EE 5741
Design of Electronic Ballasts

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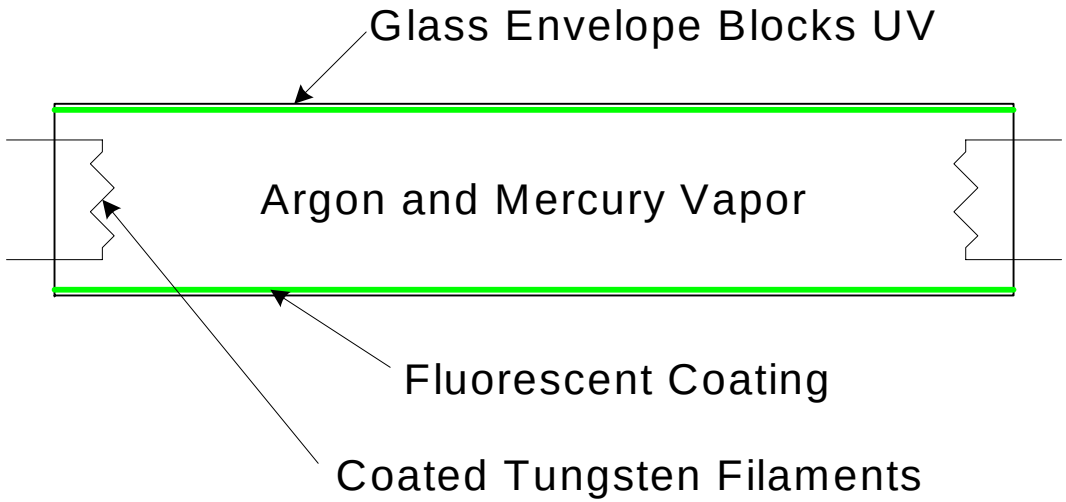
International
IOR Rectifier

Agenda

- Gas-Discharge lamps
- ZVS Resonant Half-Bridge output stage
- Typical ballast designs
- PFC
- Protection features
- Summary

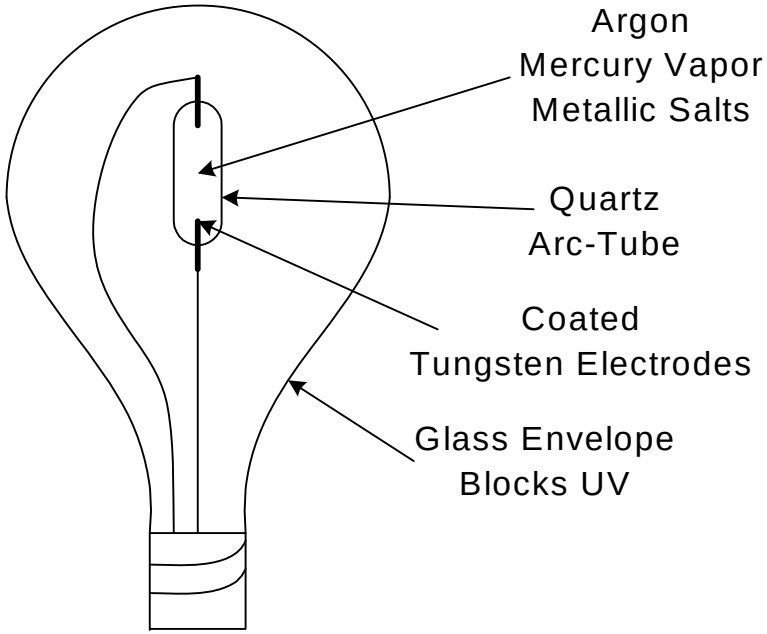
Gas Discharge Lamp Basics



“Low Pressure” Fluorescent Lamp

- Current flows through plasma between electrodes
  - Must be AC or mercury migrates to one end
- Plasma emits mostly UV radiation
- UV excites coating to fluoresce and produce visible light
- Heated electrodes improve lamp life and lower strike voltage

High Intensity Discharge (HID) Lamps



Medium Pressure Lamp

- AC current flows through plasma between electrodes
- Plasma emits UV radiation AND visible light directly

Why Gas Discharge Lamps?

