Totem-Pole PFC

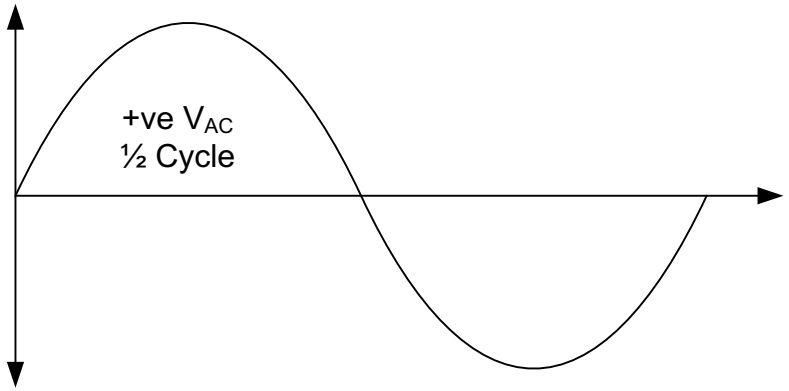
A Leading Provider of Smart, Connected and Secure Embedded Control Solutions

Tommy Chen

December 2021

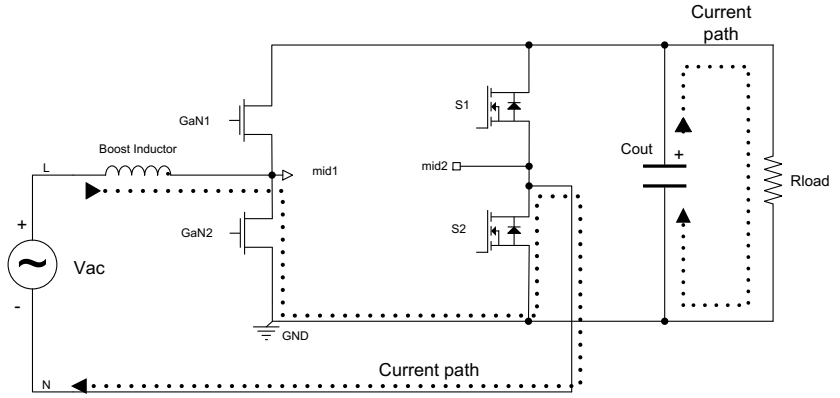
SMART | CONNECTED | SECURE

Totem-Pole PFC : Operation

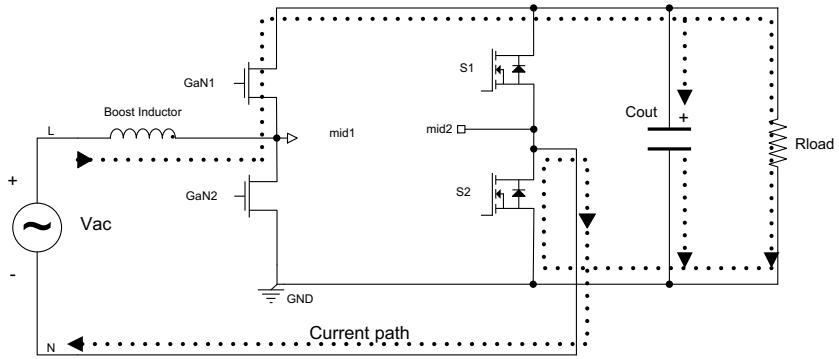


+ve V_{AC} ½ cycle :-

- GaN2 is active switch duty cycle D
- GaN1 is sync switch duty cycle 1-D
- Si MOSFET S2 is ON



Positive Vac half-cycle: Inductor charging (duty cycle = D on GaN2, S2 is on for the full positive Vac half-cycle)



Positive Vac half-cycle: Inductor discharging (duty cycle =1- D on GaN1, S2 is on for the full positive Vac half-cycle)

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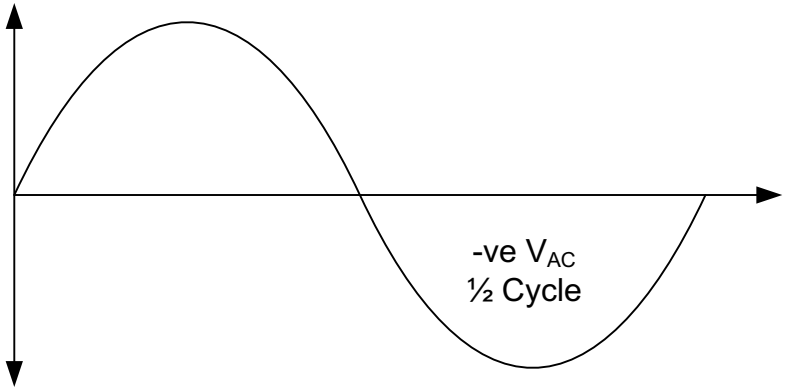
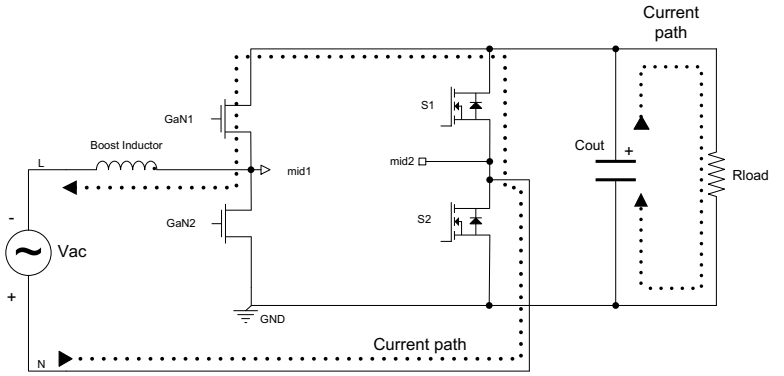
Totem-Pole PFC : Operation

