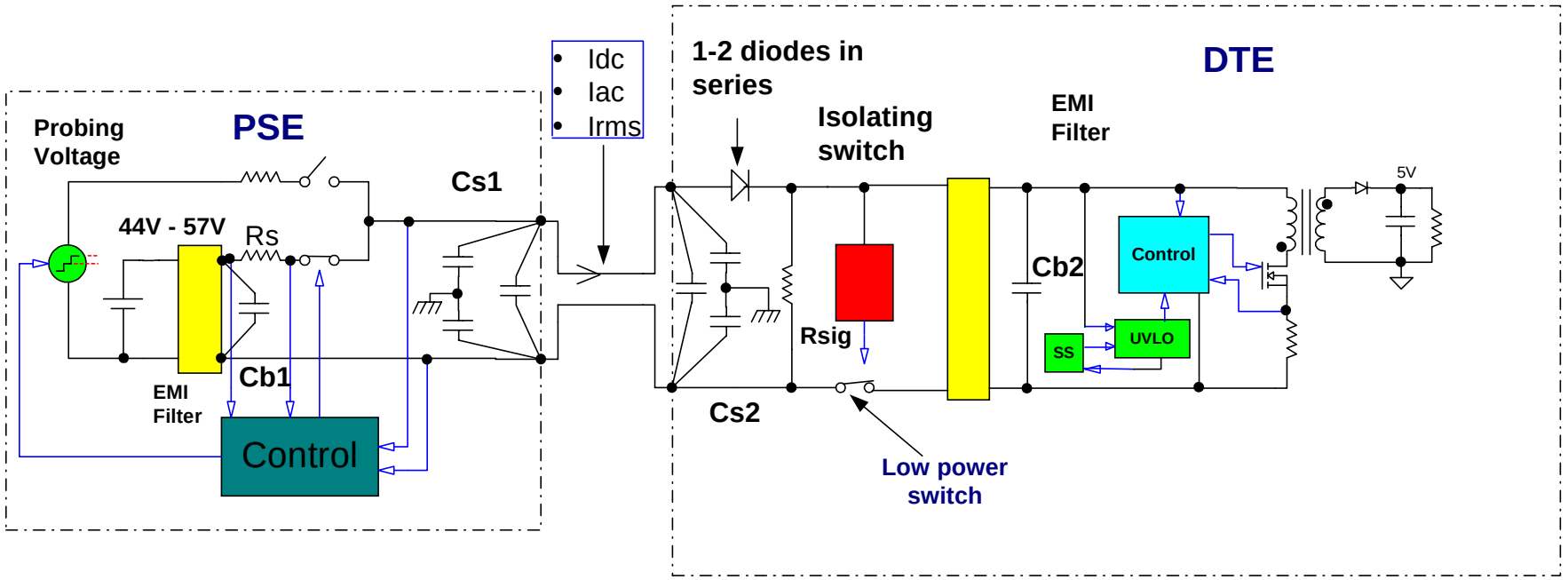
- Optimized for system performance with reasonable cost
- Using proven techniques and/or definitions from the power conversion field

- Detailed discussion can be found at “Introductory Discussion - Normal Powering Mode”, located at “Document” folder of the 802.3af web site.

