# Infineon New CCM PFC Solution ICE3PCS01G

Willion Chen

ASIC & Power IC

System Application Engineer

# Outline

## Infineon CCM PFC family

- 3rd Generation Infineon CCM PFC
  - Features
  - Functionality
  - 300Watt demo board results


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# Infineon CCM PFC controller History

**2010** — ICE3PCS01G

- **Improve dynamic response**
- **Efficiency above 95%**
- **Digital control voltage loop**
- **Synchronous frequency**
- **Boost follower mode**
- **Accurate Brownout protection sensing**
- **Lowest internal reference – 2.5V**

**2006** — ICE2PCS0x

- **BiCMOS Technology**
- **Lower internal reference – 5V**

**2003** — ICE1PCS0x

- **First Infineon standalone CCM PFC**
- **Adjustable gate switching frequency**
- **Brownout protection**


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# Pin Layout ICE3PCS01G

Pin1 =Boost Follower Setting (BOFO)

Pin2 =Current Sense Input (ISENSE)

Pin3 =Signal Ground (SGND)

Pin4 =Current Loop Compensation (ICOMP)

Pin5 =Switching Frequency Setting (FREQ)

Pin6 =Bulk Voltage OK Signal

Pin7 =PFC Enable Function (VBTHL_EN)

Pin8 =Voltage reference (VREF)

Pin9 =Brownout Protection (BOP)

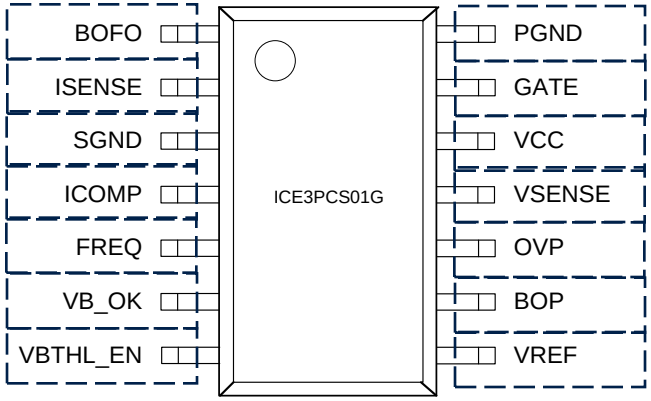
Pin10 =Over Voltage Protection (OVP)

Pin11 =Bulk Voltage Sense (VSENSE)

Pin12 =IC Supply Voltage (VCC)

Pin13 =Gate Drive (GATE)

Pin14 =Power Ground (PGND)





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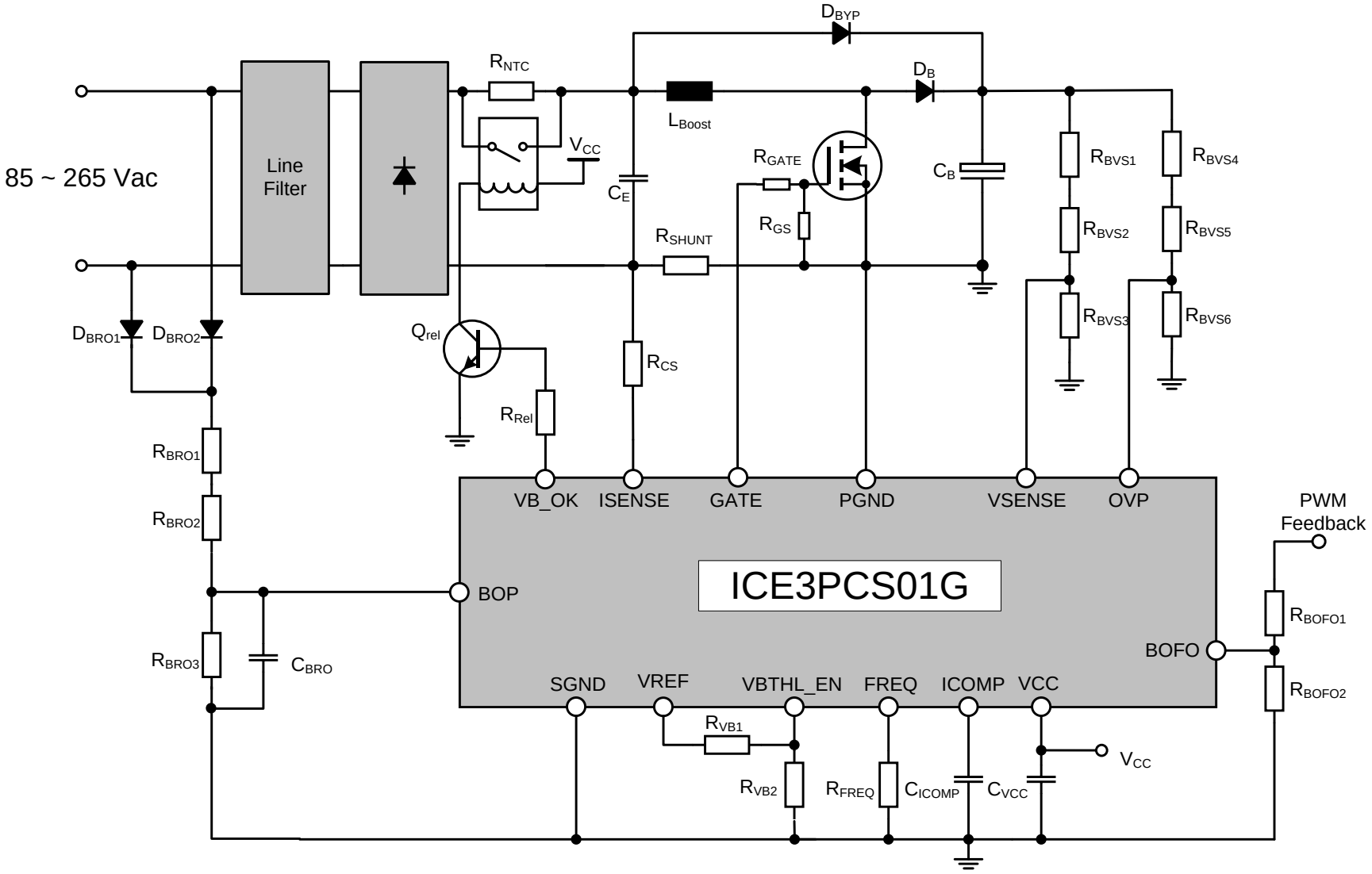
# Typical Application Circuit





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# Outline

- Power Factor Correction Continuous Conduction Mode Converter
- Infineon CCM PFC family
- 3rd Generation Infineon CCM PFC
  - Features
  - Functionality
  - 300Watt Demoboard results


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# ICE3PCS0xG
## Key Features

- Low Peak Current Limit (0.2V)
- Average current control without direct sinewave reference signal sensing
- Adjustable operating frequency (20kHz - 250kHz)
- Synchronous frequency (50kHz – 150kHz)
- Boost Follower Mode with adjustable bulk voltage at low step
- Accurate Brown Out protection
- Second Over Voltage protection (OVP2)
- PFC enable function
- Enhanced dynamic response without current distortion
- Digital Control Voltage Loop
- Simple and easy design with very few external components reduces system and assembling cost.
- Supports the trends: High efficiency, High power factor, High Power Density and Low System Cost
- Target Applications: PC, Server, TV, gaming console, Adapter


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# Outline

- Power Factor Correction Continuous Conduction Mode Converter
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  - Features
  - Functionality and 300Watt demo board results


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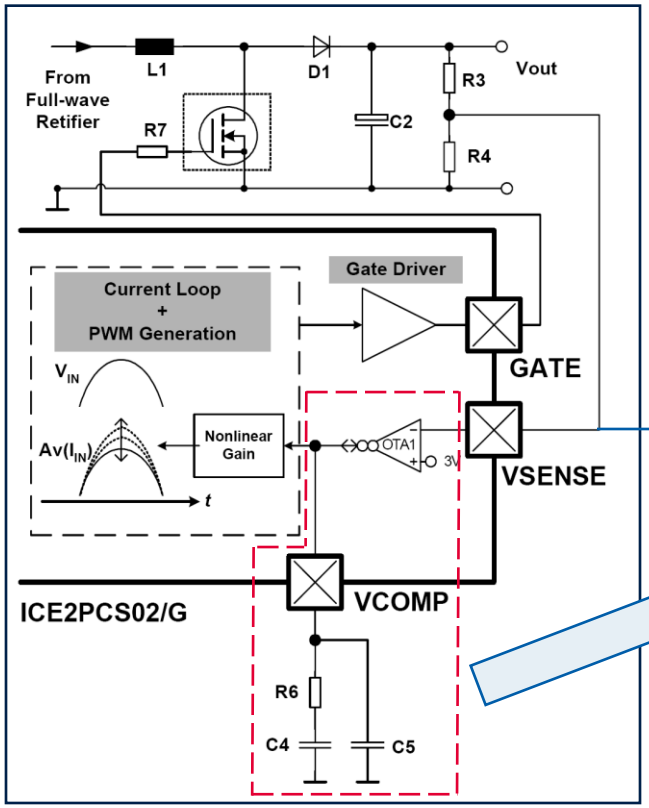
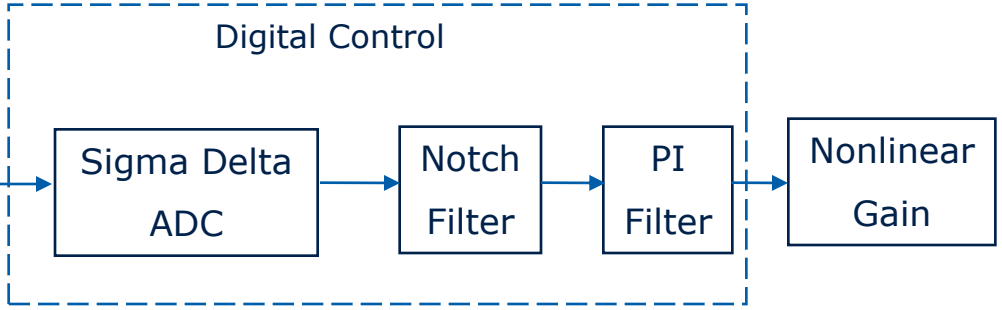
# Voltage Loop Control




- Example of voltage loop compensation for ICE2PCS0X.