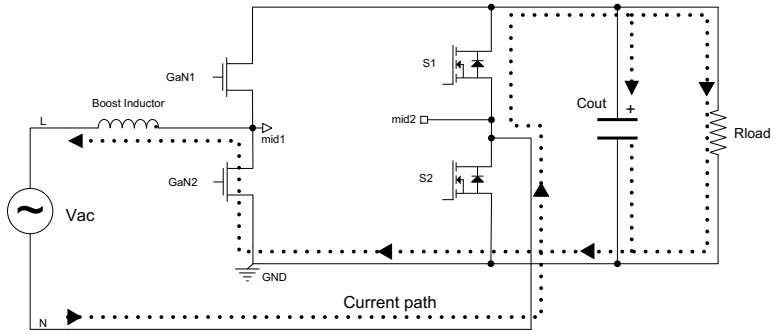


-ve V_{AC} ½ cycle :-

- GaN1 is active switch duty cycle D
- GaN2 is sync switch duty cycle 1-D
- Si MOSFET S1 is ON



Negative Vac half-cycle: Inductor charging (duty cycle = D on GaN1, S1 is on for the full negative Vac half-cycle)



Negative Vac half-cycle: Inductor discharging (duty cycle = 1-D on GaN2, S1 is on for the full negative Vac half-cycle)

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DSPIC33CK256MP506 DIGTIAL POWER PIM

- Microchip dsPIC33CK256MP506 16-Bit Digital Signal Controller
- ICSP™ programming header
- On-board LDO with Power Good (PG) function
- Micro USB connector
- MCP2221A USB to UART/I2C serial converter
- Board edge connection interface for analog inputs/outputs, PWM outputs and GPIO ports

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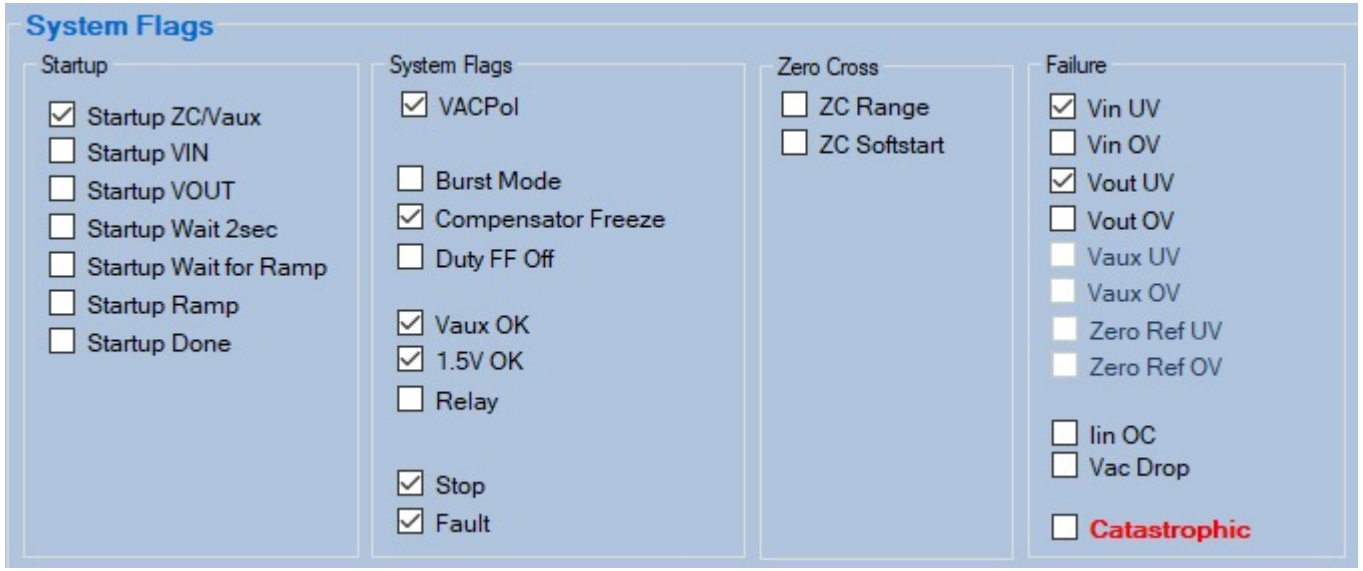
ADC0 ISR every PWM Period (66kHz)