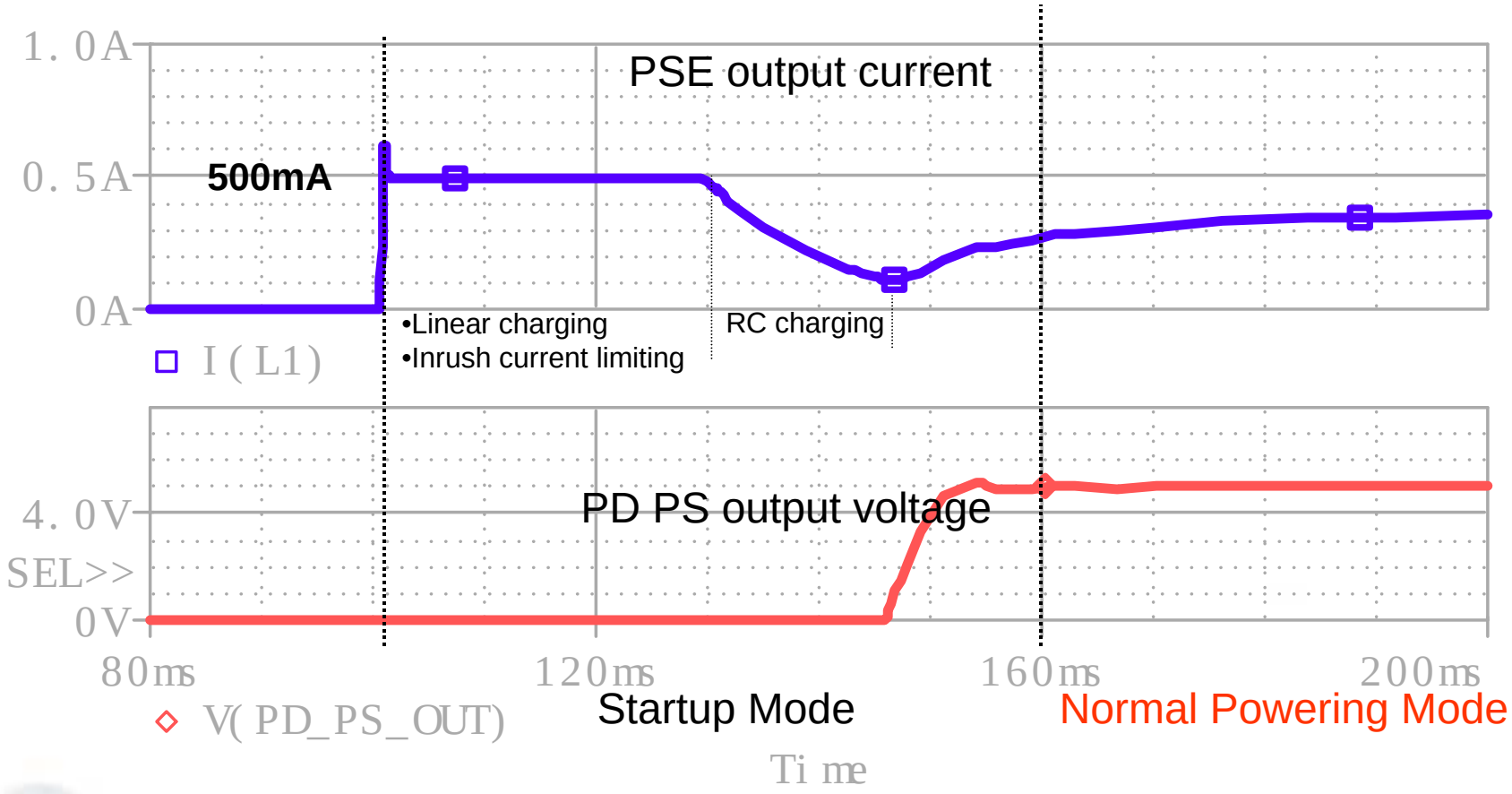
Topics

- Is the "350mA maximum continuous current" requirement well defined?
  - 350mA_peak or 350mA_avg or 350mA_rms?
- PSE output power limitations
- PD input power limitations

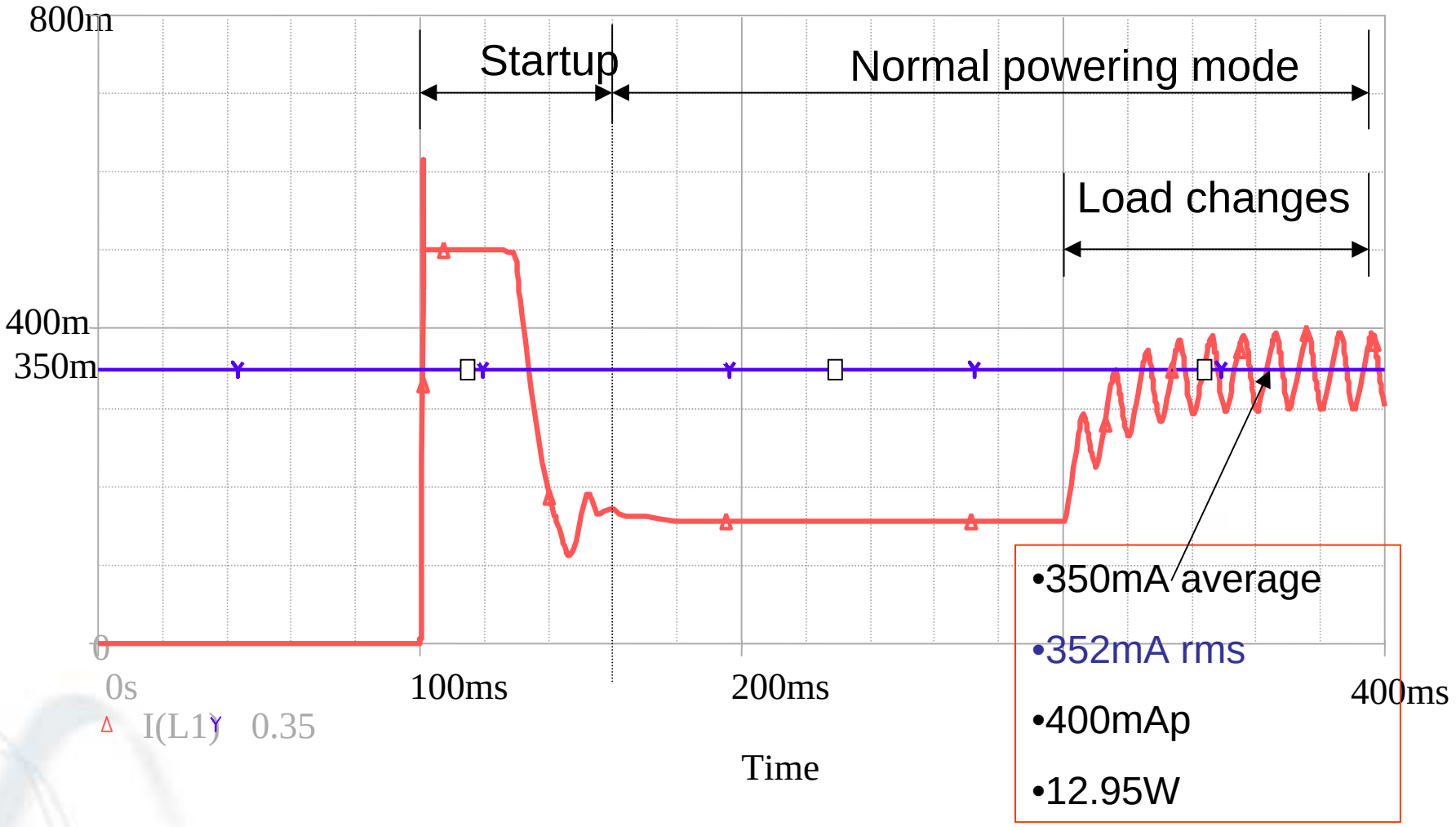
System Description at Normal Powering Mode



Typical behavior of PSE output current



PD input current at normal powering mode
Typical behavior example



350mA peak or 350mA avg or 350mA rms?