ICE3PCS0xG




- Advantage of this concept:
  - Input current distortion during load jump is significantly reduced
  - The voltage drop during load jump is reduced and allow bulk capacitor size reduced.
  - The external pin (e.g. VCOMP) for adjusting the control bandwith is not needed.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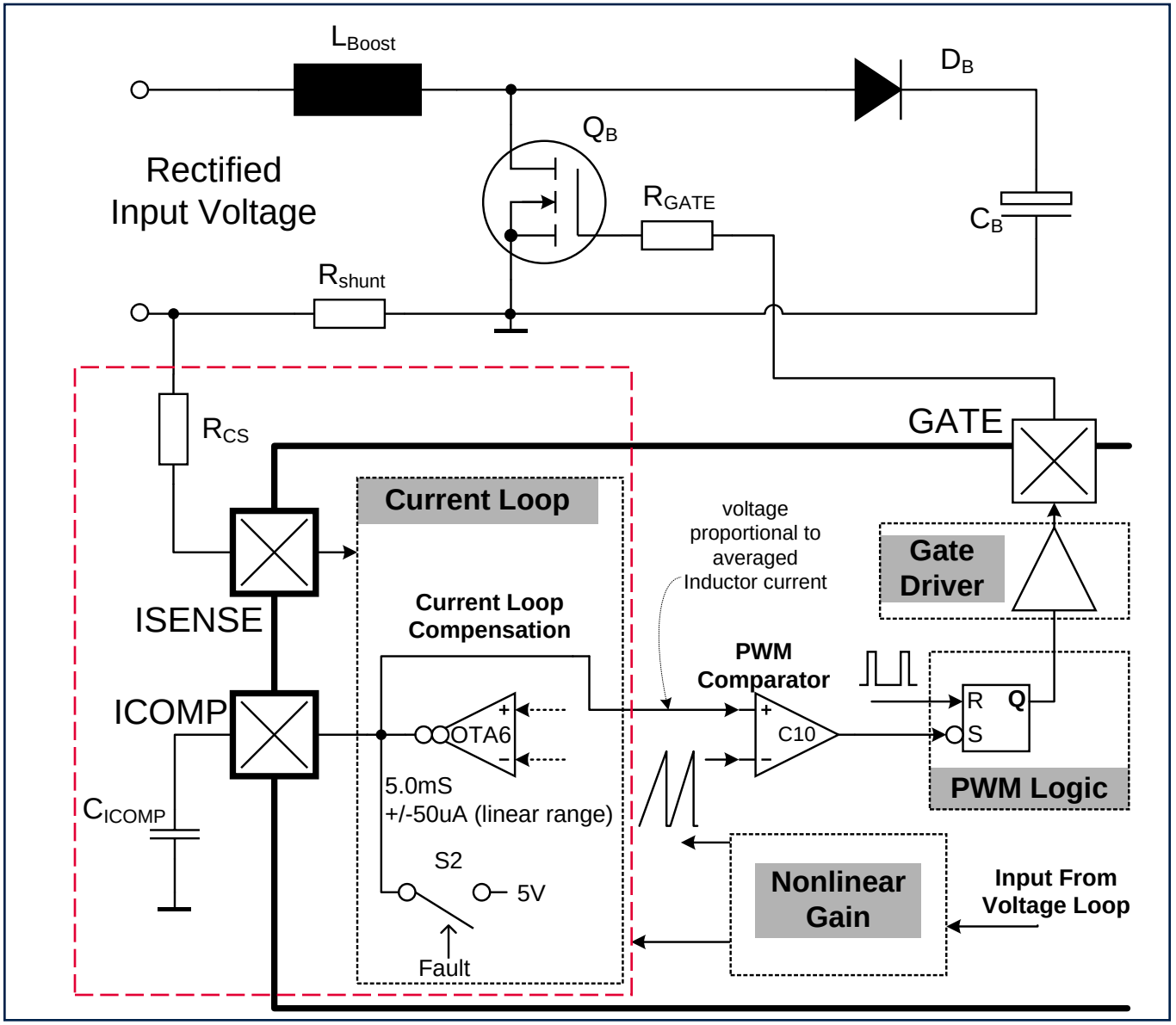
# Current Loop





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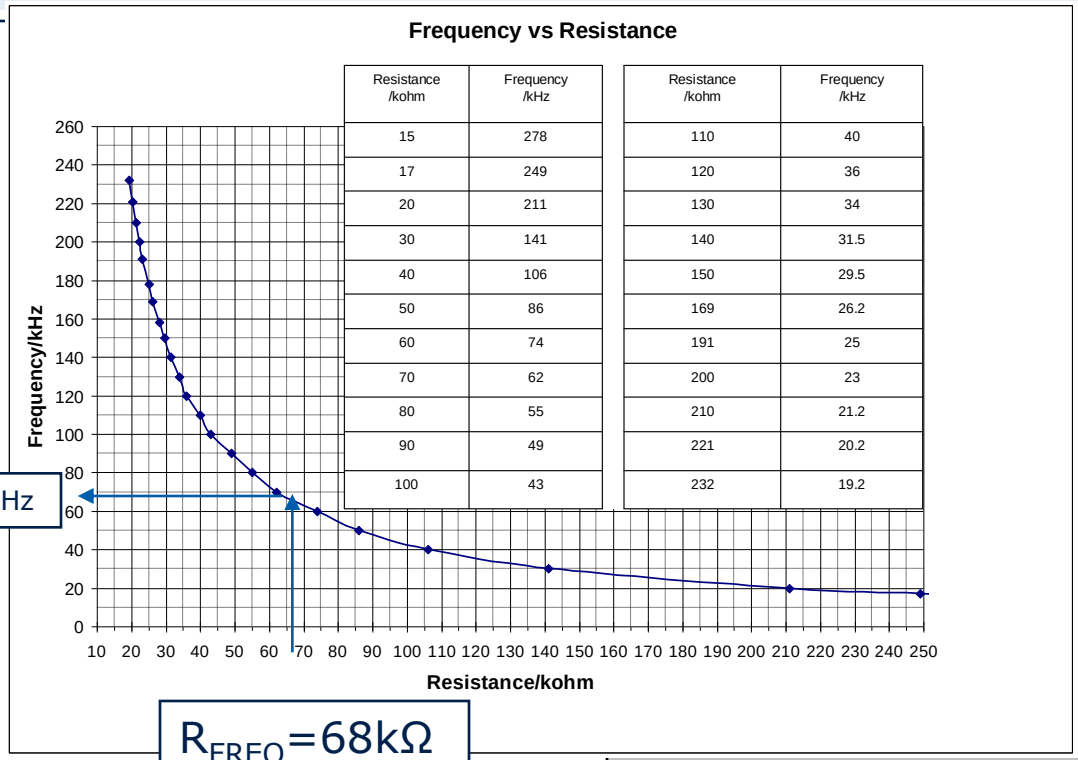
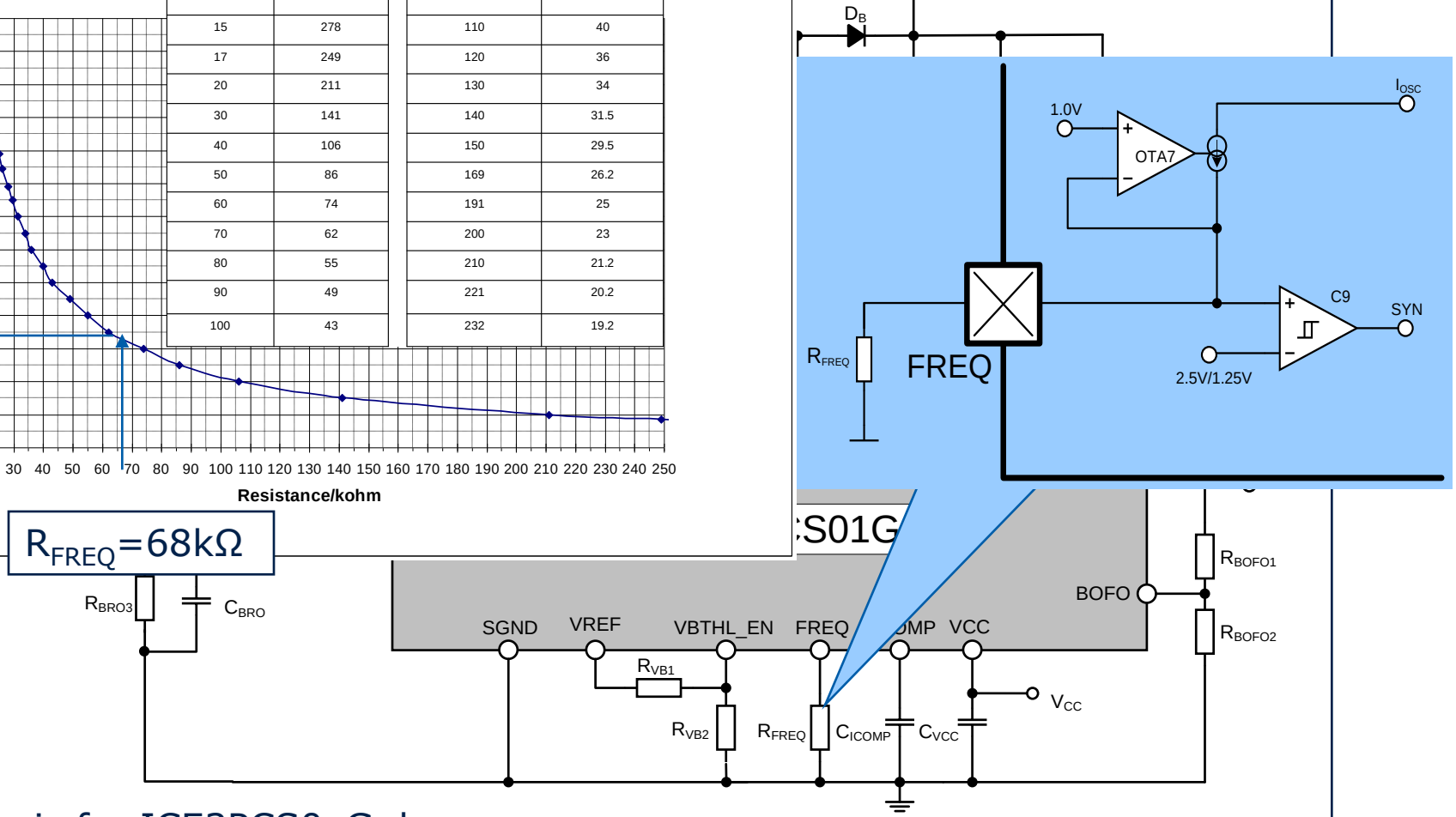
# Adjustable Switching Frequency




| Resistance /kohm | Frequency /kHz | Resistance /kohm | Frequency /kHz |
|---|---|---|---|
| 15 | 278 | 110 | 40 |
| 17 | 249 | 120 | 36 |
| 20 | 211 | 130 | 34 |
| 30 | 141 | 140 | 31.5 |
| 40 | 106 | 150 | 29.5 |
| 50 | 86 | 169 | 26.2 |
| 60 | 74 | 191 | 25 |
| 70 | 62 | 200 | 23 |
| 80 | 55 | 210 | 21.2 |
| 90 | 49 | 221 | 20.2 |
| 100 | 43 | 232 | 19.2 |




- $R_{FREQ}$ is for ICE3PCS0xG demo board is set at 68kΩ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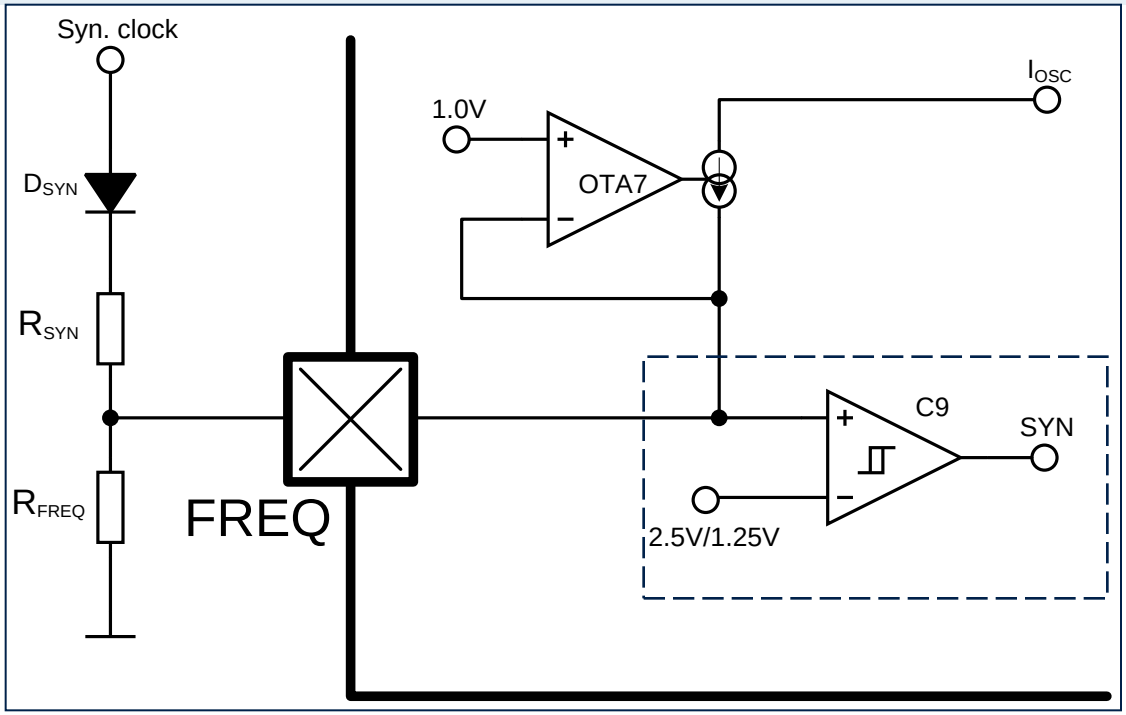
# Gate Synchronisation