Measure Signals:
IAC = ADCBUF0
VAC = ADCBUF1
Vout = ADCBUF10
VNTC = ADCBUF17
V1,5V = ADCBUF15

IAC	IAC	IAC	IAC
VAC	VAC	VAC	VAC
Vout	VNTC	V1,5V	Vout
Period x	Period x+1	Period x+2	Period x+3

- Convert IAC and VAC to positive 0-2048
- ISR_ZC
- ISR_AVG_Calc
- ISR_Startup_After_ZC
- Every 11th Period Voltage Controller
- Check for Burst Mode
- Current Controller with DFF
- Check for DCM
- Check for VAC drop



ZC Flags:
_ZCRange
_ZCRange_last
_SoftStart_ZC
_ZeroCross

ZC Values:
_ZCTimeDiff
_ZCRangeTime

Fault Flags:
inputUnderVoltage
inputOverVoltage
outputUnderVoltage
outputOverVoltage

inputOverCurrent

auxUnderVoltage
auxOverVoltage

zeroRefUnderVoltage
zeroRefOverVoltage

vacDrop

catastrophicFault

SystemFlags:
_VACPol
_VACPol_last

_Stop
_Fault

_AuxOK

_Relay
_1_5OK
_RelayWait

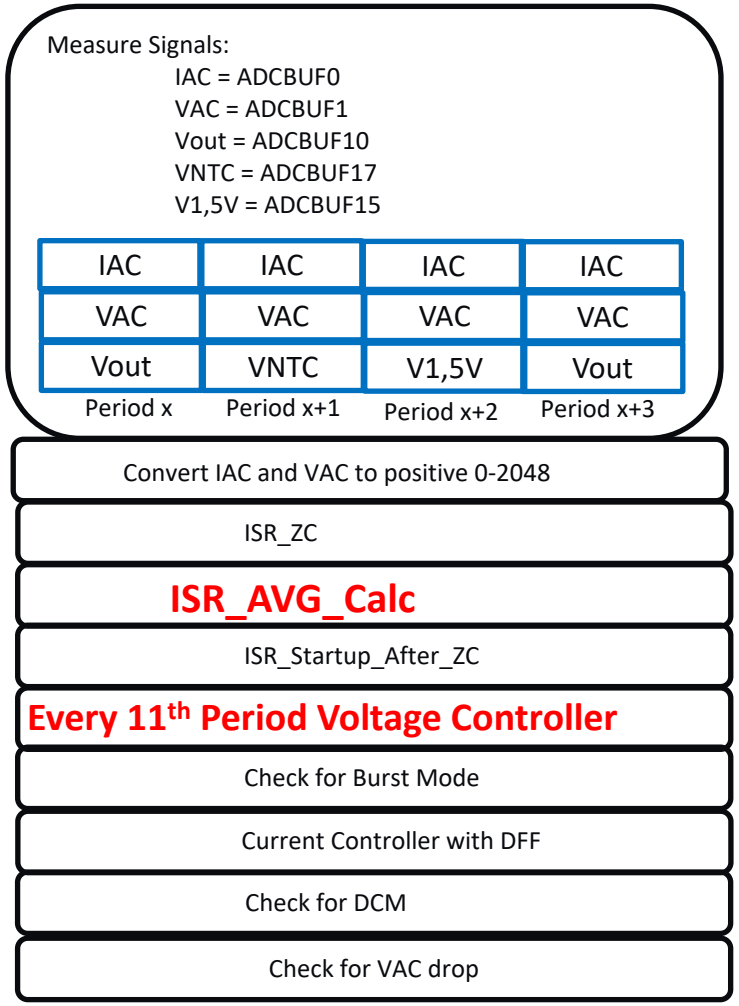
_BurstModeDetect
_BurstMode
_CompFreeze
_dffOff

Startup Flags:
_StartupZC
_StartUpVinMeasure
_StartUpVoutMeasure

_StartUpWaitRelay2s
_StartUpWaitForRamp

_StartUpIRamp
_StartUpVRamp
_StartUpDone

ADC0 ISR every PWM Period (66kHz)