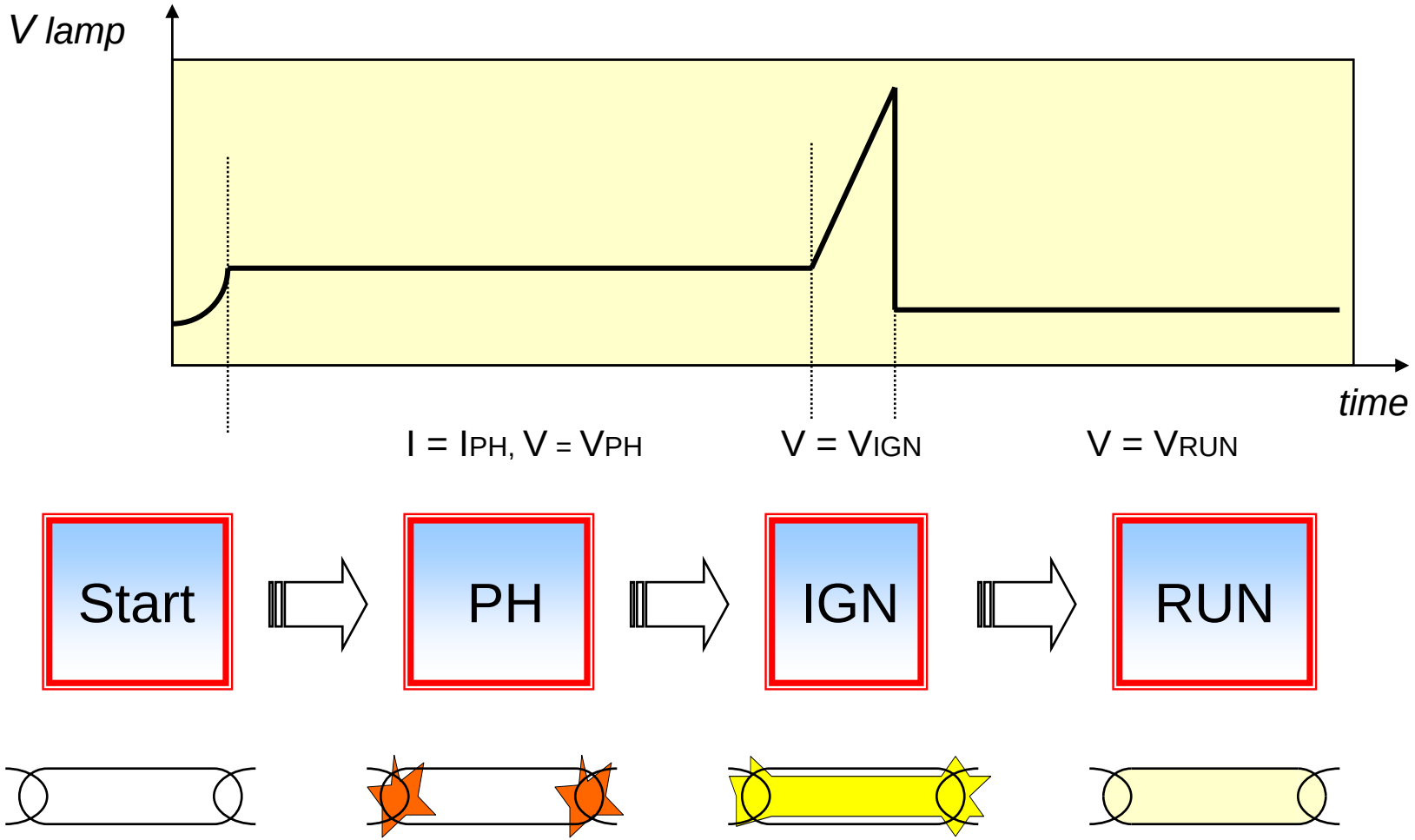
Advantages

- Lower total cost of ownership
- Higher efficacy (Lumens/watt)
- Broad-spectrum, high CRI (HID)
- Long lifetime (15k hours)
- Dimmable (fluorescent)

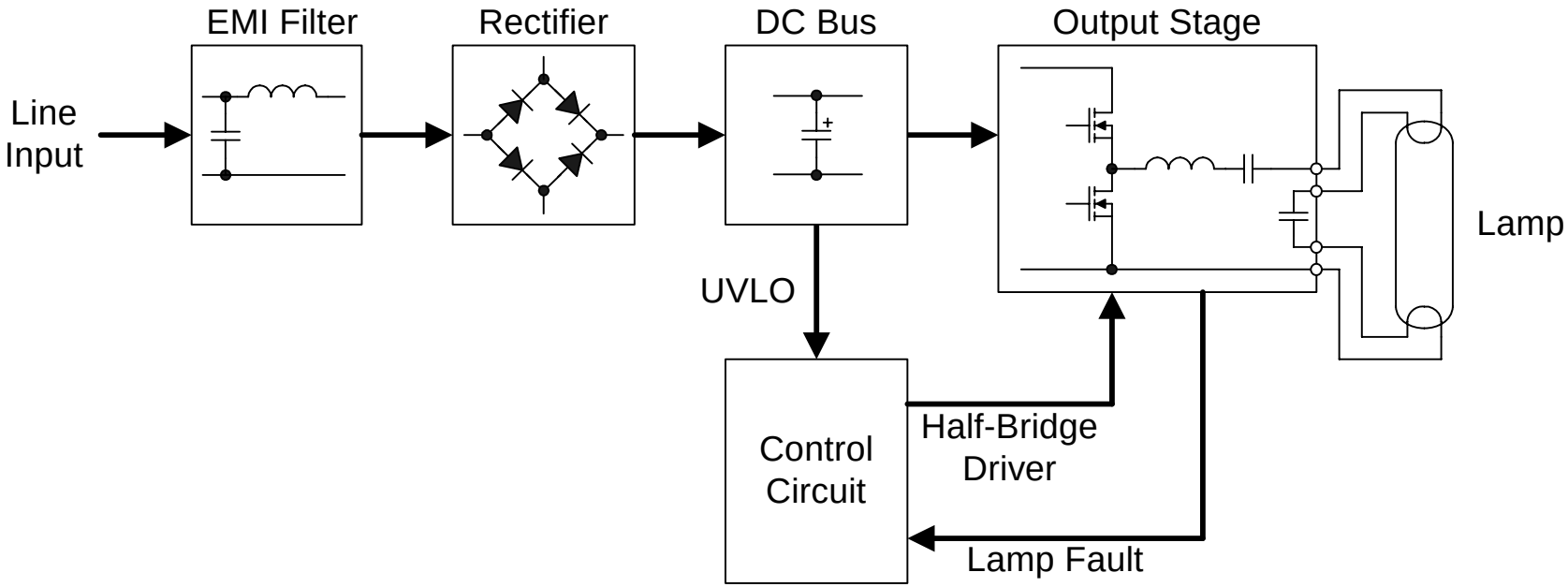
Disadvantages

- Higher initial cost
- Requires ballast for operation
- Narrow spectrum, lower CRI (most fluorescent)
- Long warmup time (HID)
- Disposal/recycling issues