- Switching frequency can be synchronized to external pulse signal after 6 external pulses delay once the voltage at FREQ pin is higher than 2.5V.
- The IC will only synchronize with external signal frequency between 50kHz to 150kHz and the duty on should be within 10% to 70%.
- During synchronization, the IC is able to track with external changing frequency.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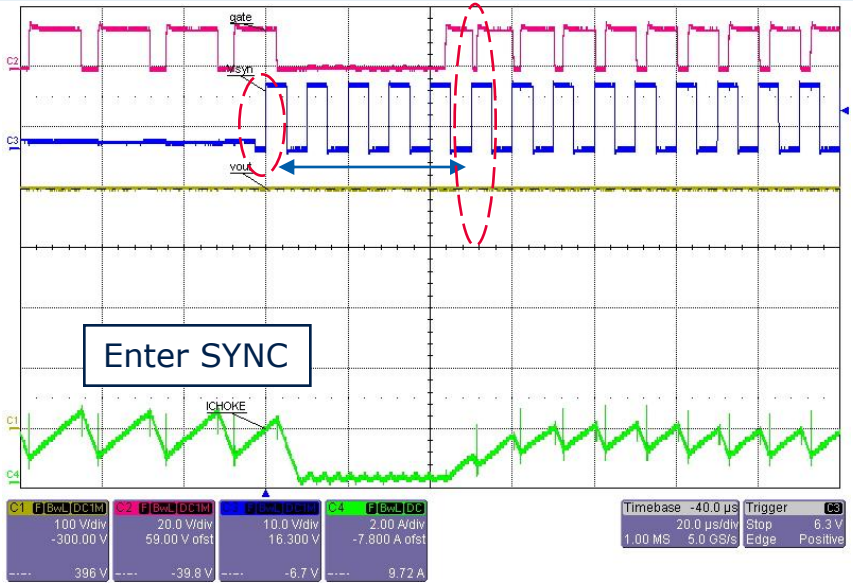
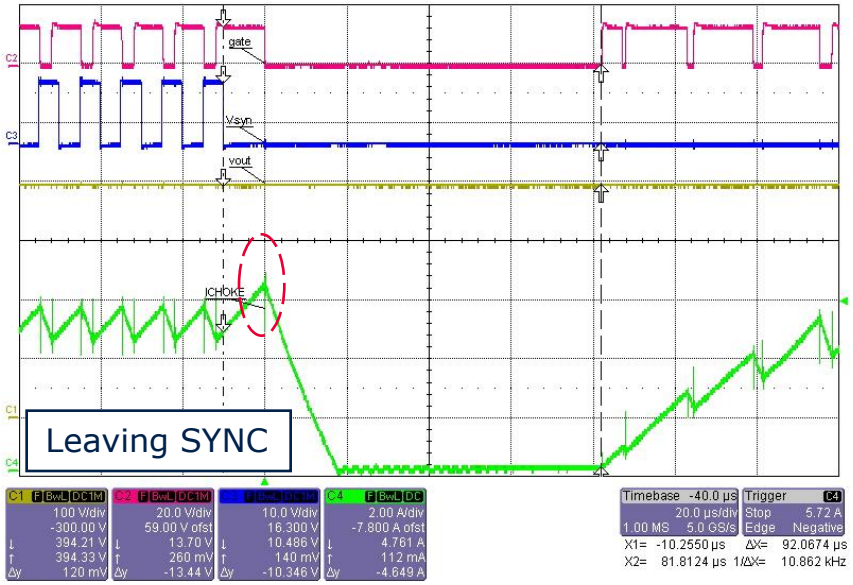
# Gate Synchronisation




Legend:

| | |
|---|---|
| RED | =Gate |
| Blue | =External Synchronous Signal |
| Yellow | =Bulk Voltage |
| Green | =Choke Current |

- External signal detect when voltage at FREQ pin higher than 2.5V
- Gate will sync with external signal within 6 pulses.
- Falling edge of IC's gate signal is in phase with external signal's rising edge.
- When external signal at pin FREQ (pin5) is lose, IC will trigger 'Peak Current Limit' because gate will only shut down when it detect a rising edge of the external signal hence the IC gate switching will return to it's original switching frequency which is define by $R_{FREQ}$.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# Protections

- Under Voltage Lock Out (UVLO)
- Brown Out Protection (BOP)
- Open Loop Protection (OLP)
- Peak Current Limit (PCL)
- Over Voltage Protection (OVP1)
- Second Over Voltage Protection (OVP2)
- PFC enable (VBTHL_EN)

ICE2PCS0x

ICE3PCS0xG


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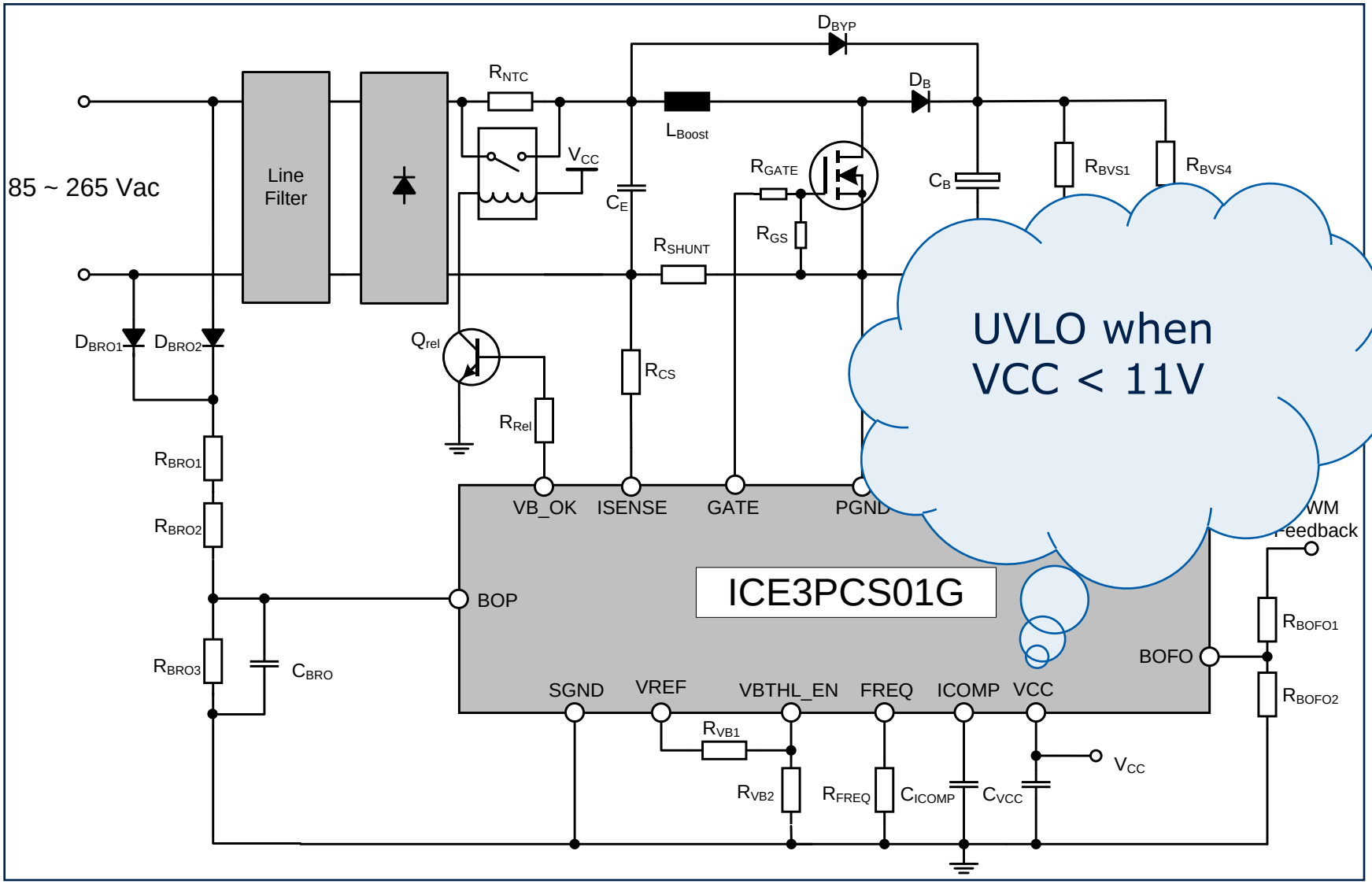
# Under Voltage Lock-Out (UVLO)





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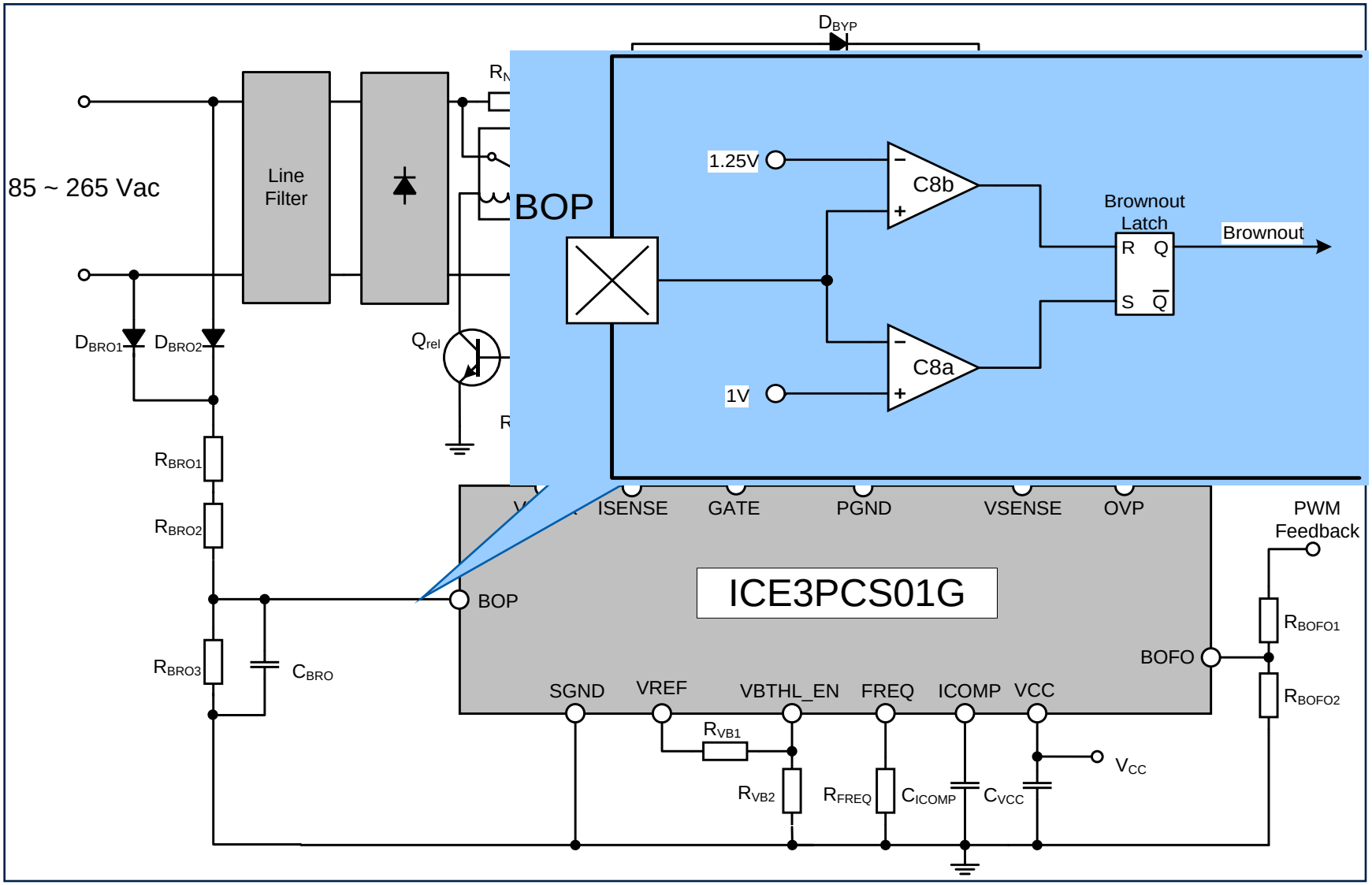
# Brown-Out Protection