Average over 1 Period:
VAC Average
IAC Average
Vout Average
1,5V Average

Check for VAC OV and VOUT OV,UV

Check for Relay Switch On
Reset _ZeroCross

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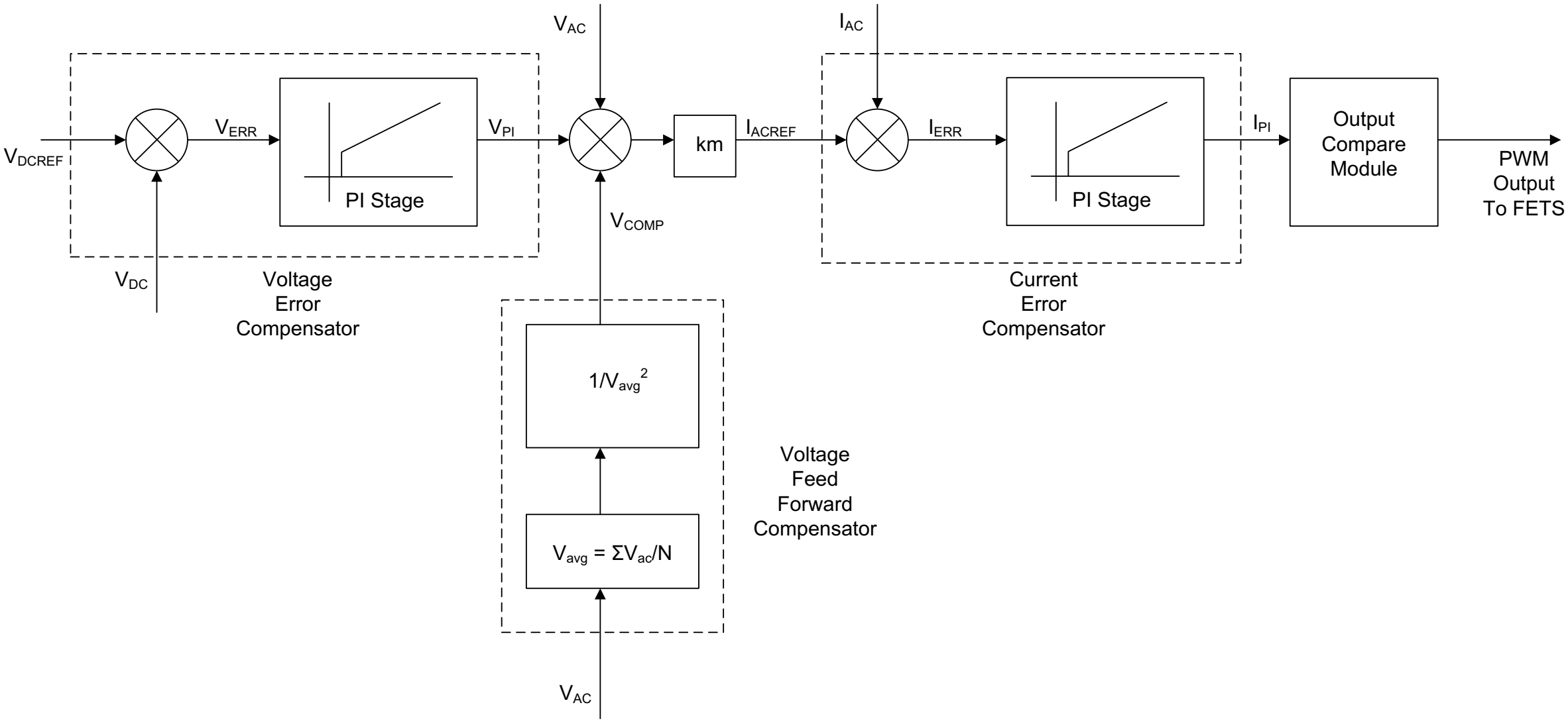
Control Strategy with additional FF