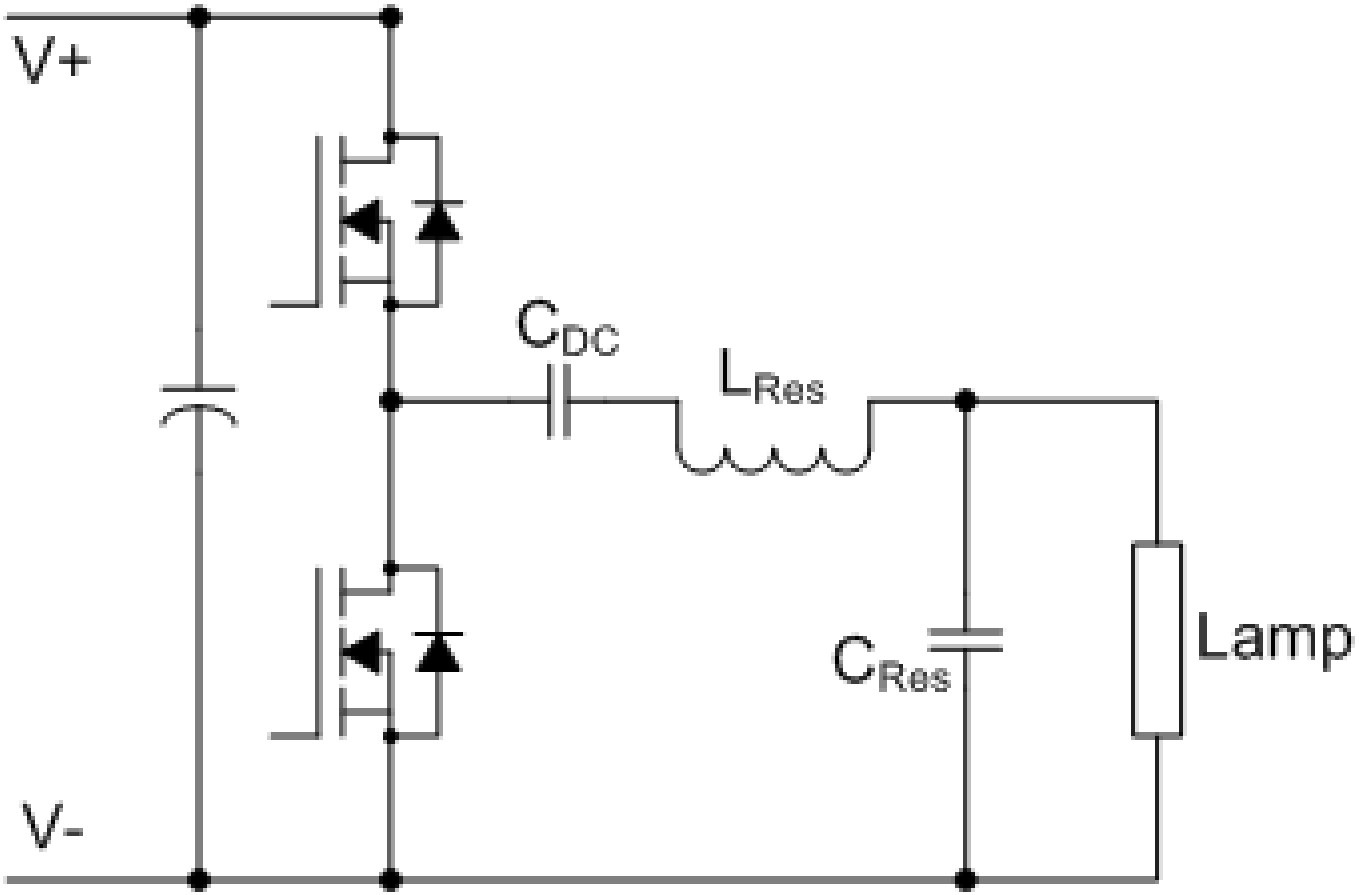
Fluorescent Lamp Operating Modes



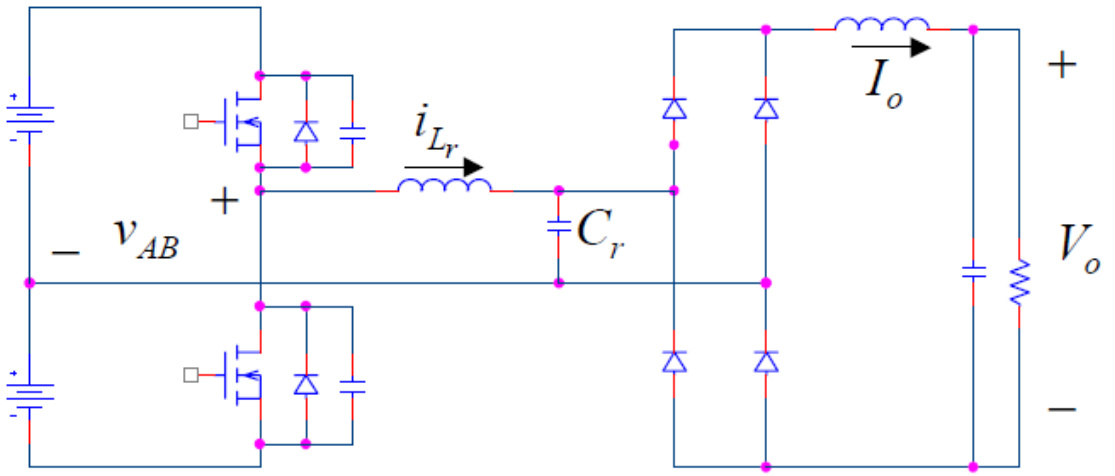
Simple Ballast Block Diagram

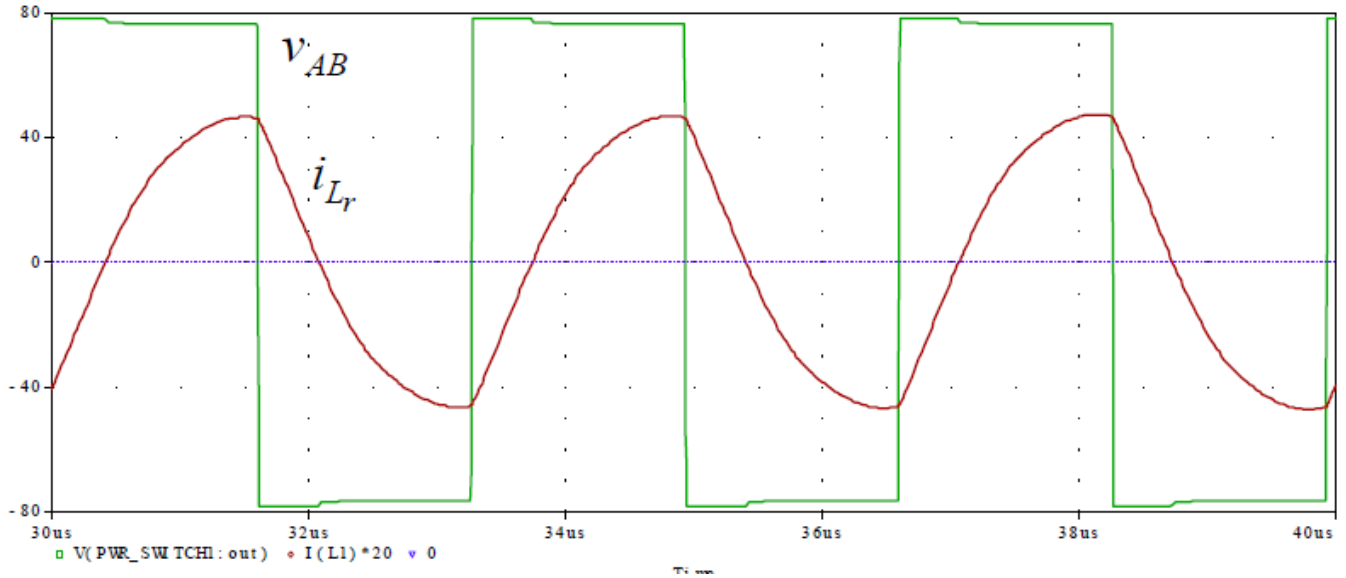


Power stage - resonant LC Circuit

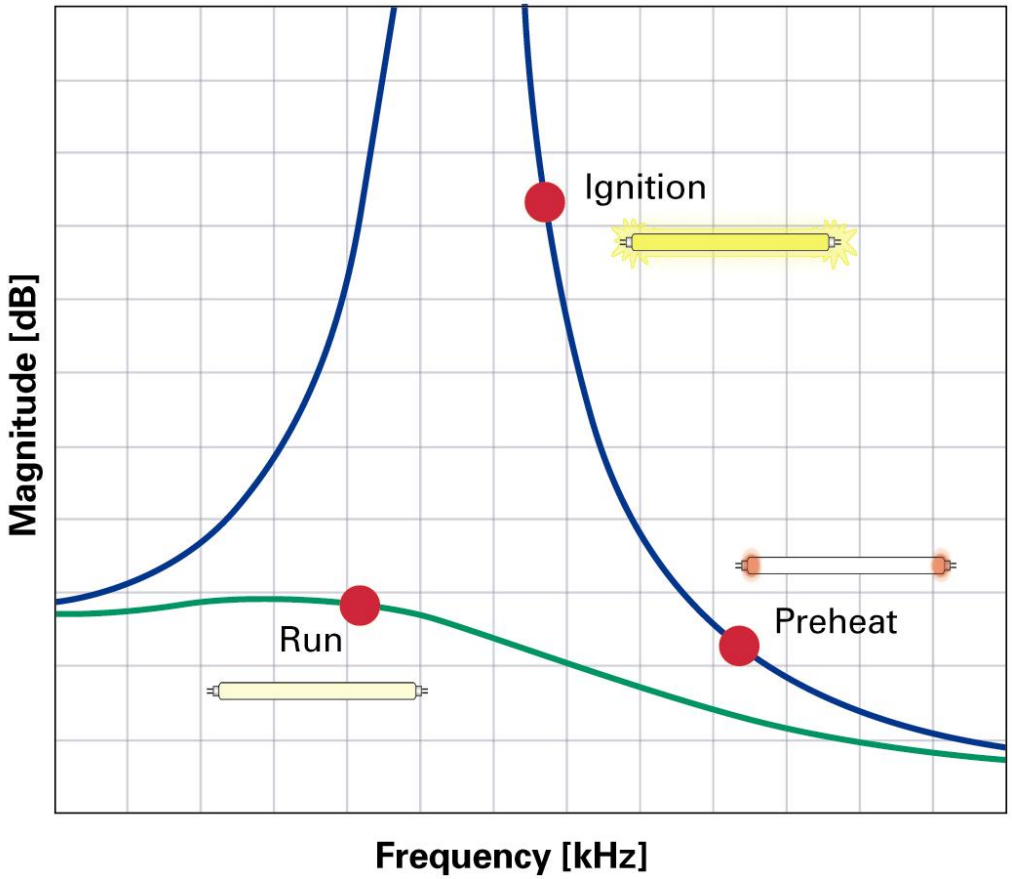


Parallel Resonant, Above Resonance