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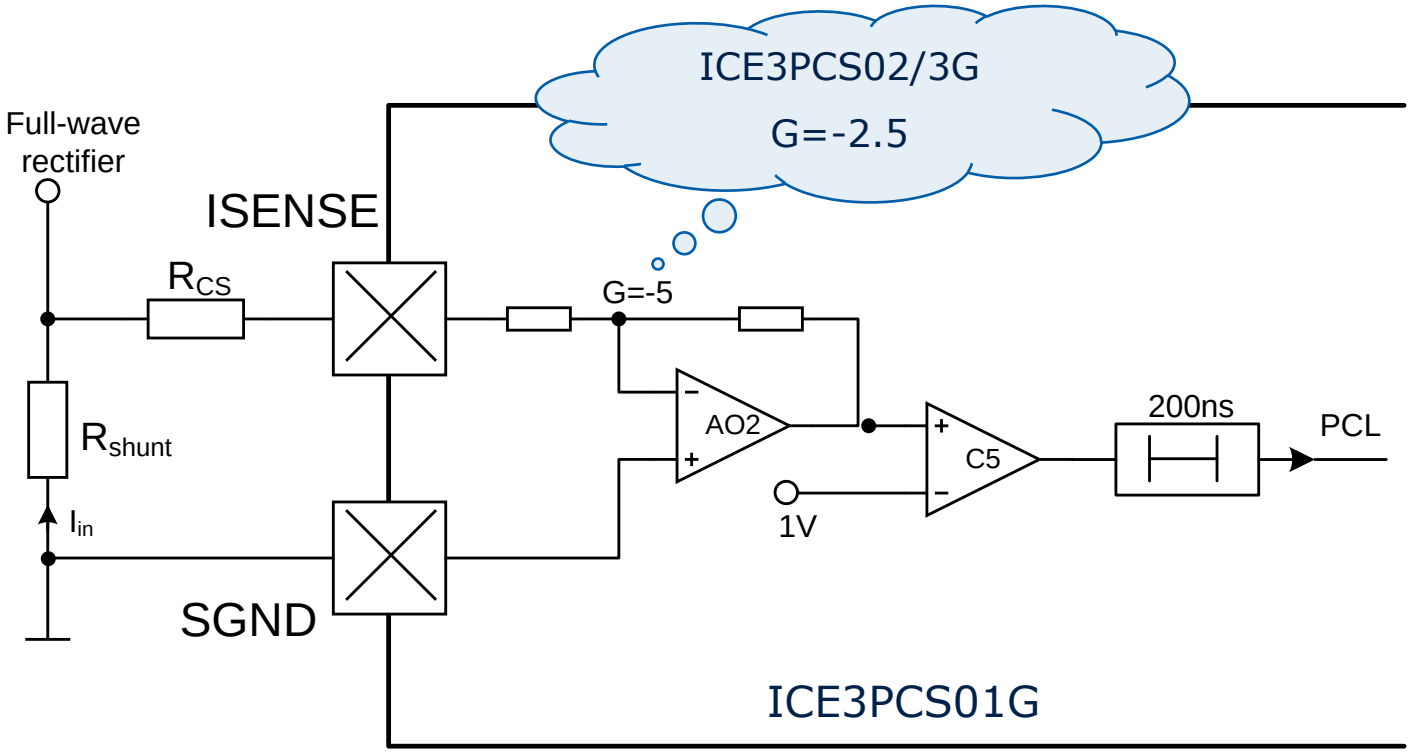
# Low Peak Current Limit Threshold




- Low Peak Current Limit:
  - ICE3PCS01G = -0.2V
  - ICE3PCS02/3G = -0.4V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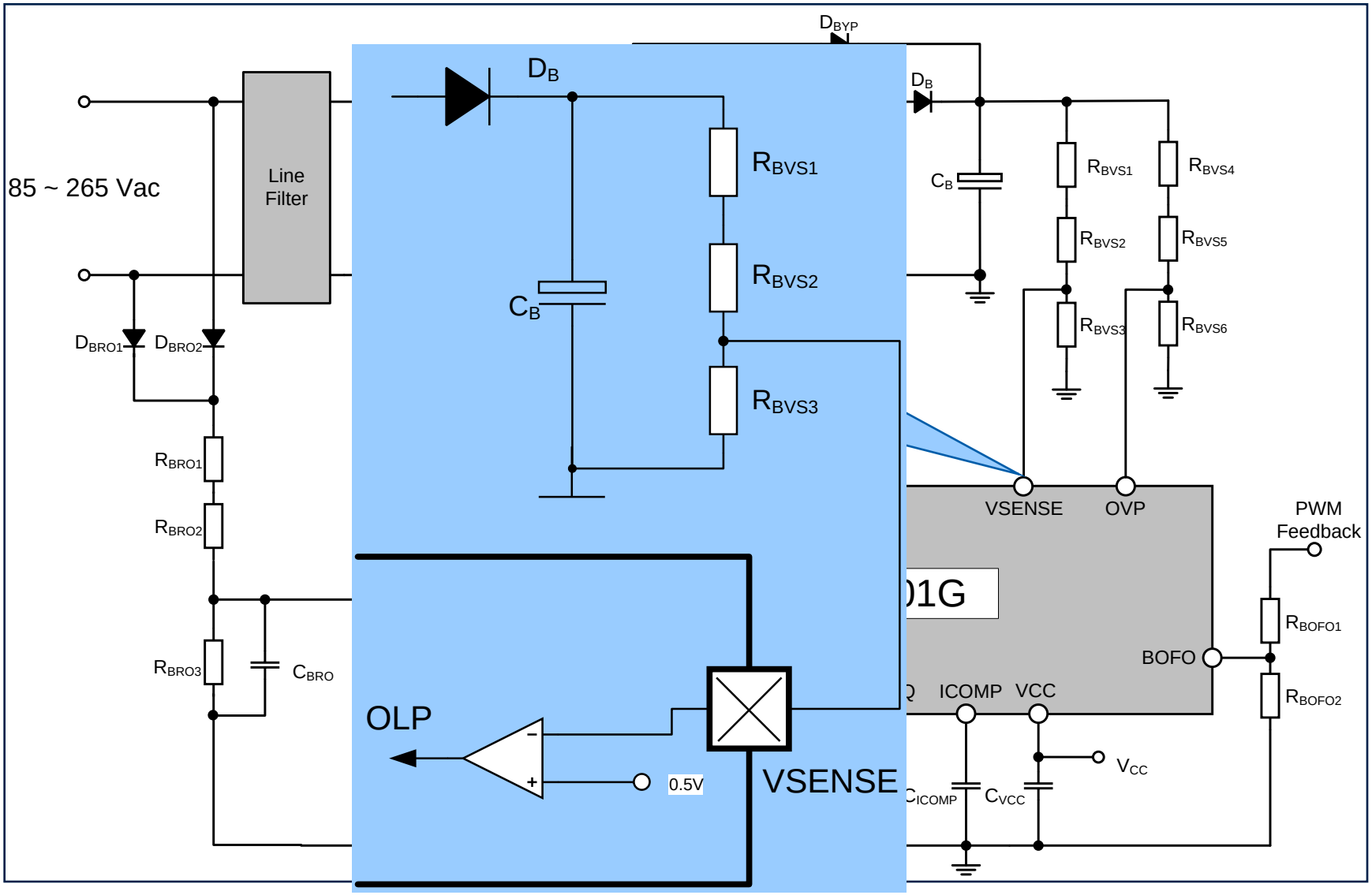
# Open Loop Protection





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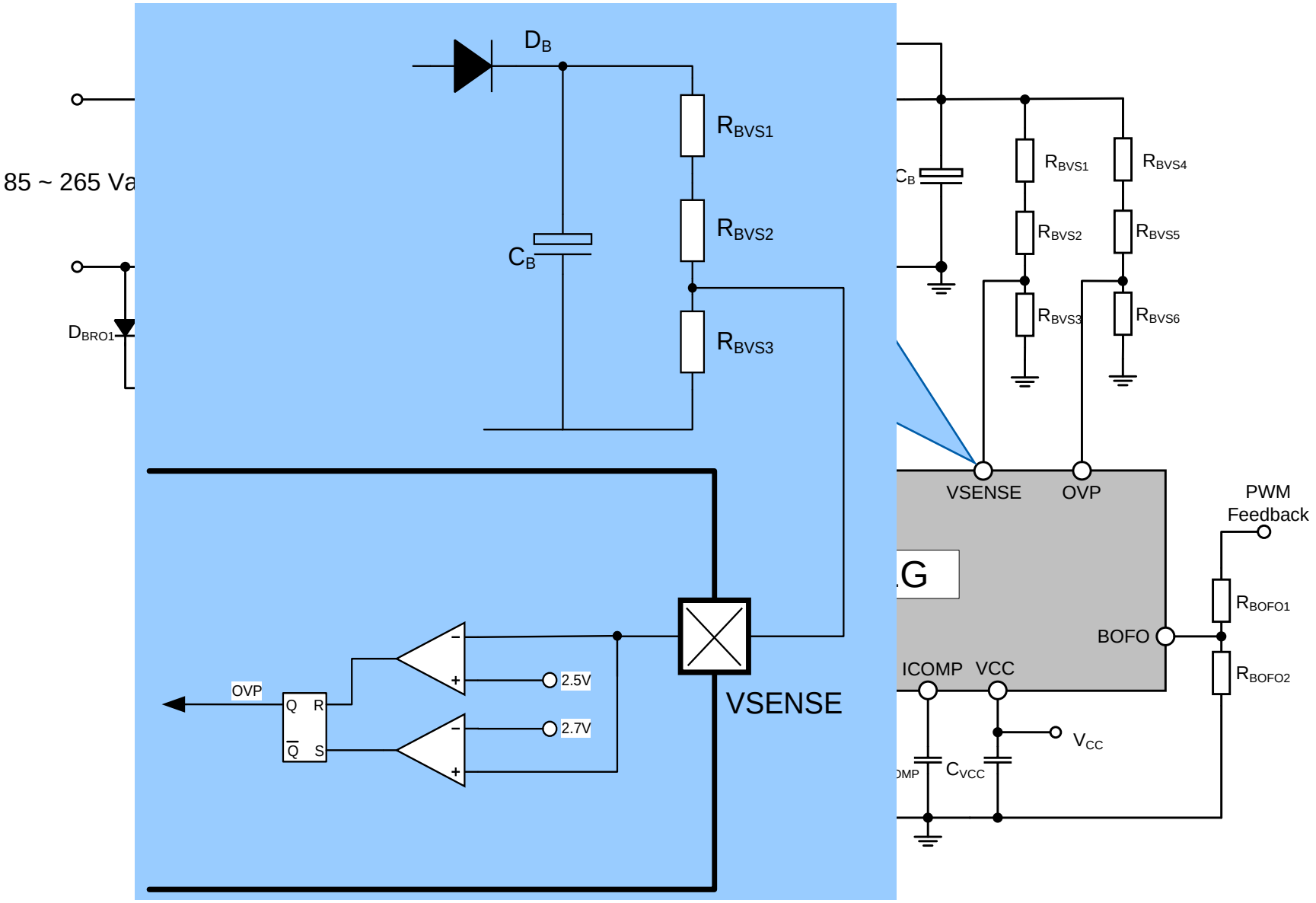
# First Over Voltage Protections (OVP1)