Case 1- 350mAp

Assuming PSE Voltage=44V

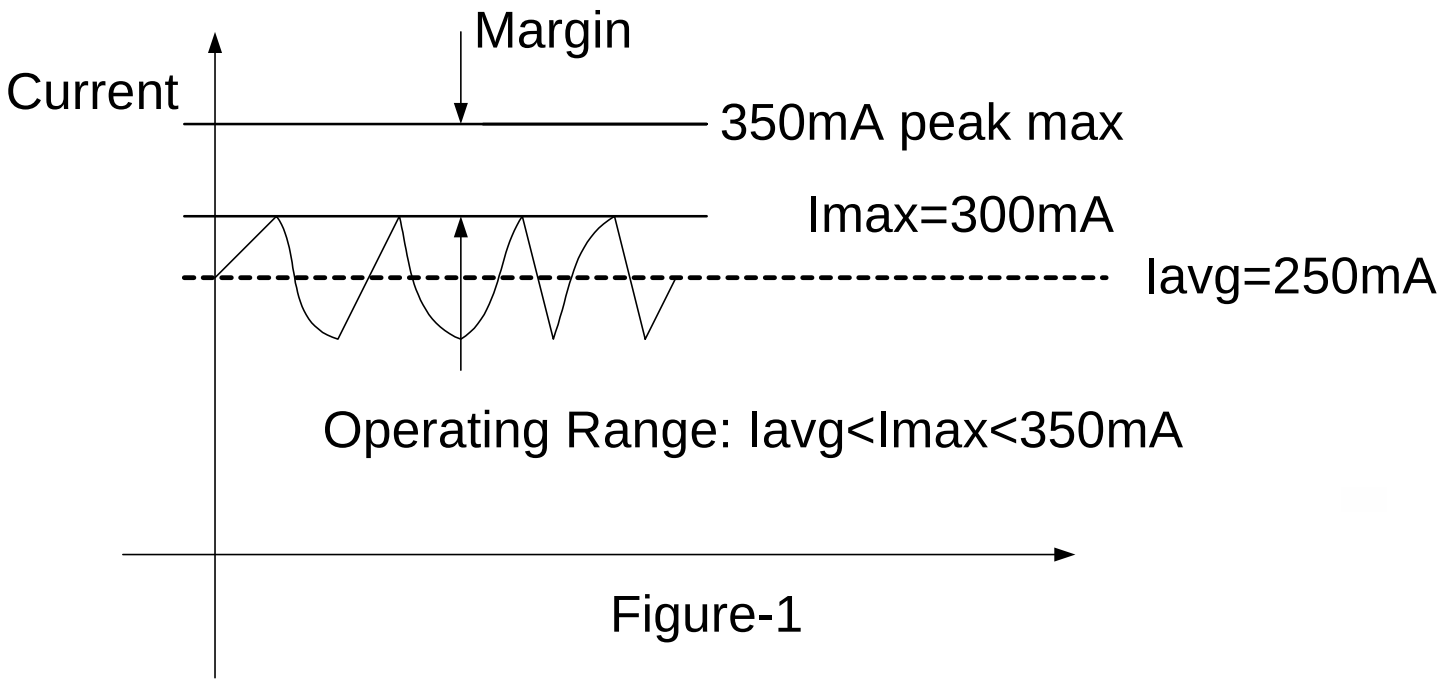


Figure-1

PD max power available=(44V-20Rx250mA)x250mA=9.75W < 12.95W

350mA peak or 350mA avg or 350mA rms?

Case 1 - 350mApeak

- Drawbacks of specifying 350mAp
  - PSE full power can't fully be utilized. (We are paying for unused Watts!)
  - The problem will increase in respect to low power applications in which the power is limited due to utilization of classification feature.
  - Reduces the number of possible applications supported by the PSE
- Conclusion: 350mAp definition should be abandoned.

Case 2 :350mA avg or Case 3: 350mA rms?