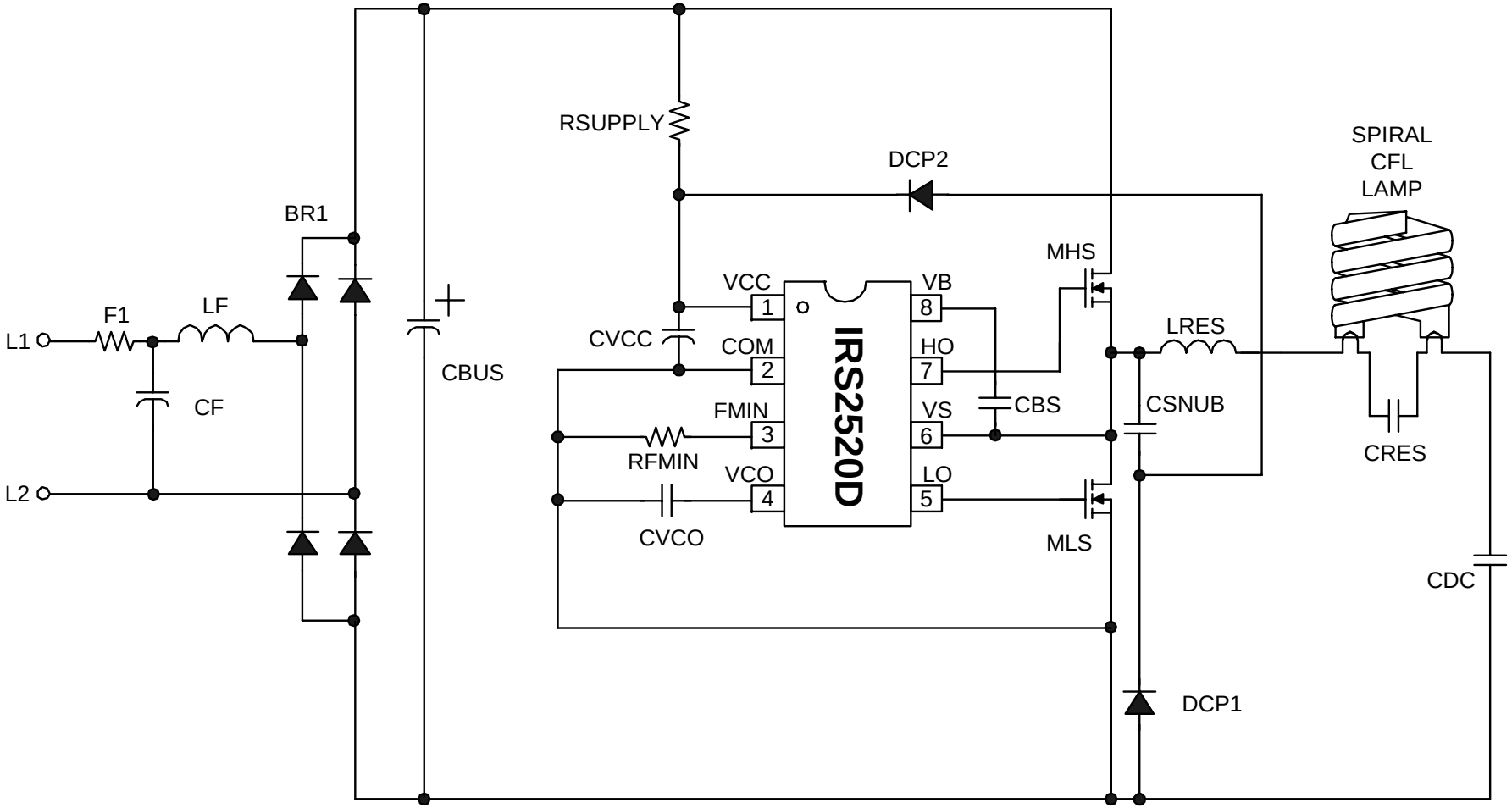
Frequency Controls V, I



Design Constraints

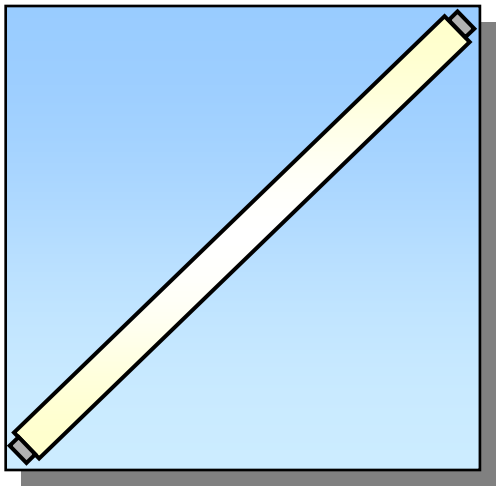
- $f_{RUN} \geq 42KH_Z$ (infrared)
- $f_{PH} - f_{IGN} \geq 10KH_z$ (tolerances)
- $V_{PH} \leq V_{PH_{MAX}}$ (ignition during preheat)
- $I_{IGN} \leq I_{MAX}$ (component ratings)