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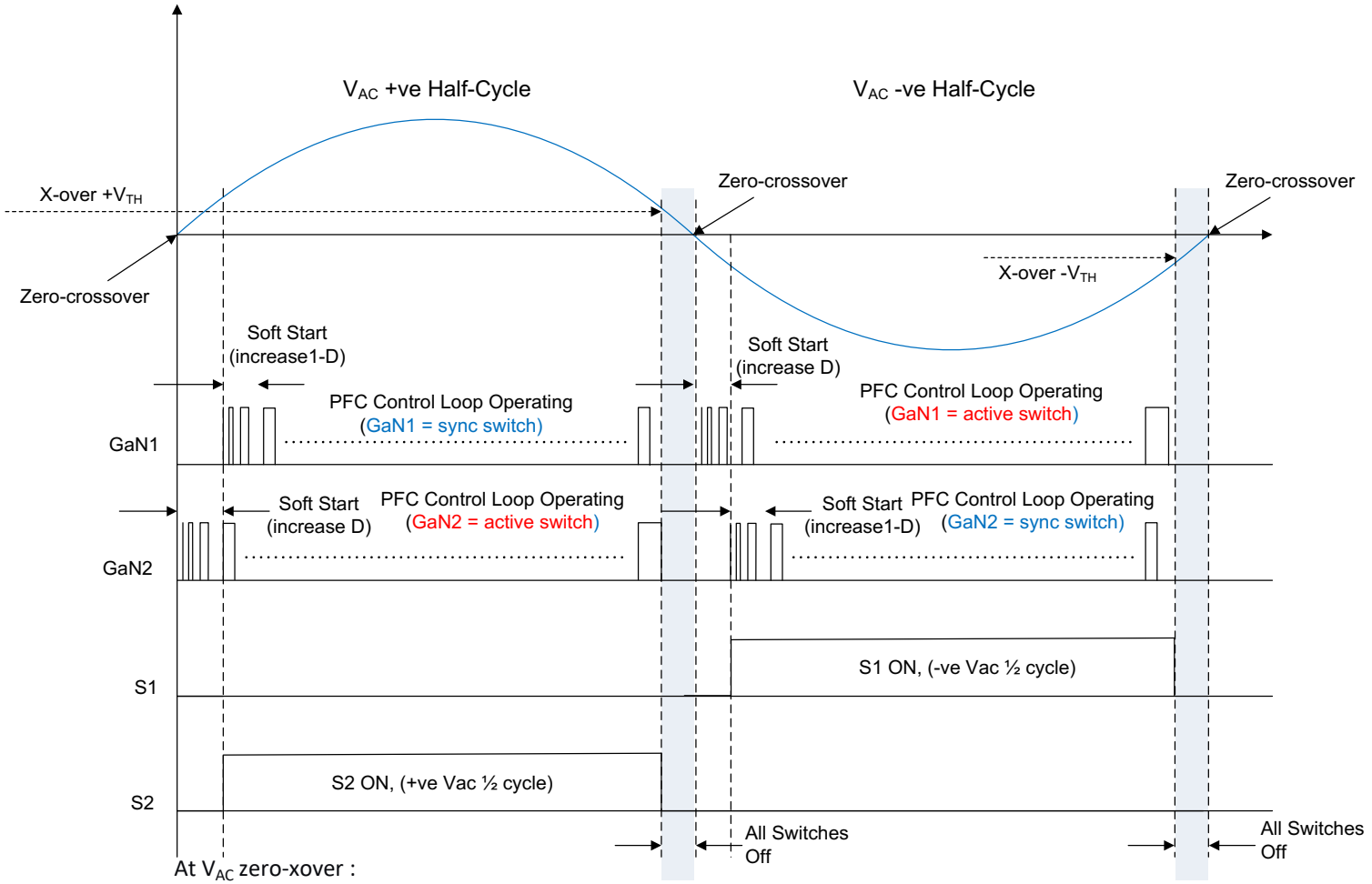
V_{AC} Zero-xover Soft-start



- Potential for large current spikes, if timing is wrong.
- Therefore, switching is stopped approaching zero-xover.
- Soft-start operation used on the other side of zero-xover.
  - Duty cycle begins small and is increased over 10-20 cycles
  - Until D_{SS} is the same as D_{loop} calculated from the PFC control loop
  - Then PFC control loop takes over (until the next zero-xover)

MICROCHIP

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Convert IAC and VAC to positive 0-2048