- Output current units = Source voltage units
- Ensures “correct” Power in Watts

- PSE is a DC source
- Hence:
- PSE output current must be defined as an Average current (See Annex C for details)
  - The RMS current value will be used to limit the power loss across system components

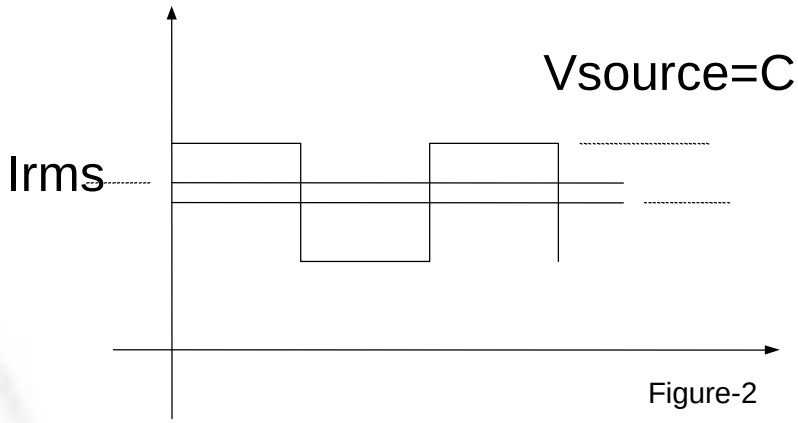


Figure-2

Ppeak, Ipeak
Pavg, Iavg

Summary

- PSE output current = 350mA average.
- Power loss on system components will be limited by the RMS value of the current.
  - The RMS value will be specified by the current waveform parameters

Specifying waveform parameters

Source Voltage & Current

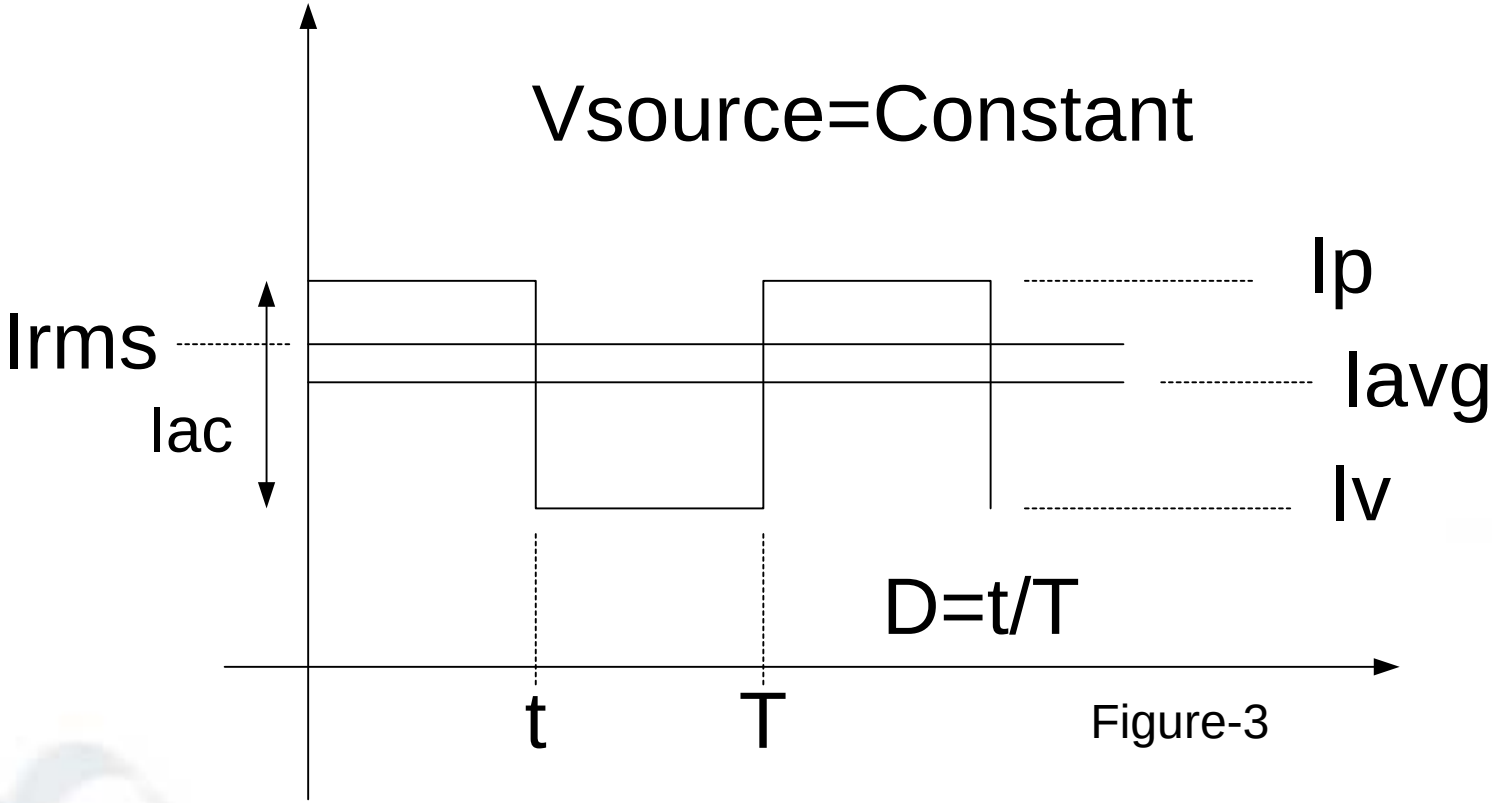


Figure-3

Specifying waveform parameters

List of facts

- Standard power supply delivers 20-50% more power without additional cost for limited time (100mSec).