CFL Ballast Typical Schematic



Typical Design Procedure for Ballast

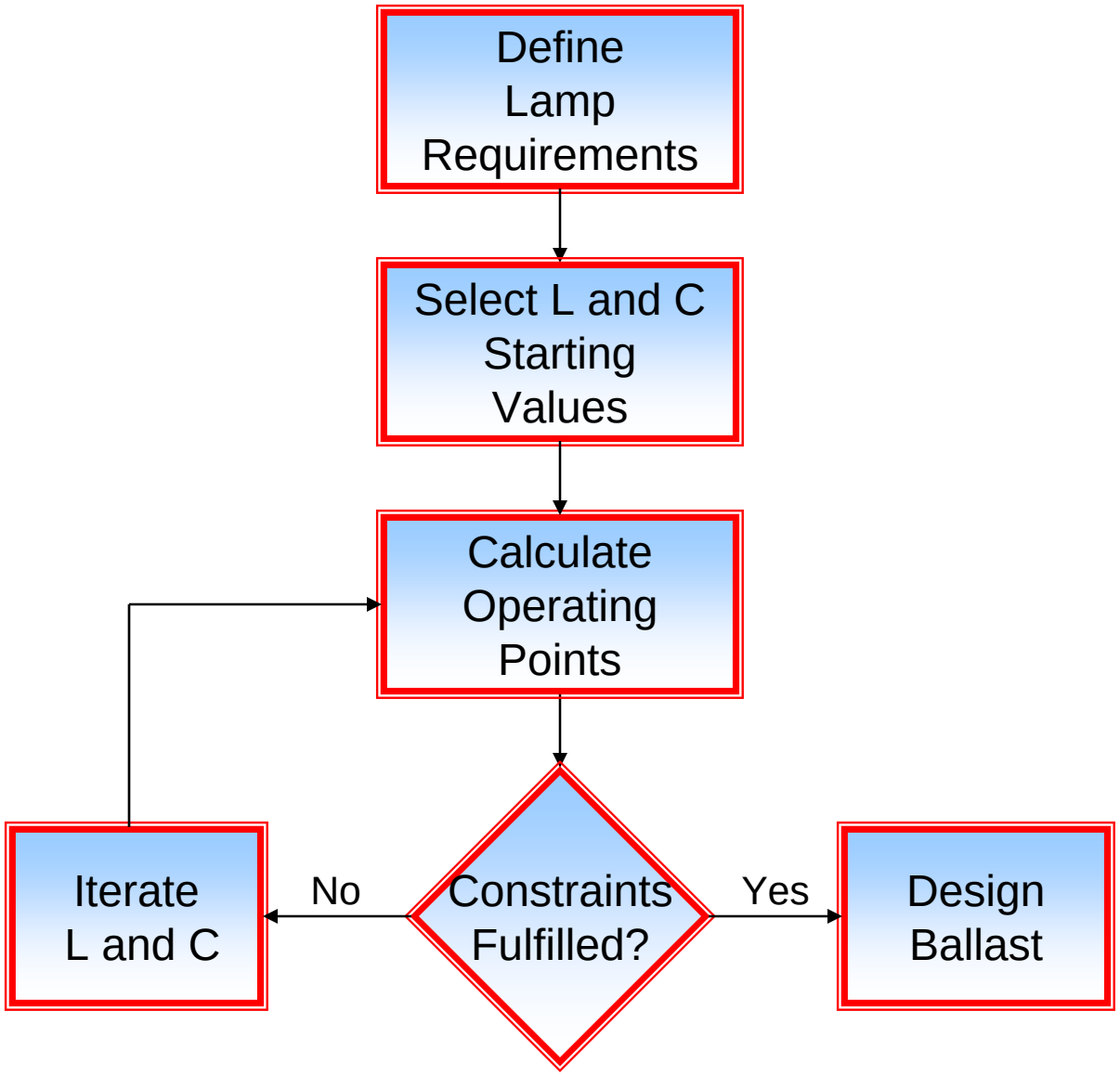
Begin with lamp requirements



Lamp Type: 36W/T8

• Preheat Current:	0.6	[A]
• Preheat Time:	2	[sec]
• Max Preheat Voltage:	600	[Vpp]
• Ignition Voltage:	1500	[Vpp]
• Running Lamp Power:	34	[W]
• Running Lamp Voltage:	141	[Vpk]