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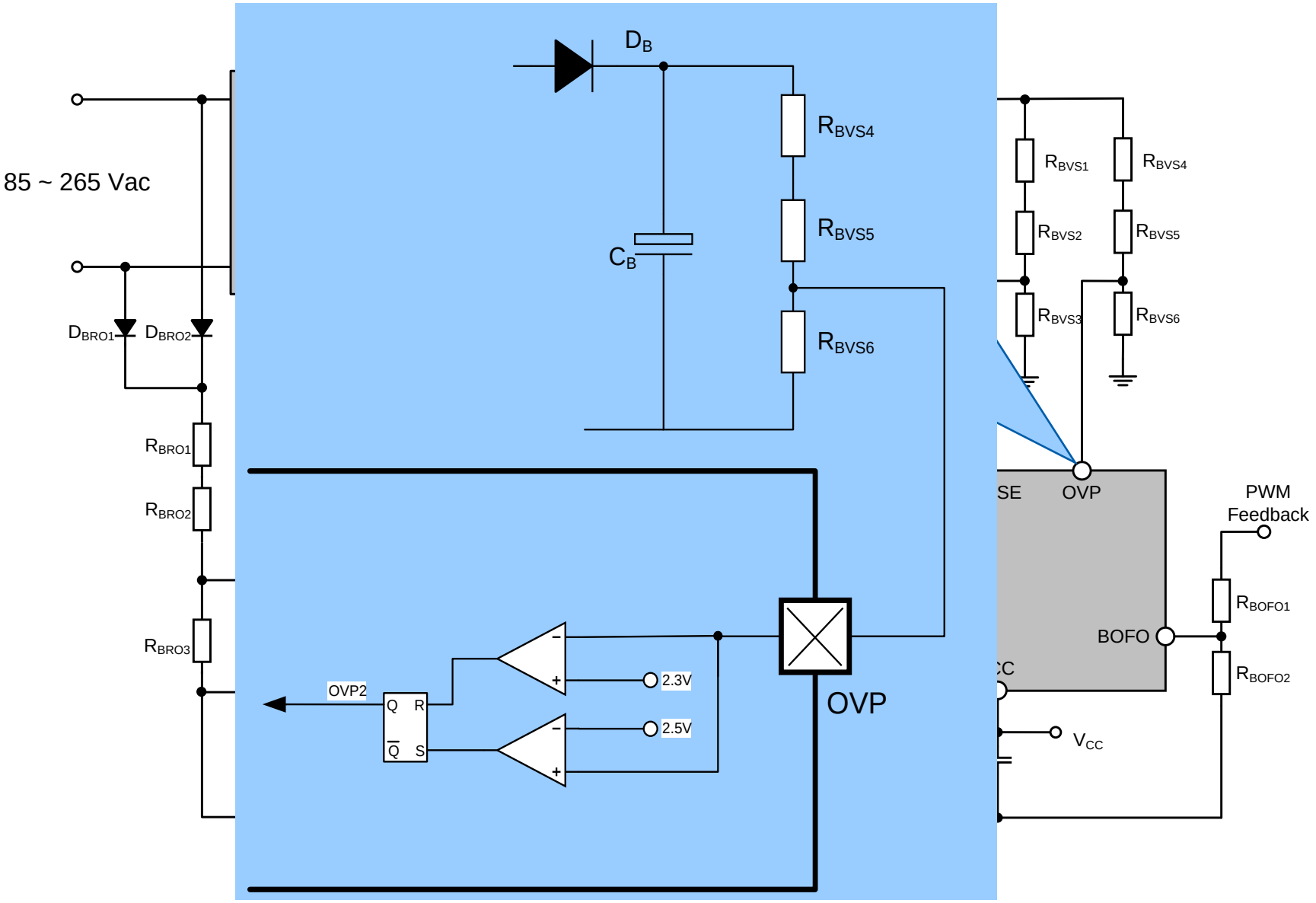
# Second Over Voltage Protections (OVP2)





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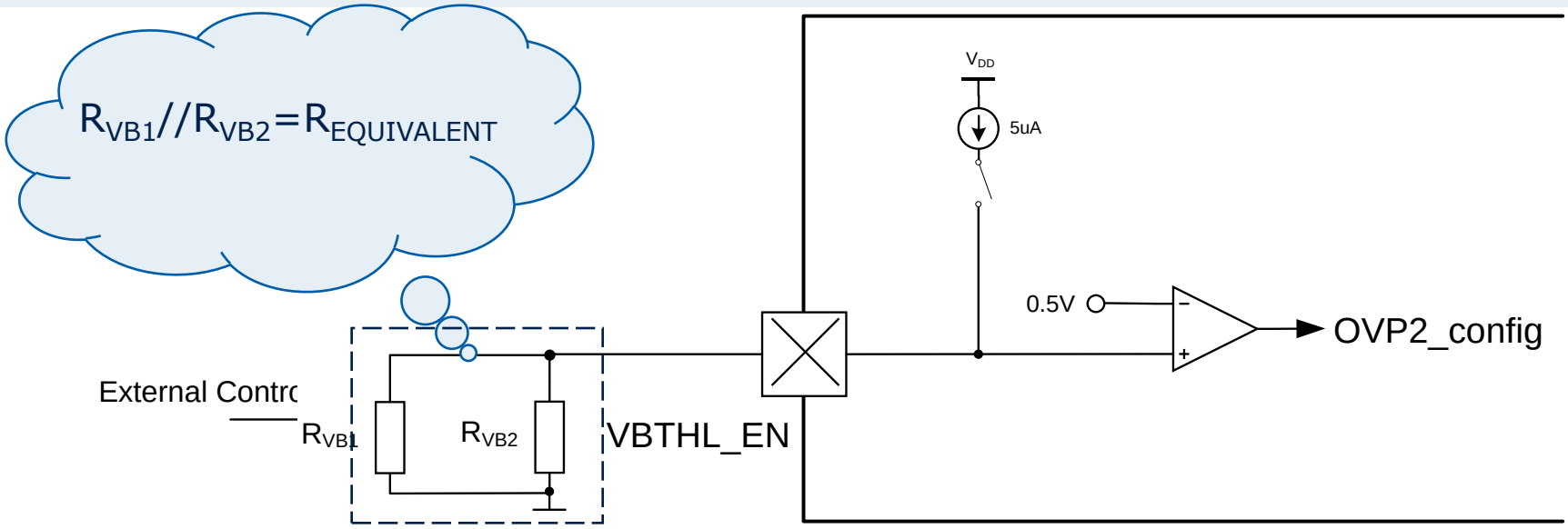
# Mode Selection for Over Voltage Protection 2 (OVP2) – During Start-Up




| Condition | Default Mode (restart) | Alternative Mode (latch) |
|---|---|---|
| | VBTHL_EN < 0.5V ($R_{EQUIVALENT}$<100kΩ) | VBTHL_EN > 0.5V ($R_{EQUIVALENT}$>100kΩ) |
| OVP2 detected | Gate disable<br>The IC auto softstart as soon as OVP2 is not detected anymore | Gate disable<br>IC latched until next UVLO |
| OVP1 detected then OVP2 detected | Gate disable<br>(IC resumes regulation as soon as OVP1 is not detected anymore) | |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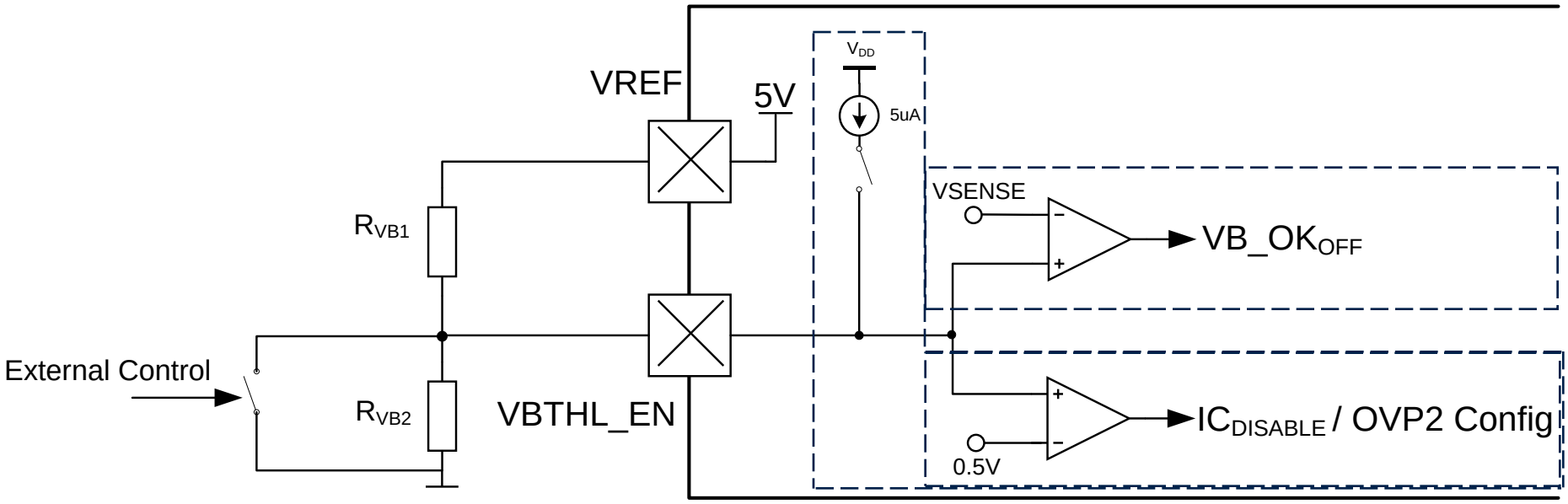
# Pin VBTHL_EN




- Define OVP2 mode
  - Latch Mode
  - Auto restart
- Turn off threshold for VB_OK signal
- PFC enable function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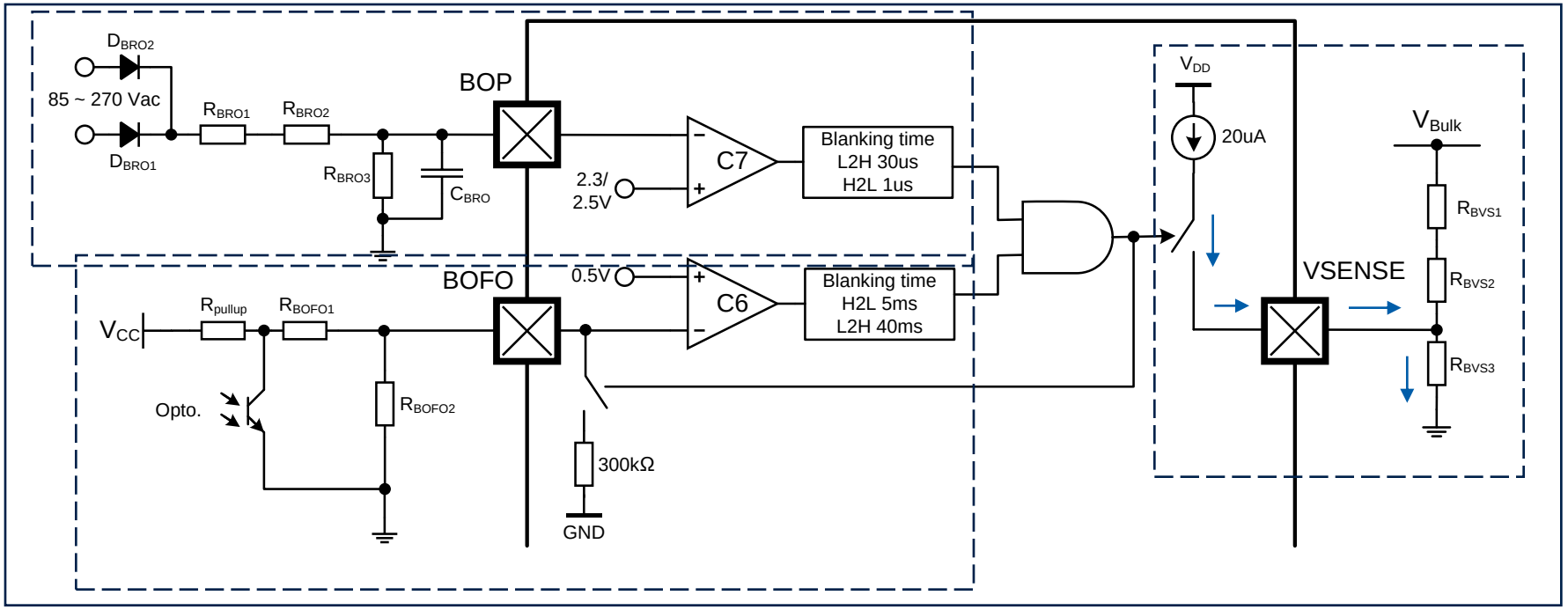
# Boost Follower Mode




Boost Follower mode:

- Light load detection from PWM_feedback signal is lower than 0.5V at the pin BOFO.
- Line voltage detection which is lower than 2.3V at pin BOP.
- 20uA current will flow out of VSENSE pin during boost follower mode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# ICE3PCS01G's 300W Demoboard Description

- Board power rating = 300W
- Input Voltage = 85VAC~265Vac
- Output Voltage = 400V
- Efficiency = >95%
- Switching frequency = 67kHz