		Data from PS vendors	
Iavg	**Ip**	**Additional peak power for 100ms**	**Additional Cost**
0.35A	**0.4**	**15%**	**0%**
0.35A	**0.455**	**30%**	**0%**
0.35A	**0.5**	**43%**	**<3%**

- The peak power will be used to support peak currents > 350mA for limited time
- For optimum cost/performance ratio:
  - PSE Ip min: 0.45A to 0.5A
  - Pd Ip max: 0.45A

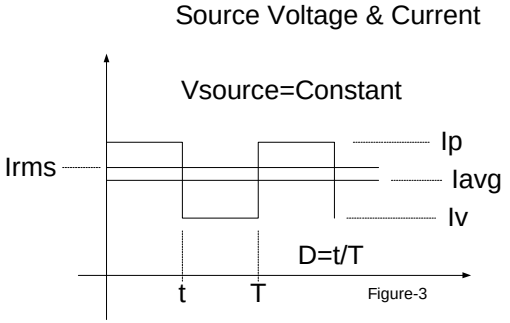
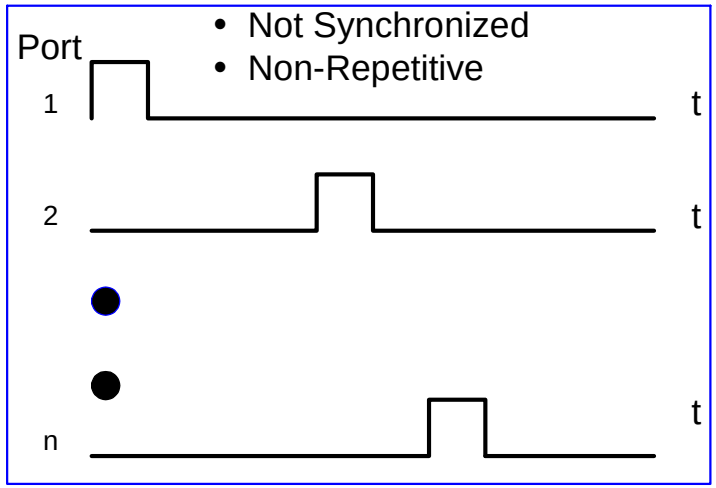
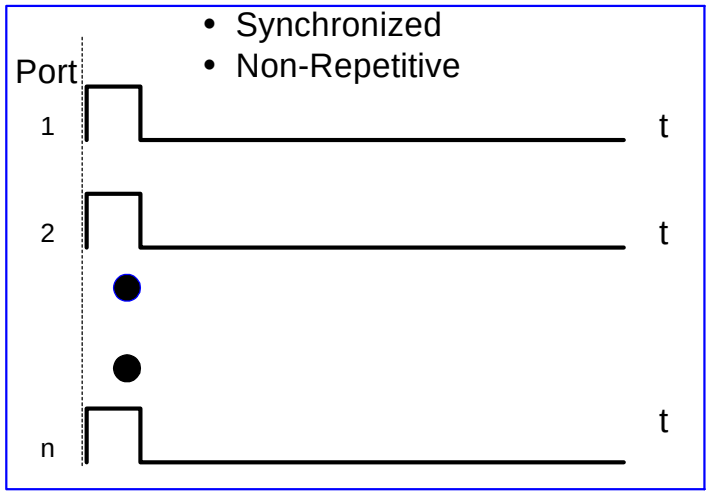
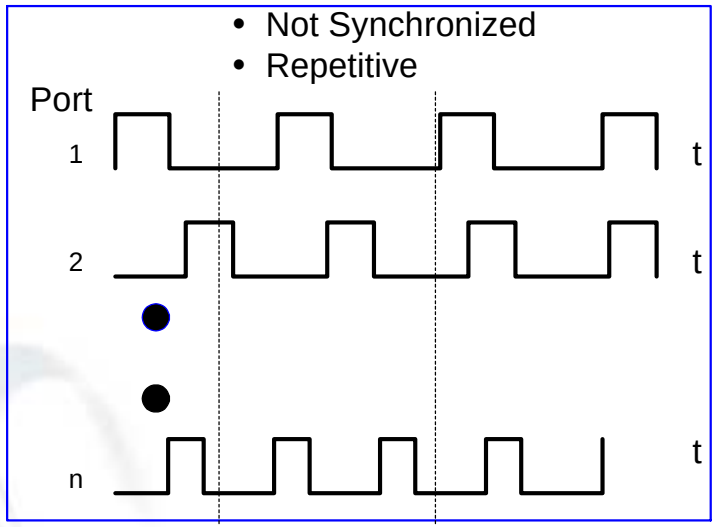


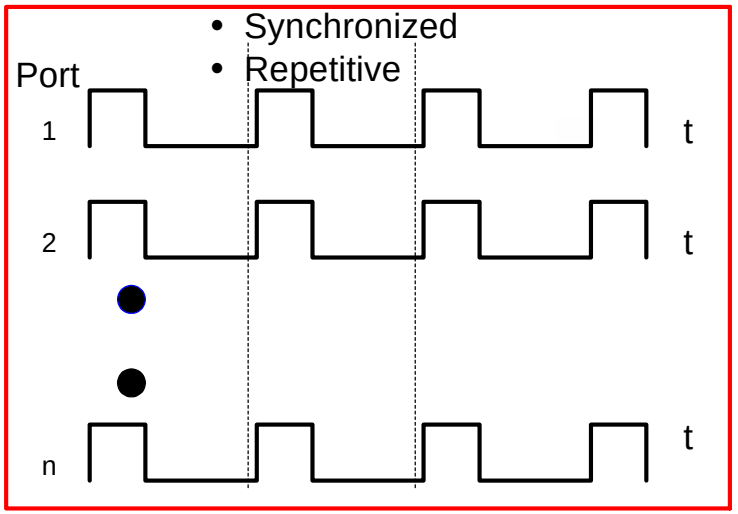
Figure-3

Possible Load combinations









Specifying waveform parameters

- Supporting the worst case: Repetitive, Synchronized

  - Non-Repetitive,Synchronized loads
  - Achievable by Ip=0.455 to 0.5 for 100ms without additional cost. (0.455/0.35=1.3, 0.5/0.35=1.43)

  - Repetitive
  - Affects power loss, It is required to limit RMS/AVG ratio and specifying waveform parameters.