Select Resonant L and C



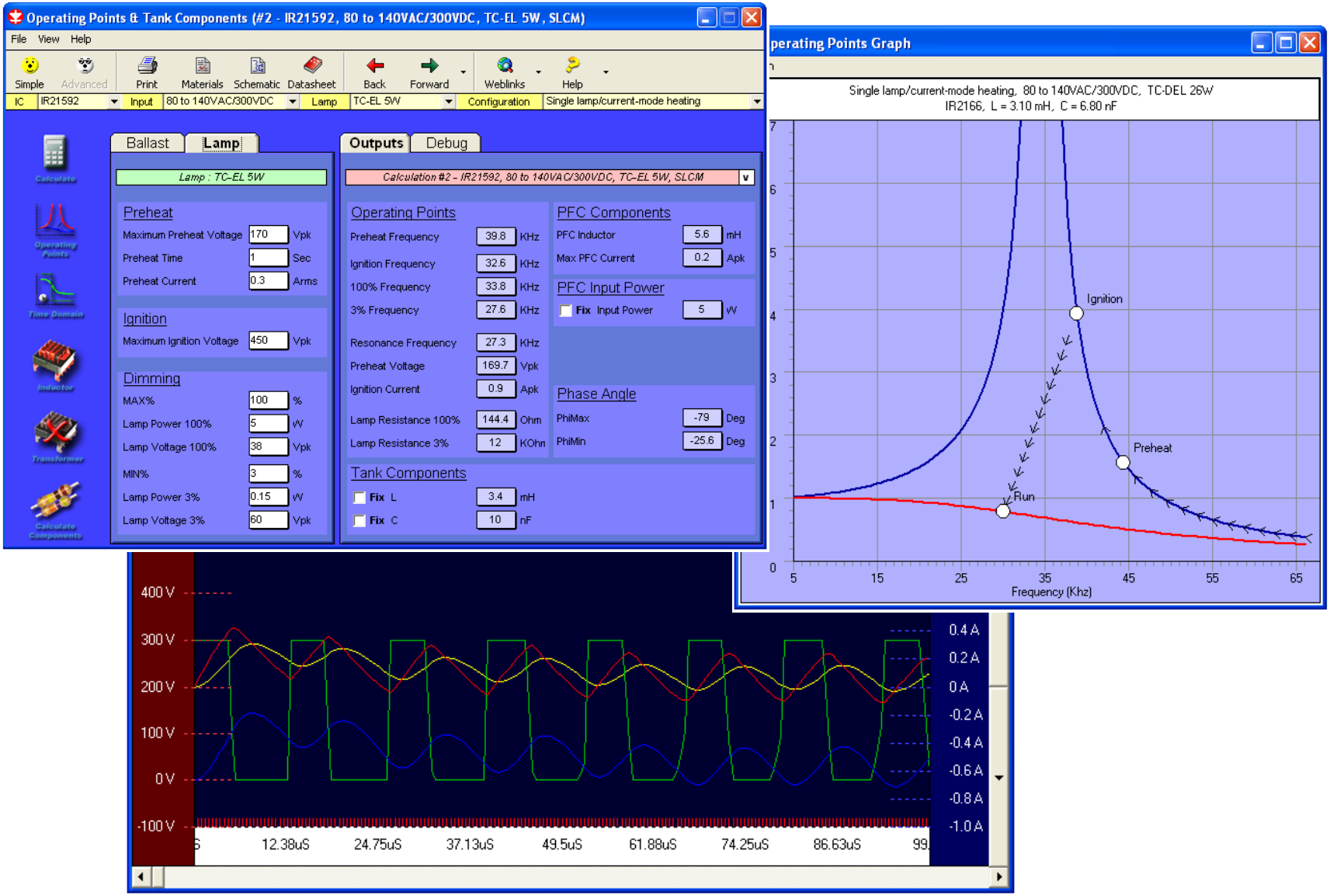
Spreadsheet Method

L and C selection example for linear lamp:

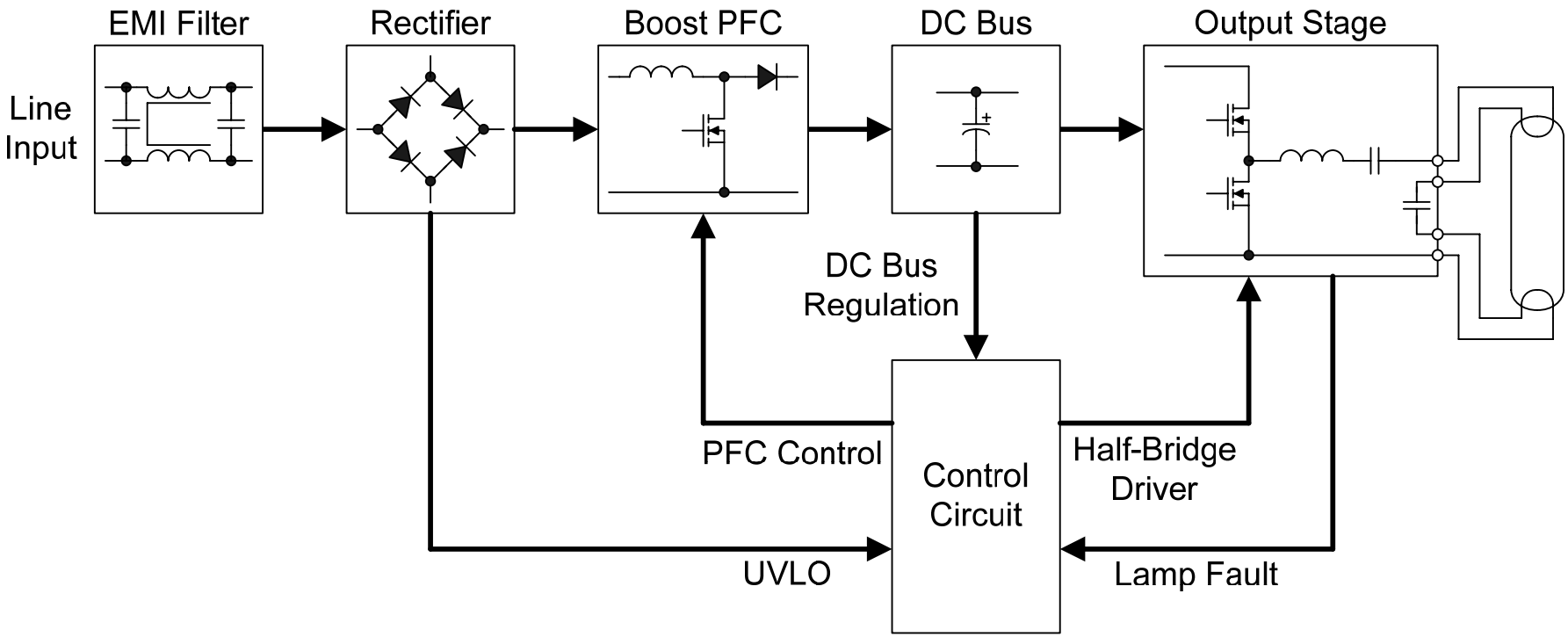
Lamp Type = T8/36W, P_{RUN} = 32W, V_{RUN} = 141 Vpk, V_{PHMAX} = 300 Vpk, I_{PH} = 0.6 Arms, and V_{IGN} = 600 Vpk.

Inputs		Outputs				
L (H)	C (F)	I_{IGN} (Apk)	f_{PH} (KHz)	f_{IGN} (KHz)	f_{RUN} (KHz)	V_{PH} (Vpk)
0.002	3.3E -9	0.9	75	74	43	545
0.002	6.8E -9	1.3	57	52	45	350
0.002	1.0E -8	1.6	49	42	43	273
0.002	1.5E -8	2.0	43	35	39	208