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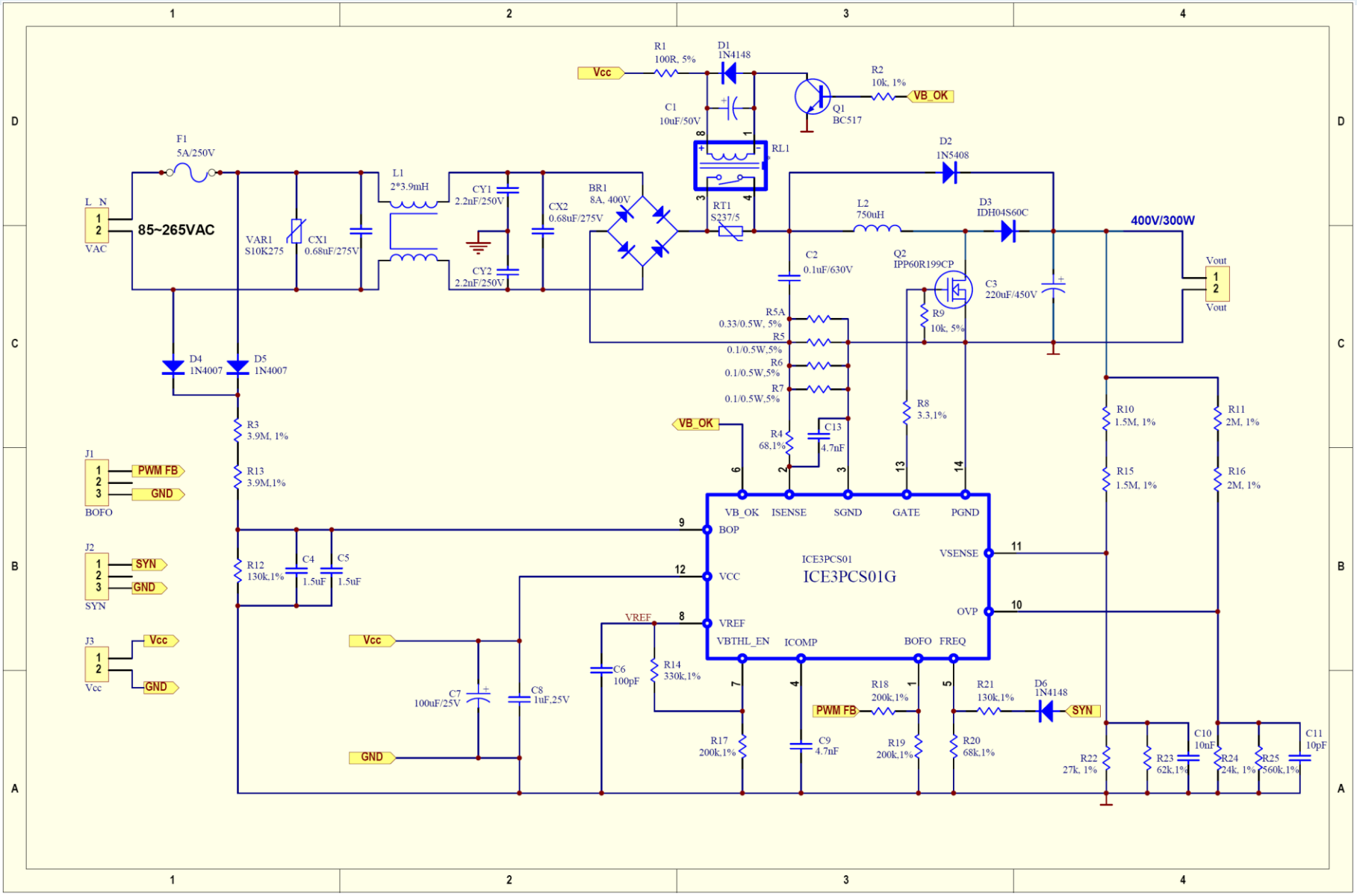
# Schematic of ICE3PCS01G Demoboard





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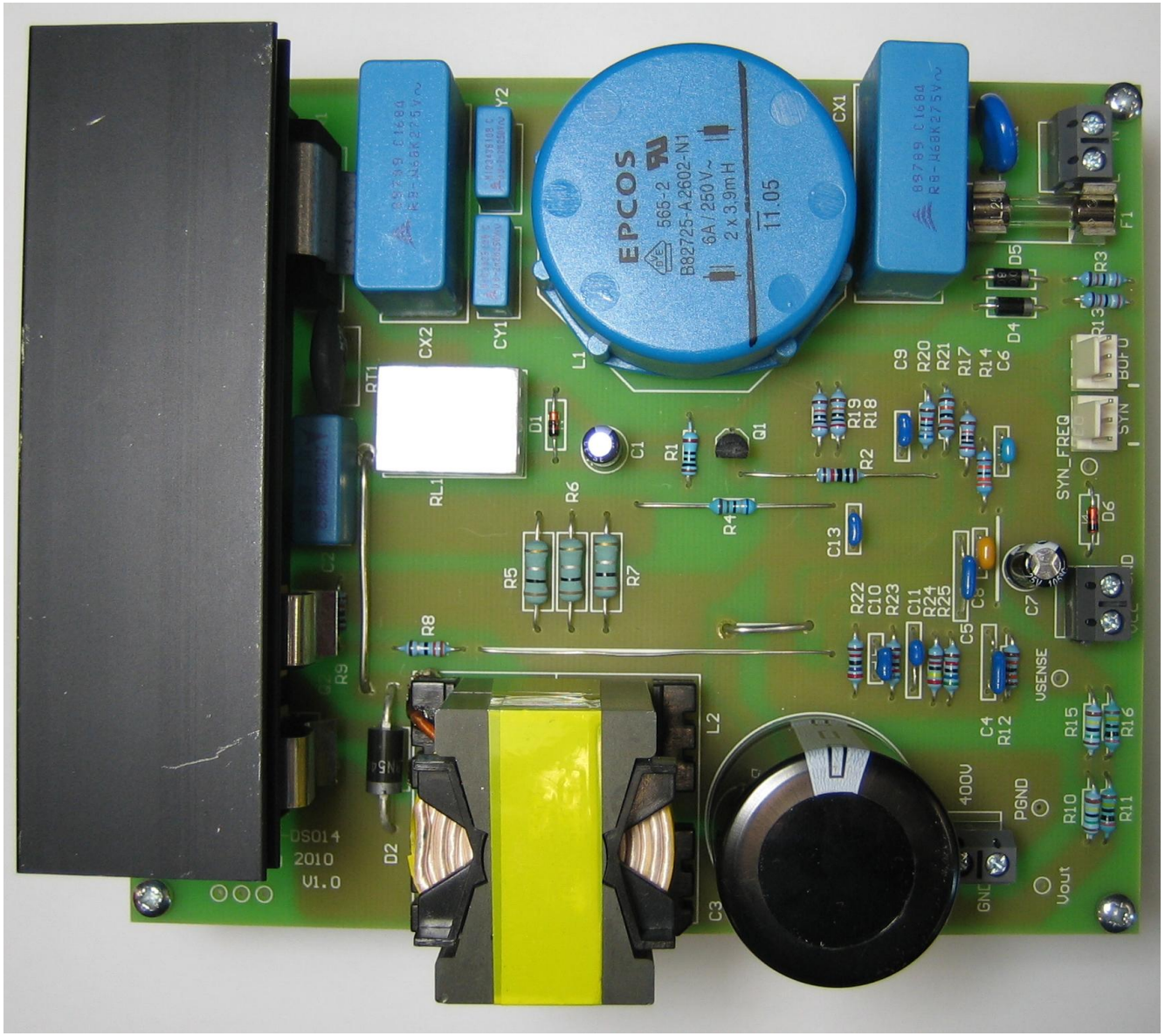
# ICE3PCS01G's 300W Demoboard





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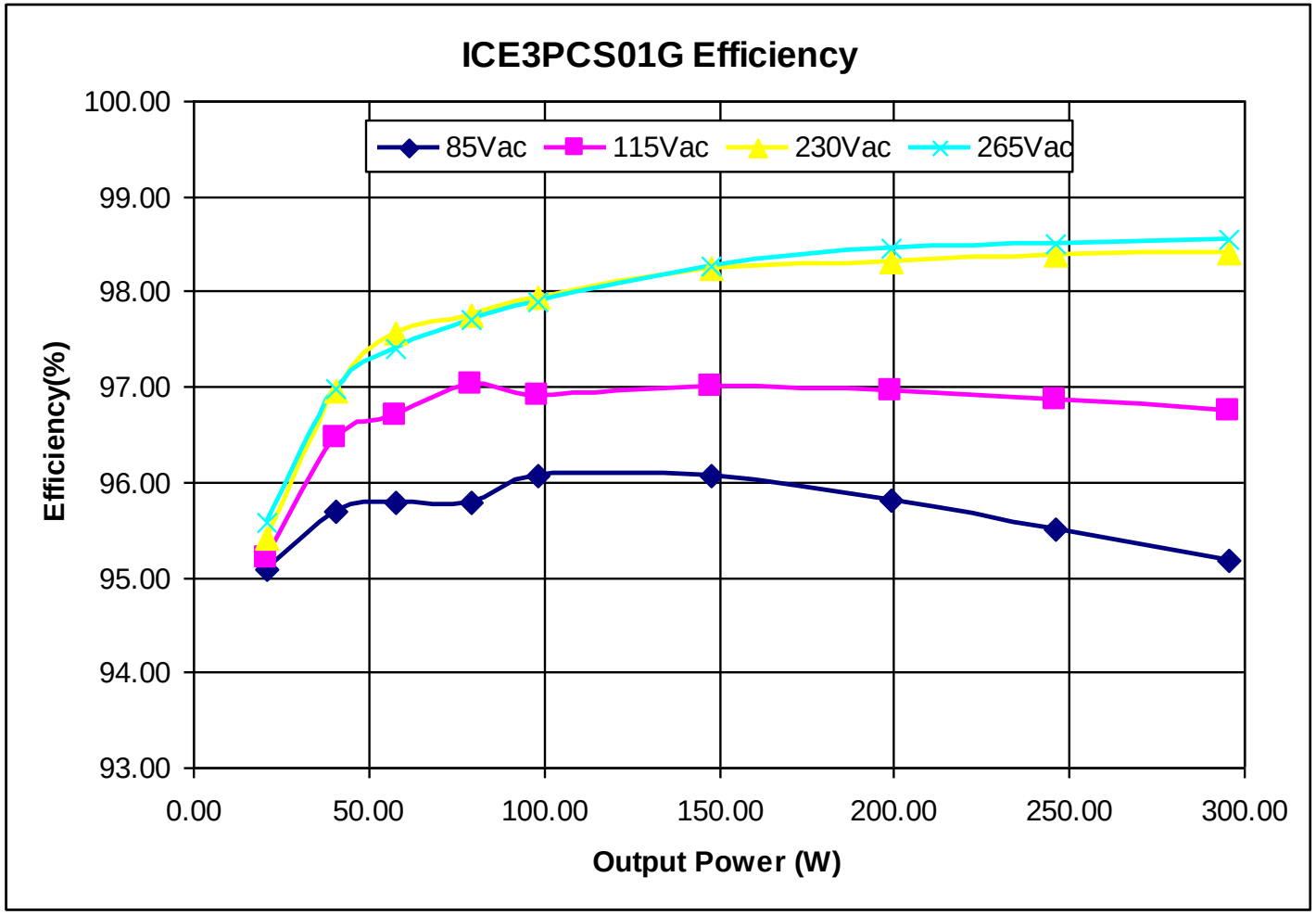
# Performance of Evaluation Board Efficiency Vs Output Power