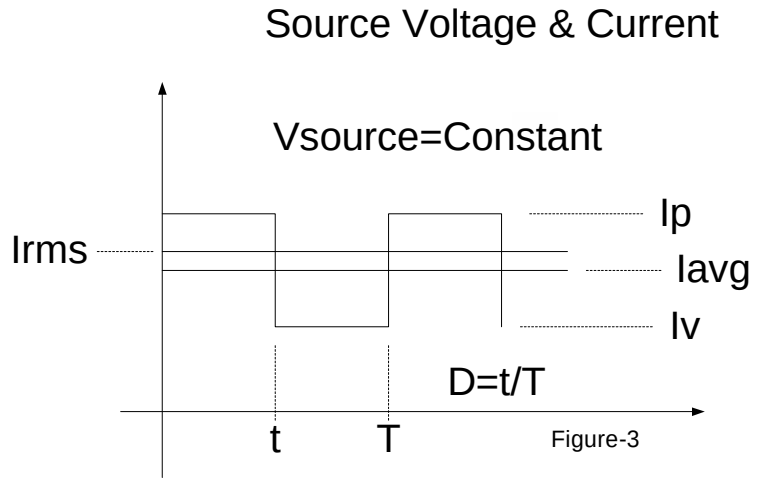


Figure-3

Suggested waveform parameters for the repetitive case
Iavg is set to 0.35A. Irms>Iavg (See Annex D for details)

- Max. values for the repetitive case.
  - Iavg 350mA
  - Ip 500mA
  - Pulse width 100mSec
  - Dmax 0.24@Ipmax=0.5

Irms 360mA
(Efficiency loss 1% max)

- The Non-Repetitive case is a subset of the above.

Summary

- Utilization of system resources is optimized if Iavg=350mA max and the RMS value is allowed to be slightly above Iavg.

- No effects on total average power required.

Suggested PSE-PD parameters

Parameter	Units	Conditions	PSE		PD	
			min	max	min	max
Operating voltage	Vdc	Note 1	44	57	35	57
Current, Iavg	mAdc		350		10	350
Current cut off	mAdc		355	375	NA	NA
Current peak, Ip	mA	Non repetitive: Max values: Pulse width=100mSec Tmin=4s	0.45	0.5	NA	0.45
		Repetitive: (Note 4) Max values: Pulse width=100mSec Duty cycle=0.24 max Irms =0.36A max				
Output power	W		15.4	19.95	0.44	12.95
Turn On voltage	Vdc	Note 2			38	44
Turn Off voltage	Vdc	Note 3			30	33

Note 1: PD min input voltage is given by Vmin=44V-Ipx20R. For Ip=0.45,Vmin=35
Note 2: Turn on must be starting at V<=44V. 6V window gives the lower limit, 38V.
Note 3: From theory, Turn Off must be above (PSE output voltage max/2)=28.5V.
Additional margin gives 30V, allowing window of 3V gives the upper limit, 33V.
The upper limit must be < (44-Ipmax20R)=34V

Note 4: Duty cycle>0.24 is permitted if Ip< Ipmax and meeting the following equation: $Iac\_rms = \sqrt{Irms^2 - Idc^2}$, in addition see Annex F

Annex A

- When we use standard power supply specified for 150W, 50V, this refers to the nominal continuous average current being 3A.
- The over current threshold point is set at 20% to 50% above the nominal number to guarantee meeting 3Adc nominal current.
- Why in the above example (standard power supply), can't we set the current limit to 3.01 ADC or 3.11 ADC?
  - Answer:
    - It is not practical since the load type is unknown, and it is a general-purpose power source.
    - It should support constant load and dynamic loads both repetitive and non-repetitive types.
    - It should support loads at noisy environment
- Typical standard power supply will exhibit the following parameters: (See Annex B for lab tests)

Pout_avg=153.6W, 3.2A average continuous. The current limit threshold is set to 4A. The current limit circuit will be activated at 4A peak if the pulse width is longer than 500uSec.
For pulse width shorter than 500uSec, the peak current can be higher than 4Apeak.
Meaning that at D=10%, and Frequency=7KHz, Ip=34Apeak! And the average is 3.2A. Negligible effects on power loss!

The reason for these results is that at pulse width < 500uSec, the power supply output filter, is reducing the ac components and reflects DC current to the power supply internal circuits.
For pulse width > 500uSec, the power supply output filter reflects the peak current without attenuation.