ISR_ZC

ISR_AVG_Calc

ISR_Startup_After_ZC

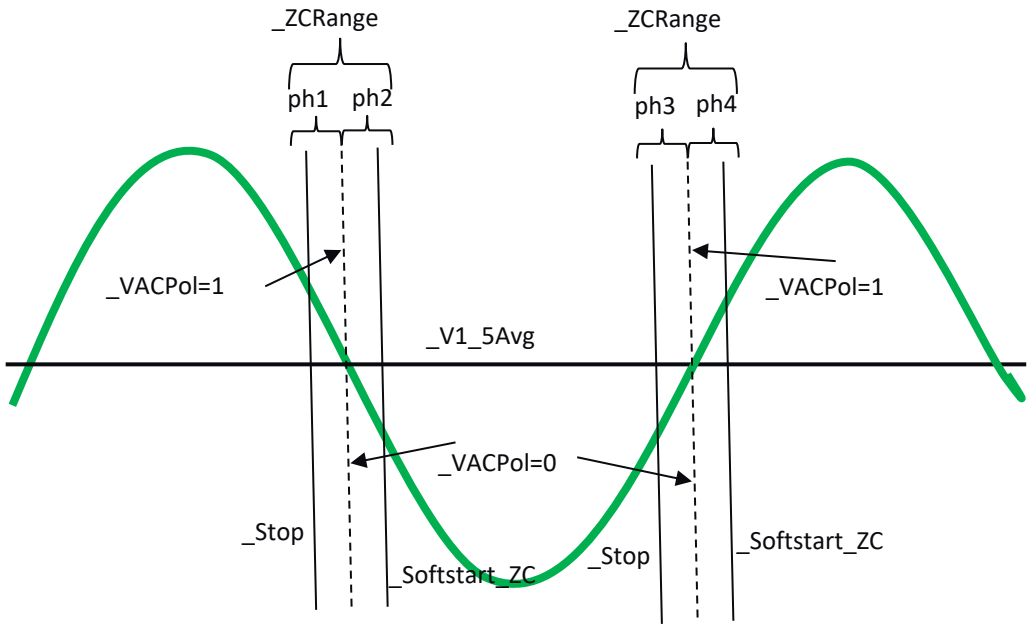
Every 11th Period Voltage Controller

Check for Burst Mode

Current Controller with DFF

Check for DCM

Check for VAC drop



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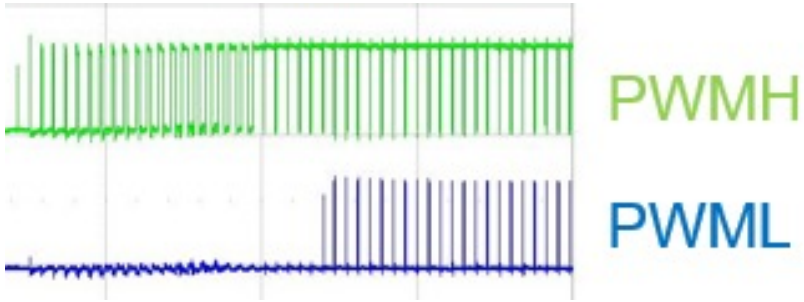
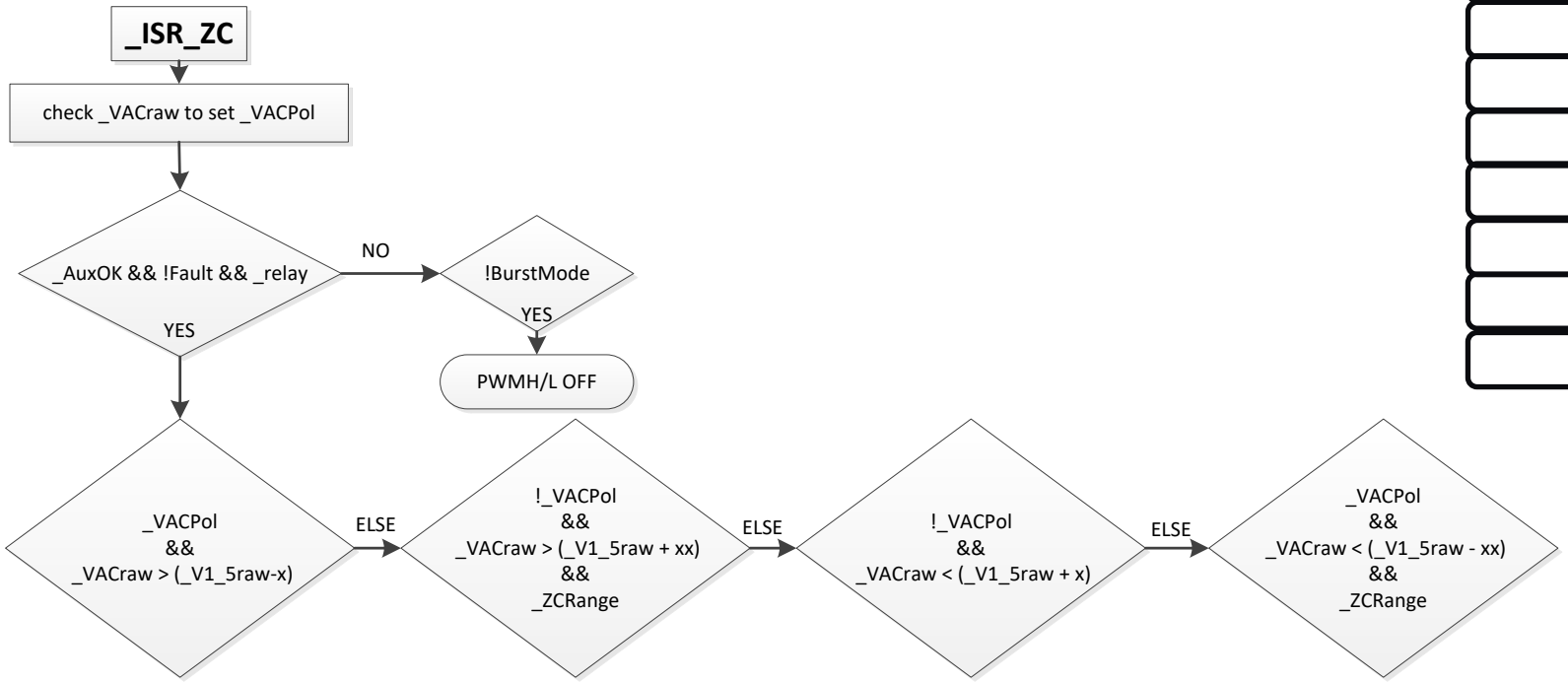
ADC0 ISR every PWM Period (66kHz)

Startup after ZC with DC = 0 to calculated DC
in max 20 Period. Startup in asynchronous mode.