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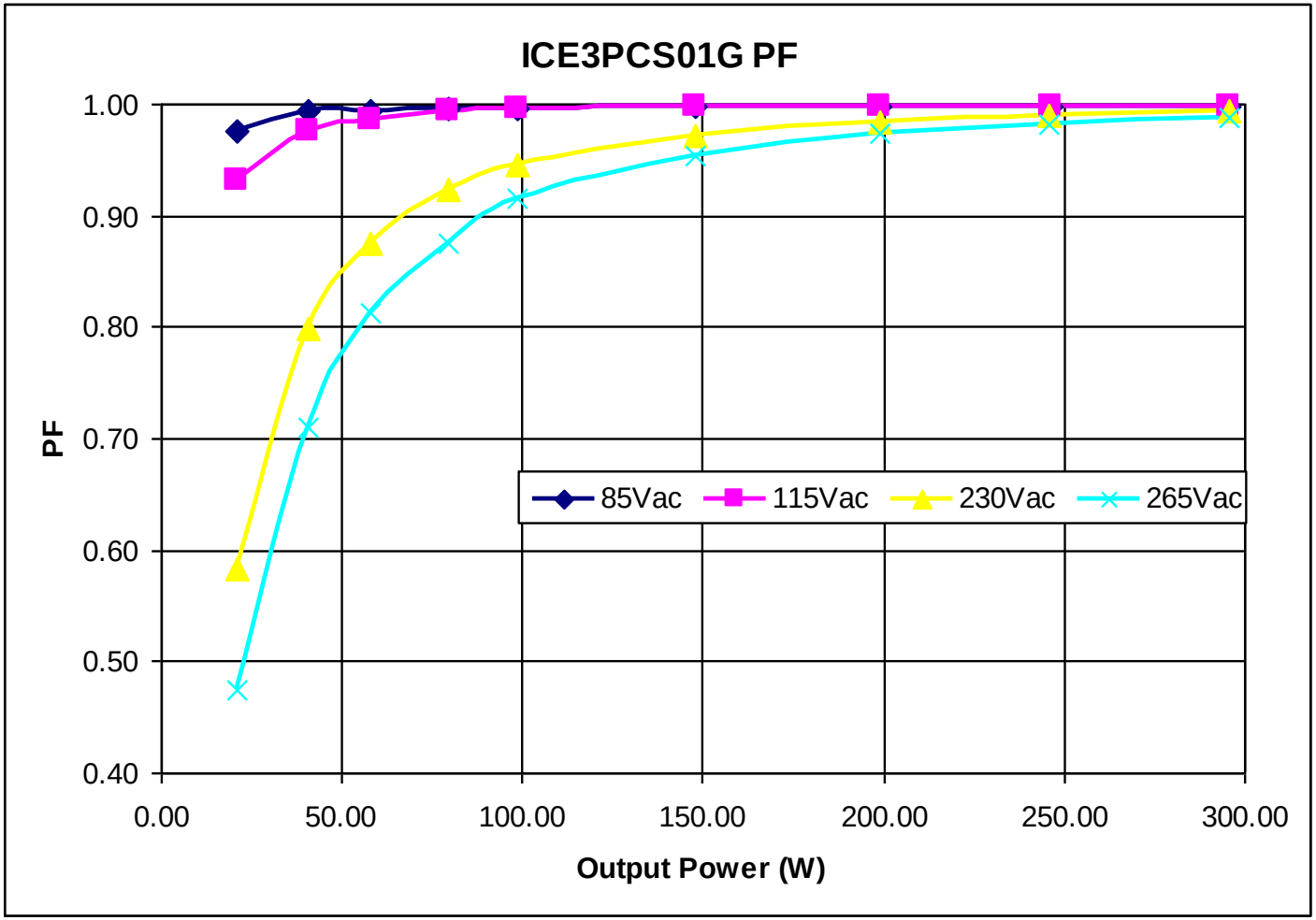
# Performance of Evaluation Board Power Factor Vs. Output Power





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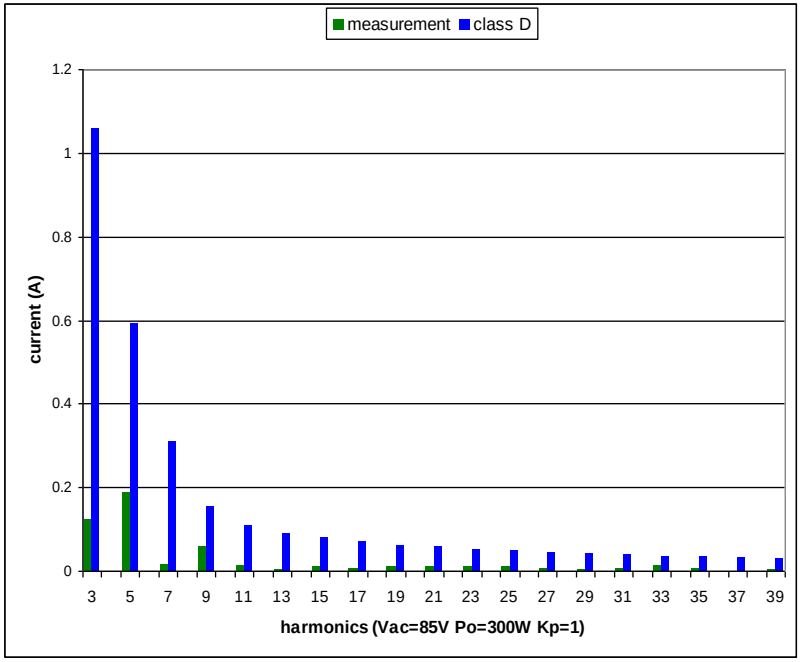
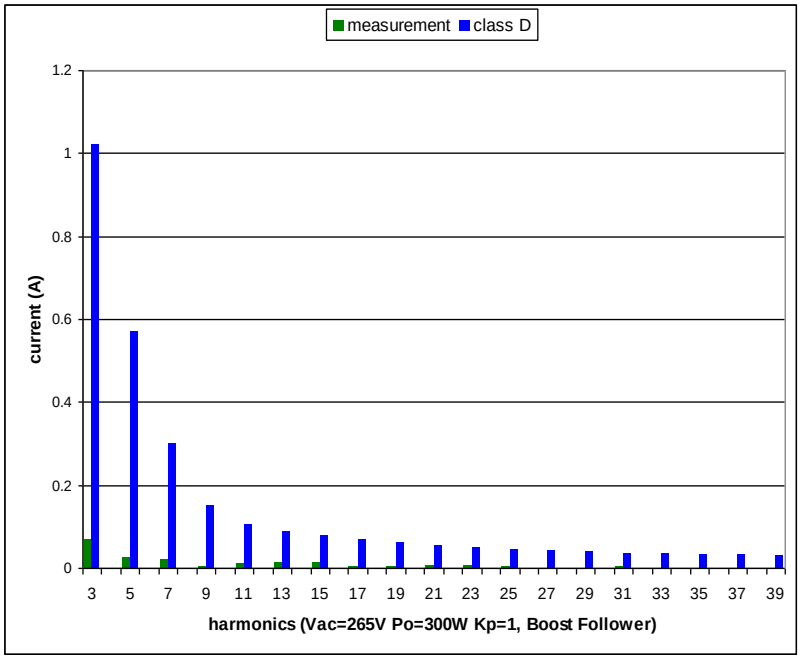
# Performance of Evaluation Board THD





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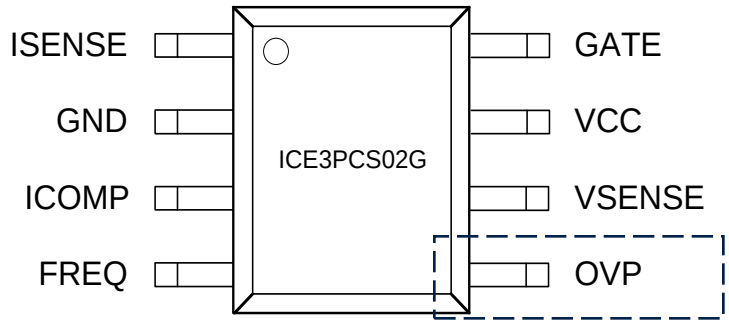
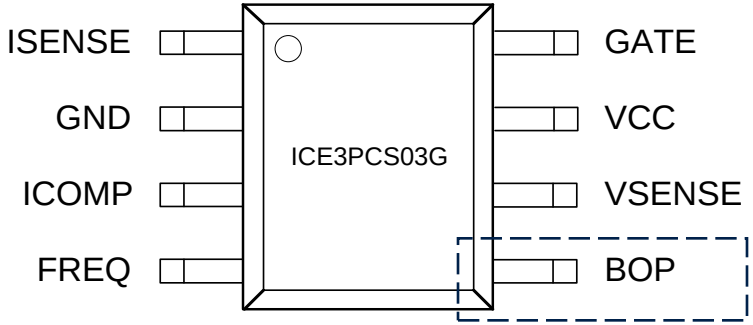
# ICE3PCS0xG in 8-pin

Other ICE3PCS0XG family




- The difference between ICE3PCS02G and ICE3PCS03G is at pin 5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# Summary of ICE3PCS0xG Family

| Function \ Product | ICE3PCS03G | ICE3PCS02G | ICE3PCS01G |
|---|---|---|---|
| digital control voltage loop | YES | YES | YES |
| variable frequency | YES | YES | YES |
| synchronous frequency | YES | YES | YES |
| open loop protection | YES | YES | YES |
| low peak current limit | -0.4 | -0.4 | -0.2 |
| brown out protection | YES | | YES |
| over voltage protection | YES | YES | YES |
| second over voltage protection | | YES | YES |
| PFC enable function | | | YES |
| boost follower mode | | | YES |
| 5V regulator | | | YES |


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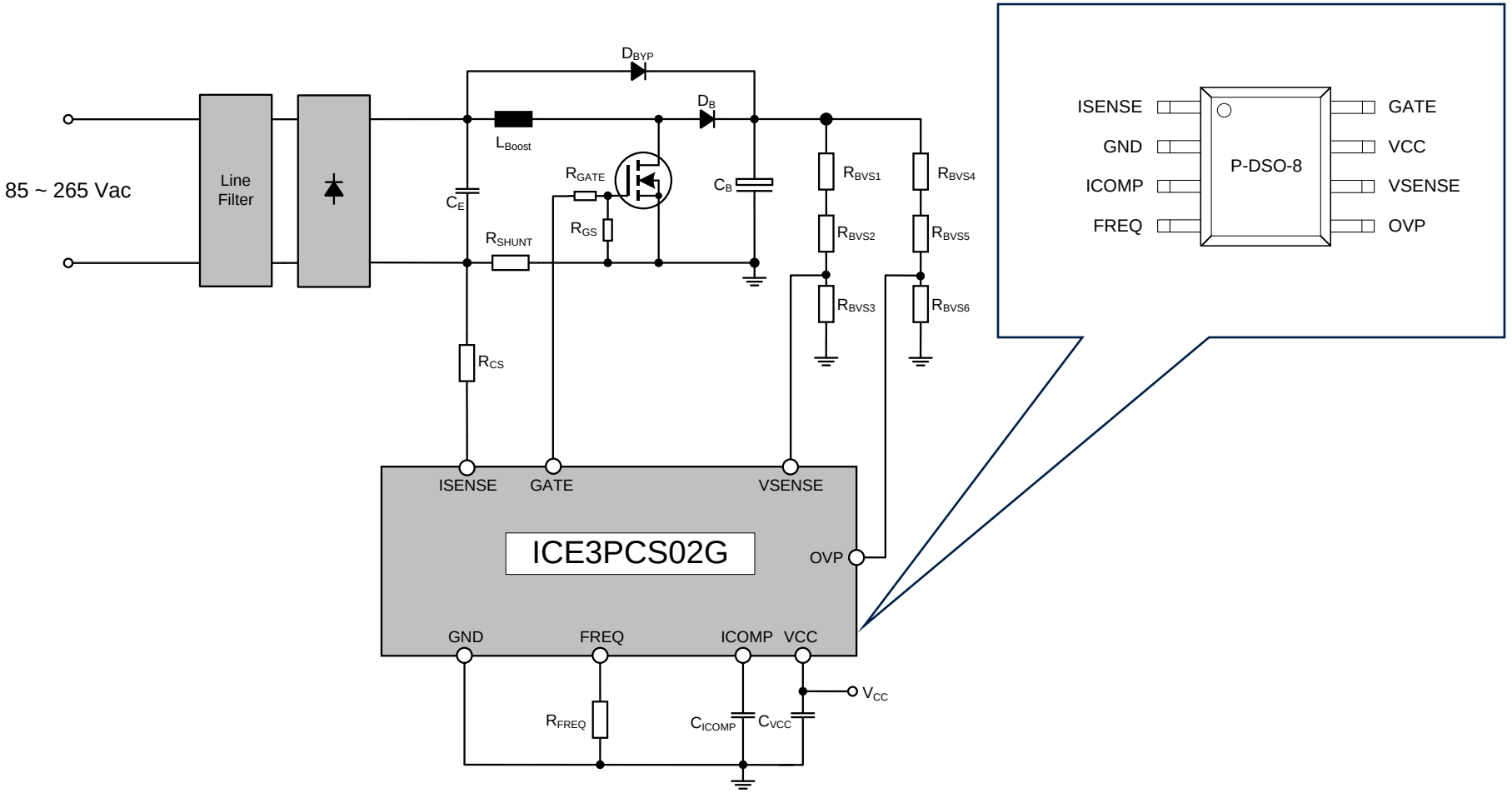
# Typical Application Circuit ICE3PCS02G