Annex B

Vin=150Vdc Vout=48 Ioutavg=3.2A

Frequency	10		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	Irms/Iavg
100	3.2	3.20	3.2	1.254	1.25	1.312	1.0000
80	4.016	3.21	3.573	1.263	1.38	1.901	1.0903

Frequency	20		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.25	1.25	1.312	1.0000
80	4.031	3.22	3.59	1.278	1.36	1.734	1.0618

Frequency	50		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.264	1.26	1.328	1.0000
80	4.031	3.22	3.573	1.269	1.28	1.578	1.0118

Frequency	100		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.26	1.26	1.328	1.0000
80	4.037	3.23	3.575	1.266	1.27	1.422	1.0016

Frequency	500		Hz				Irms/Iavg
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.254	1.25	1.312	1.0000
80	4	3.20	3.559	1.268	1.27	1.328	1.0000

Frequency	2000		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.25	1.25	1.3	1.0000
90	3.588	3.23	3.377	1.27	1.27	1.328	1.0000
80	4.031	3.22	3.591	1.29	1.29	1.344	1.0000
70	4.547	3.18	3.796	1.291	1.29	1.359	1.0000
60	5.341	3.20	4.089	1.282	1.28	1.359	1.0000

Frequency	5000		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.25	1.25	1.312	1.0000
80	4	3.20	3.549	1.276	1.28	1.344	1.0000
70	4.516	3.16	3.76	1.278	1.28	1.344	1.0008
60	5.325	3.20	4.105	1.298	1.3	1.344	1.0008
50	6.312	3.16	4.396	1.296	1.3	1.344	1.0008
40	7.863	3.15	4.926	1.27	1.27	1.328	1.0000

Annex B - cont.

Frequency	6000		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	Irms/Iavg
100	3.2	3.20	3.2	1.259	1.26	1.328	1.0008
80	4.022	3.22	3.553	1.275	1.275	1.344	1.0000
60	5.384	3.23	4.071	1.283	1.284	1.344	1.0008
40	8.025	3.21	4.962	1.263	1.264	1.328	1.0008

Frequency	7000		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.264	1.265	1.312	1.0008
80	4	3.20	3.557	1.275	1.275	1.344	1.0000
60	5.334	3.20	4.093	1.294	1.295	1.344	1.0008
40	8.062	3.22	4.991	1.289	1.289	1.344	1.0000
30	10.82	3.25	5.755	1.307	1.307	1.359	1.0000
20	16.36	3.27	6.982	1.272	1.273	1.344	1.0008
10	34	3.40	9.952	1.29	1.291	1.344	1.0008

Annex B - cont.

Frequency	8000		Hz				Irms/Iavg
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.251	1.251	1.312	1.0000
80	4.013	3.21	3.543	1.269	1.269	1.328	1.0000
60	5.312	3.19	4.081	1.293	1.294	1.359	1.0008
40	7.97	3.19	4.952	1.282	1.283	1.344	1.0008
30	10.81	3.24	5.726	1.281	1.282	1.359	1.0008
20	16.88	3.38	7.068	1.294	1.294	1.359	1.0000
10	34.88	3.49	9.866	1.265	1.265	1.734	1.0000

Frequency	10000		Hz				
	Iout(A)			Iin(A)			
Duty(%)	Ipeak	Iavg	Irms	Iavg	Irms	Ipeak	
100	3.2	3.20	3.2	1.251	1.251	1.312	1.0000
90	3.606	3.25	3.356	1.255	1.255	1.326	1.0000
80	4.019	3.22	3.55	1.26	1.26	1.344	1.0000
70	4.625	3.24	3.782	1.28	1.28	1.359	1.0000
60	5.344	3.21	4.069	1.278	1.278	1.359	1.0000
50	6.438	3.22	4.434	1.284	1.284	1.359	1.0000
40	8.094	3.24	4.965	1.284	1.284	1.344	1.0000
30	10.81	3.24	5.672	1.265	1.265	1.328	1.0000
20	16.8	3.36	6.999	1.272	1.272	1.328	1.0000
10	34	3.40	9.634	1.248	1.248	1.312	1.0000

Annex C

- Average current: $Iavg = \frac{1}{T}\int_0^T I(t)dt$ RMS current: $Irms = \sqrt{\left(\frac{1}{T}\int_0^T (I(t))^2 dt\right)}$
- Power source current, is specified according to its source voltage type i.e. DC source or AC source.
- DC source: The current is specified as the average (DC) current
  - For DC source: $P[Wavg] = Vdc \cdot Idc$
- AC source: The current is specified as the RMS current.
  - For AC source: $P[Wrms] = Vrms \cdot Irms$
- The reason for the above definitions is to always ensure the correct power delivery in Watts.

Annex D: Specifying waveform parameters

Strategy

- Utilizing standard power supply ability to supply Ip>Iavg for limited time with out additional cost.
  - Starting point (See figure 3) :
    - Ipmax=0.5A.
    - Iavg=350mAmax
    - Ip / Iavg<1.43 (43%)