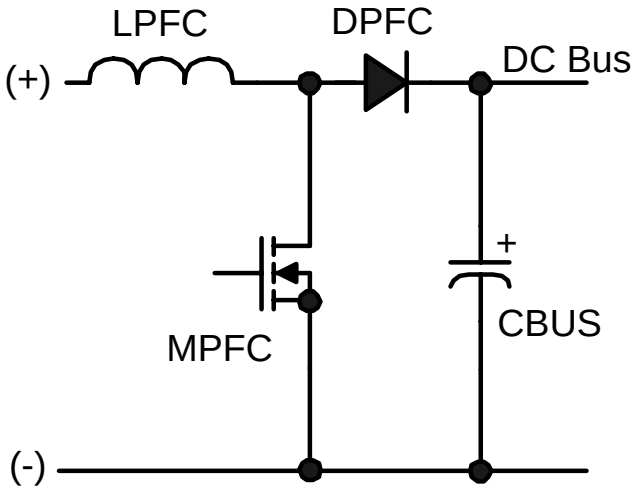
Ballast Design Assistant Software



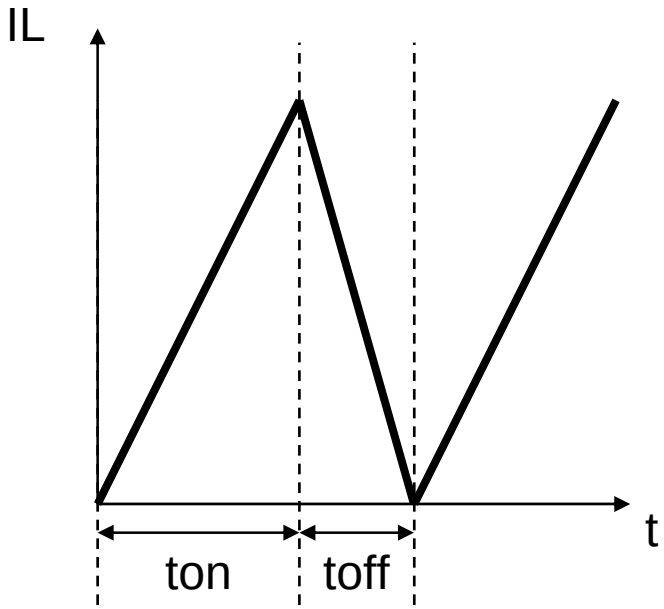
Adding Power Factor Correction



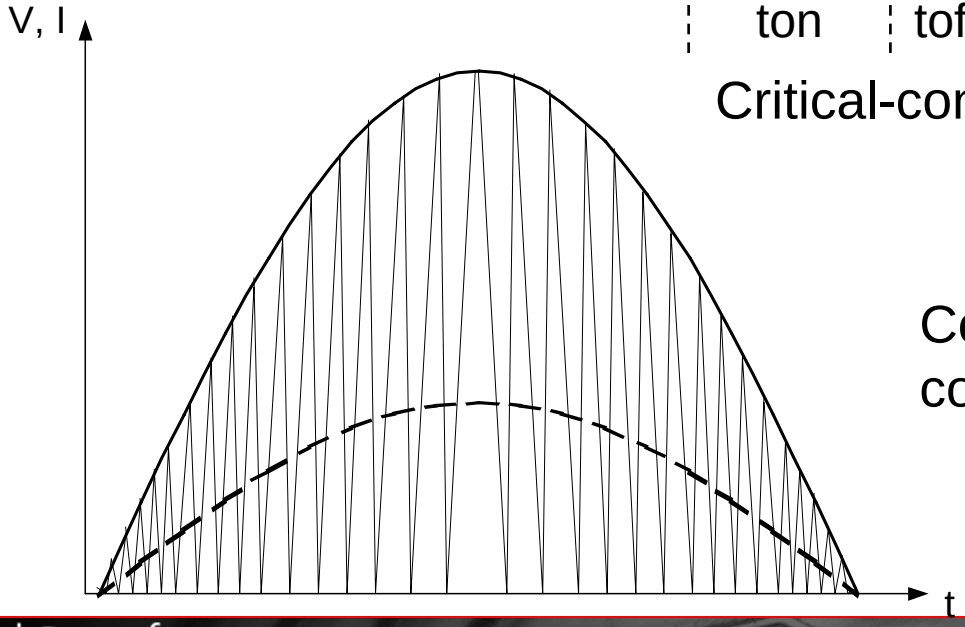
CrCM boost-mode PFC commonly used



Boost Converter

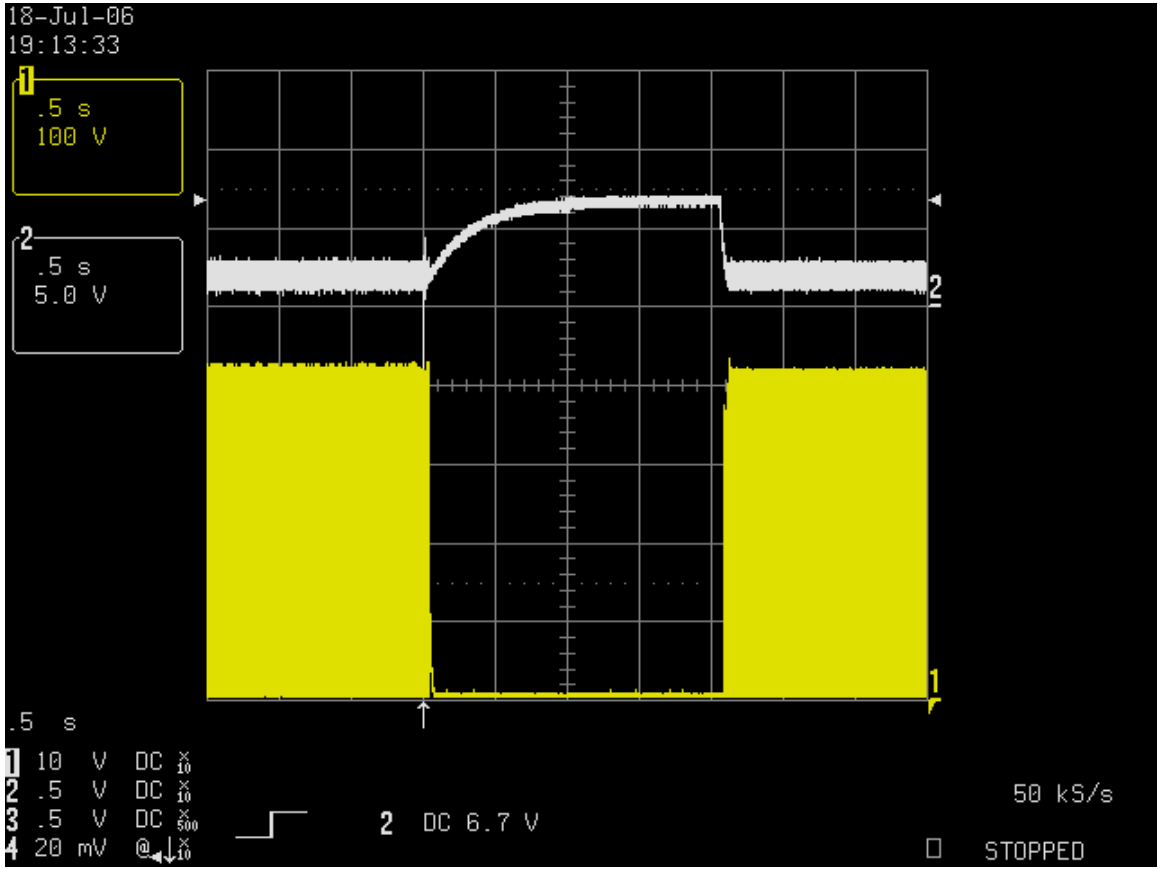


Critical-conduction Mode (CrCM)