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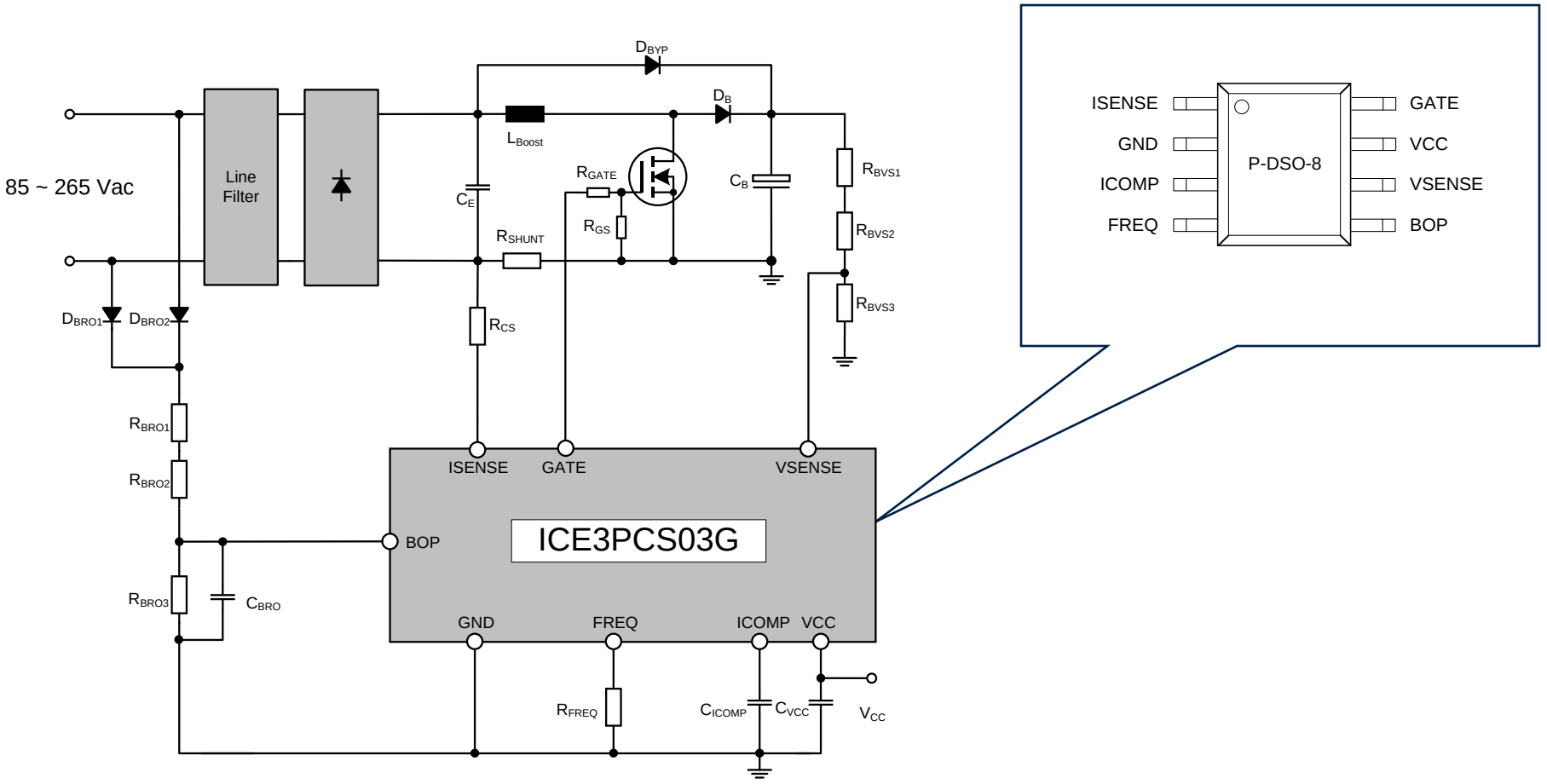
# Typical Application Circuit ICE3PCS03G





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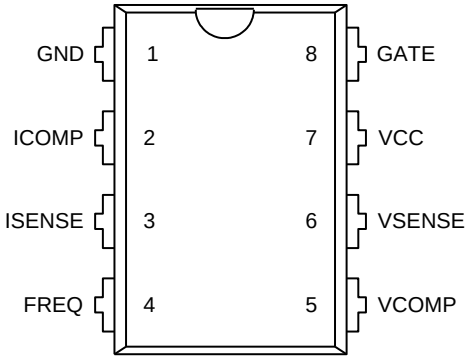
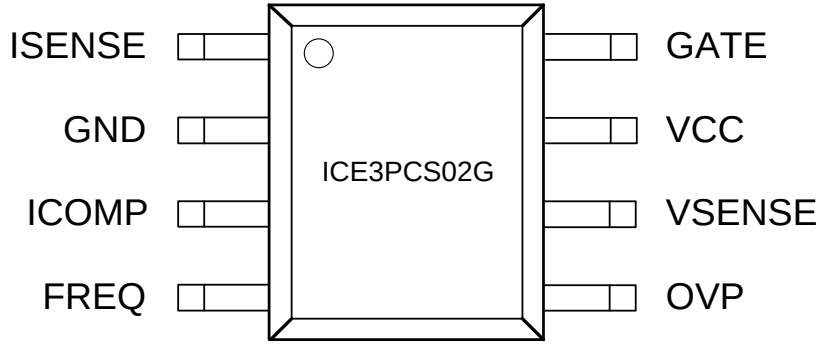
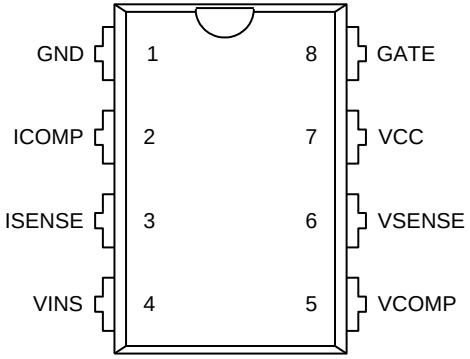
# Pin layout comparison between 8-pin ICE2PCS0x Vs ICE3PCS02/3G

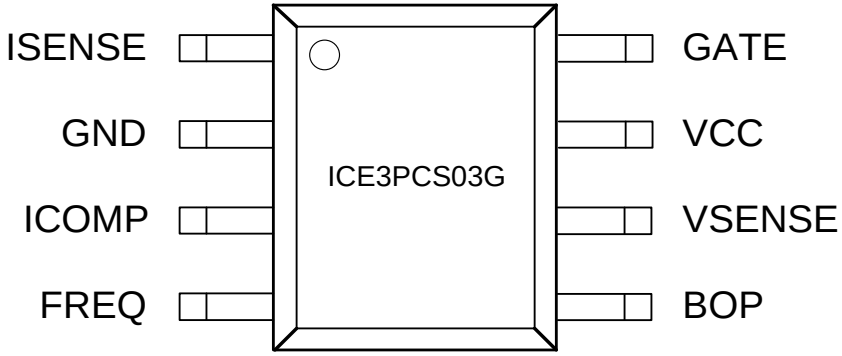
ICE2PCS01/05




ICE2PCS02/03/04





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# Features comparison

| Features | ICE2PCS0x | ICE3PCS02/03G |
|---|---|---|
| Voltage loop compensation | External and Analogue | Integrated and Digital |
| Peak current limitation threshold | -1.0V | -0.4V |
| Dynamic response | Fair | Excellent |
| Operation frequency setting | ICE2PCS01/05 → adjustable | Adjustable from 21kHz to 250kHz |
| | ICE2PCS02/03/04 → fixed | |
| Brownout protection | ICE2PCS02/03/04 → integrated | ICE3PCS03→integrated |
| Two Over voltage protection | None | ICE3PCS02→integrated |


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# Features comparison

| Improvement | ICE2PCS0x | ICE3PCS02/03G |
|---|---|---|
| Voltage Loop | The compensation of the voltage loop is installed at pin VCOMP | The compensation of the voltage loop is installed inside the IC with digital control. |
| SOC | Yes, induce over-high peak current design | Removed and -0.4V OCP threshold can limit maximum peak current in worst case without over-current design while save power loss on $R_{SHUNT}$ |
| Enhance Dynamic Response (EDR) | Yes, induce input current distortion during startup and load dynamic where bulk voltage varies over $\pm$5% detection window of EDR block | Removed and bulk voltage dynamic response is guaranteed by the integrated digital voltage loop |


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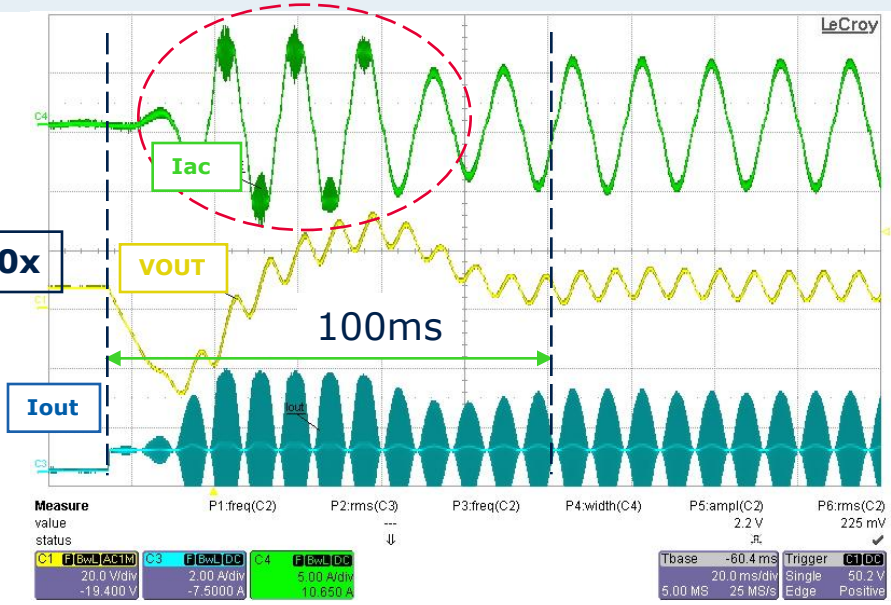
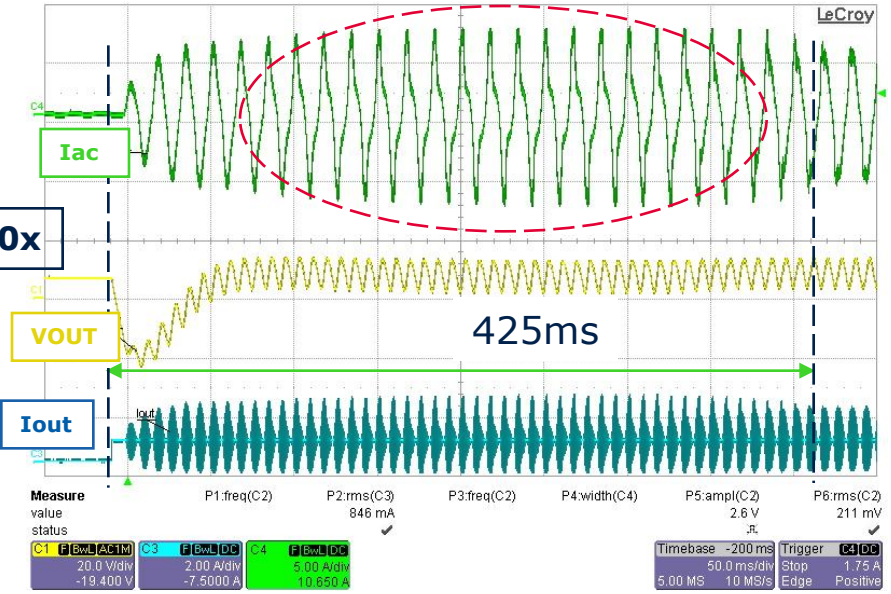
# Line Jump (0W->300W)

**ICE3PCS0x**




**ICE2PCS0x**




| ICE3PCS0x | ICE2PCS0x |
|---|---|
| Shorter recovery time | Longer recovery time |
| No current distortion | Current distortion during recovery period |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