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Every 11th Period Voltage Controller

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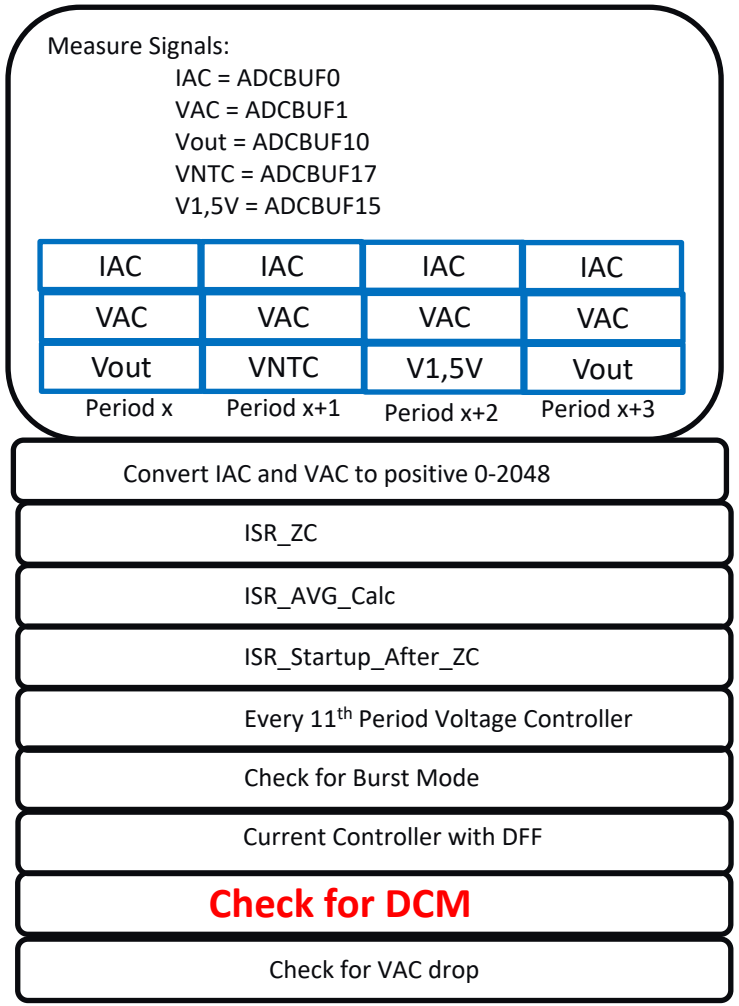
ADC0 ISR every PWM Period (66kHz)



DCM/CCM Handling

- Change Gain between DCM and CCM. Multiply a factor to ACCB in DCM !!!! Change current sample point in addition ??
- $D = \frac{\text{Vout}-\text{Vin}}{\text{Vout}}$ standard Boost Function for the Input voltage feedforward
- Vin > Vout (1-D) true in CCM
- with D=$\frac{PGDC}{PGPER} \rightarrow Vin \times PGPER > Vout \times (PGPER - PGDC)$
- $k = \frac{D \times Vout}{Vout - Vin} = \frac{\frac{PGDC}{PGPER} \times Vout}{Vout - Vin}$
- $k \times PGPER = \frac{PGDC \times Vout}{Vout - Vin}$