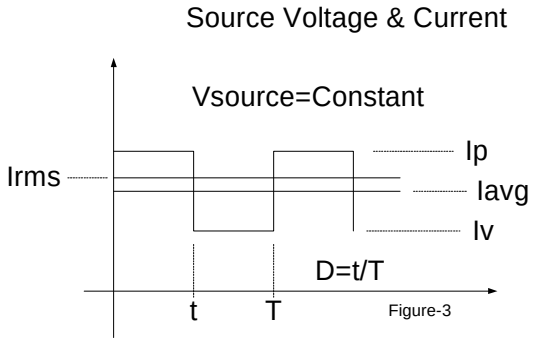


Figure-3

- Specifying k=(Irms/Iavg)^2 ratio by setting max. efficiency loss
- η = Initial power supply efficiency $$k = \frac{\eta - \eta\_new}{\eta\_new - \eta\_new \cdot \eta}$$ Eq-1
- Irms limitation can be derived from Irms=Iavg*(1+k)^0.5 Eq-2
- Max. duty cycle is derived from: $$D\max = \frac{Irms^2 - Iavg^2}{Ip^2 - 2 \cdot Iavg \cdot Ip + Irms^2}$$ Eq-3
- Tmin=t/Dmax Eq-4

Annex E - Optional waveform parameters for the repetitive case Iavg is set to 0.35A. Irms>Iavg (See annex D for details)

Parameters	Option A	Option B	Option C
Ip max.	**0.5A**	**0.5A**	**0.5A**
Iavg max.	**0.35A**	**0.35A**	**0.35A**
Irms max.	0.36A	0.351A	0.36A
Pulse width max.	**100mSec**	**100mSec**	0.205mSec
Tmin	417mSec	3.03sec	NA
Tmax	NA	NA	**0.5mSec**
Dmax	0.24	0.033	0.24
Efficiency loss			
Power supply	**1% max.**	**0.1%max**	**0%**
Port switch, RJ45, Cable	**1% max**	**0.1%max**	**1%**

Table –1

- Blue bolded numbers are input parameters.
- The other parameters are calculated from the input parameters according to Annex D.
- See Annex A for derivation of option C

Annex E - Cont..

- Option A is recommended to be used.
  - Options A and B are suitable for our system
  - Allow low frequency ripple current that cant be treated in the PD
  - No effect on EMI.
  - Option A represents and covers more applications than option B

- Option C, allows 2Khz and above ripple current which can be easily filtered by the PD power supply, hence, no added value to the current shape parameters.
- Option C ignores low frequencies (bellow 2Khz) which are the reason for specifying the waveform parameters
- Will be limited by EMI requirements at 20KHZ - 150Khz range.

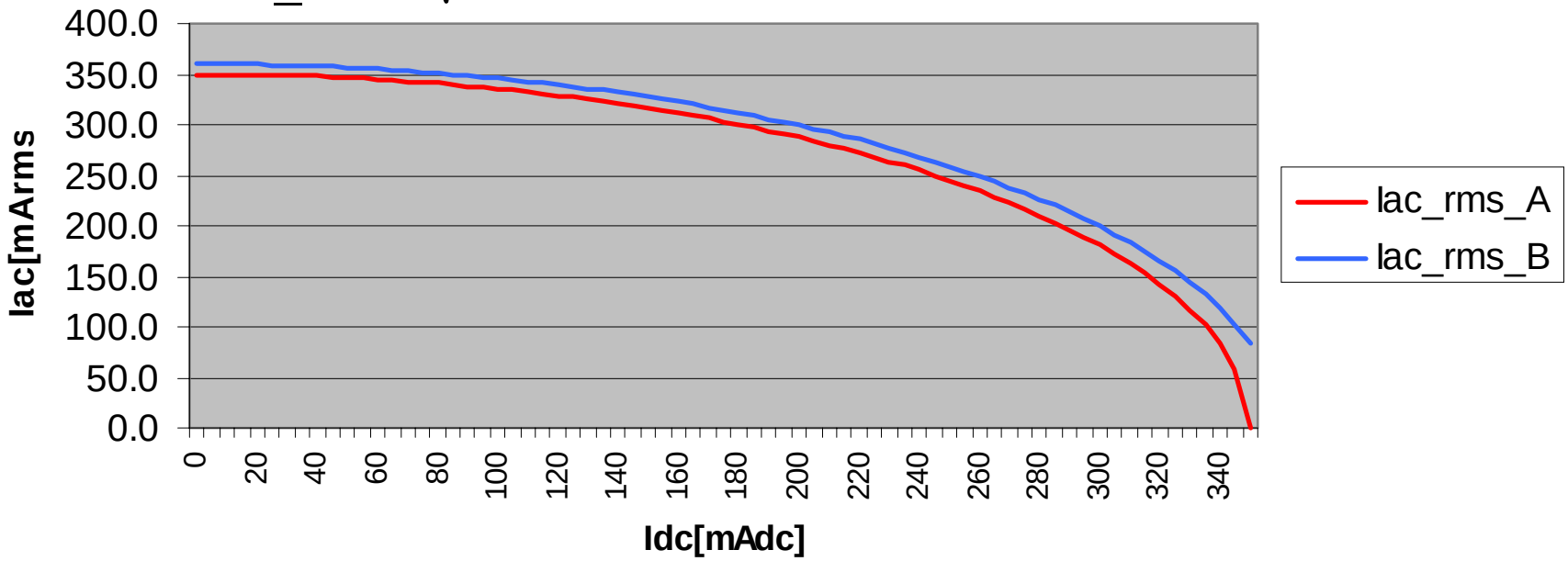
Annex F

Current ripple(Iac_rms) vs Idc

Method A: , Irms=Idc=350mA max.

Method B: Irms max=360mA, Idc max=350mA

$$Iac\_rms = \sqrt{Irms^2 - Idc^2}$$



The ripple current component, Iac_rms as function of total RMS current