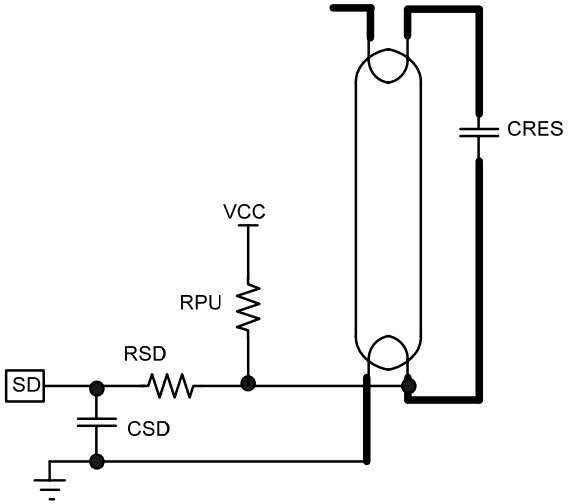


Constant on-time control

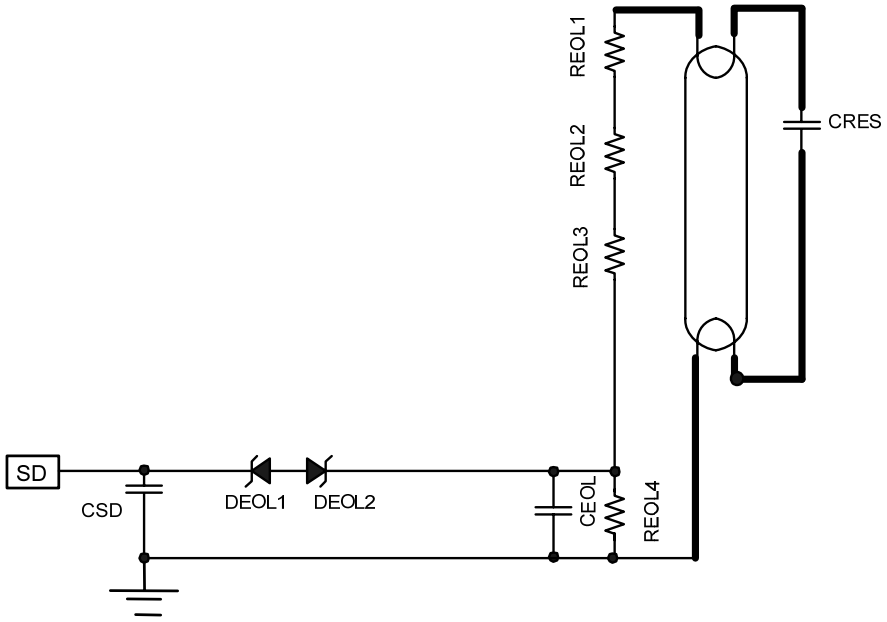
Advanced protection – lamp out circuit

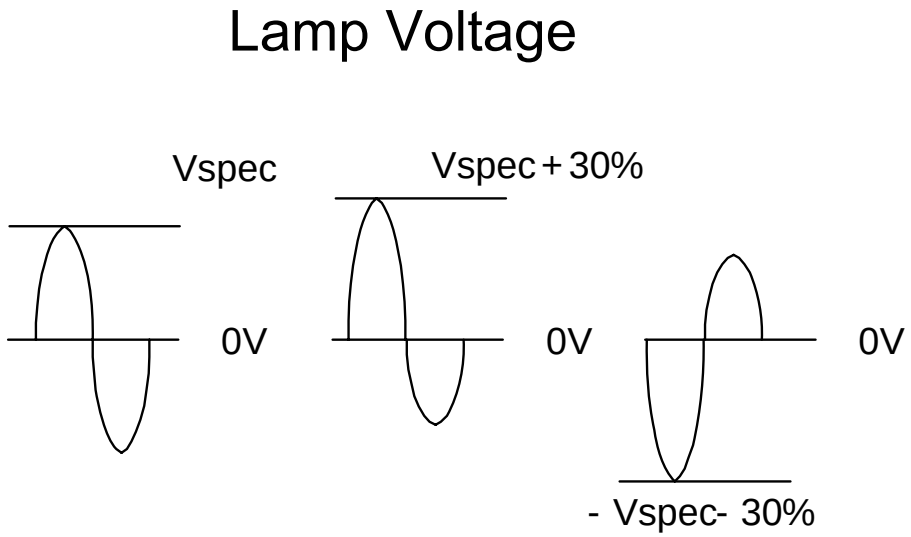


SD pin (upper) and half-bridge voltage (lower) during lamp out/re-insert condition



End-of-life detection - protection

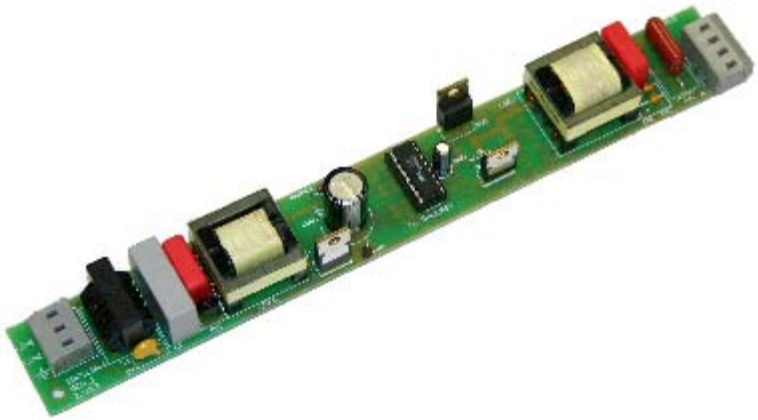




Vspec = VpK in the spec of the lamp

The SD pin is internally biased at 2V. During end of life the lamp voltage will increase asymmetrically (DC end of life). The voltage offset sensed at the top of REOL4 will increase and one of the Zeners will turn on, therefore triggering the shutdown.

Example Ballasts



Summary

- Gas-discharge (Fluorescent) lamps offer:
  - Improved efficacy (lumens/watt)
  - Lower total operating cost
  - Better CRI lowers light output
- Ballast is necessary to operate lamp
- Ballast operates ZVS to minimize switching loss
- Ballast controls frequency to adjust lamp current
- Ballast self protects by shutdown when lamp misbehaves