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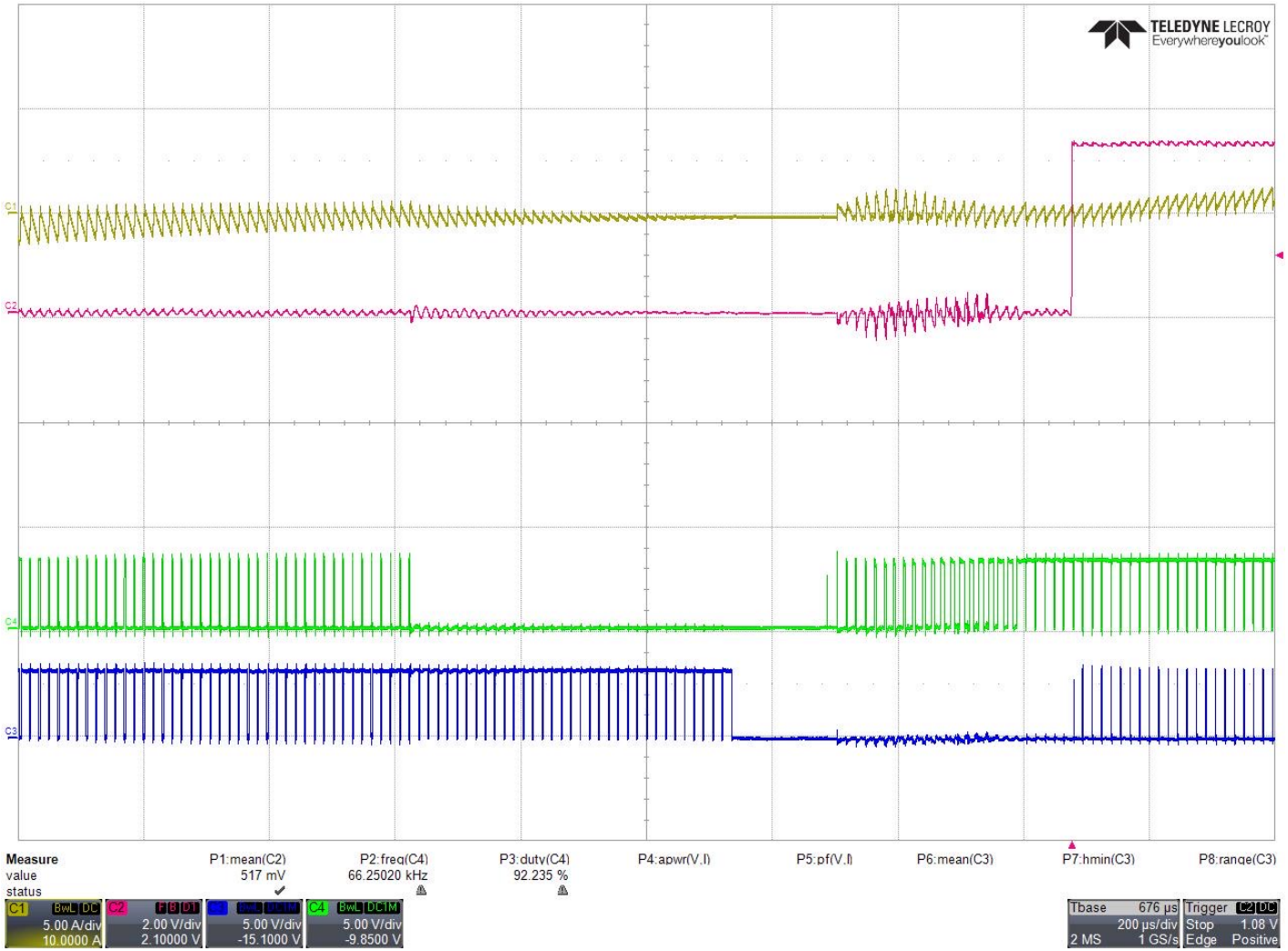
DCM/CCM Handling



ZC, negative halfwave to positive halfwave

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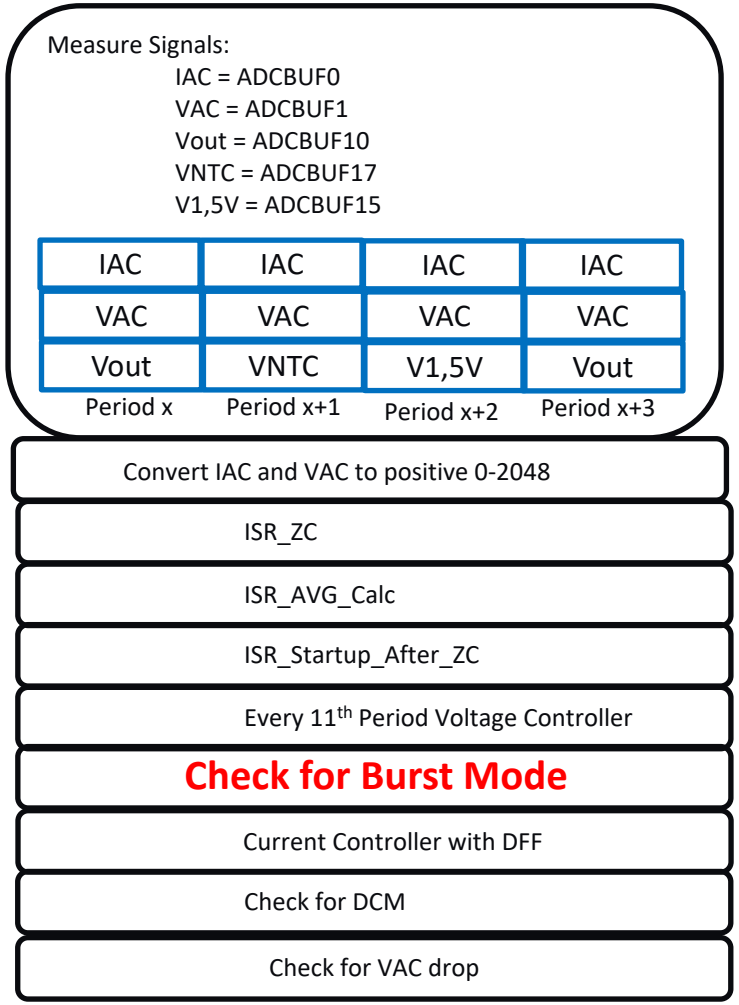
ADC0 ISR every PWM Period (66kHz)



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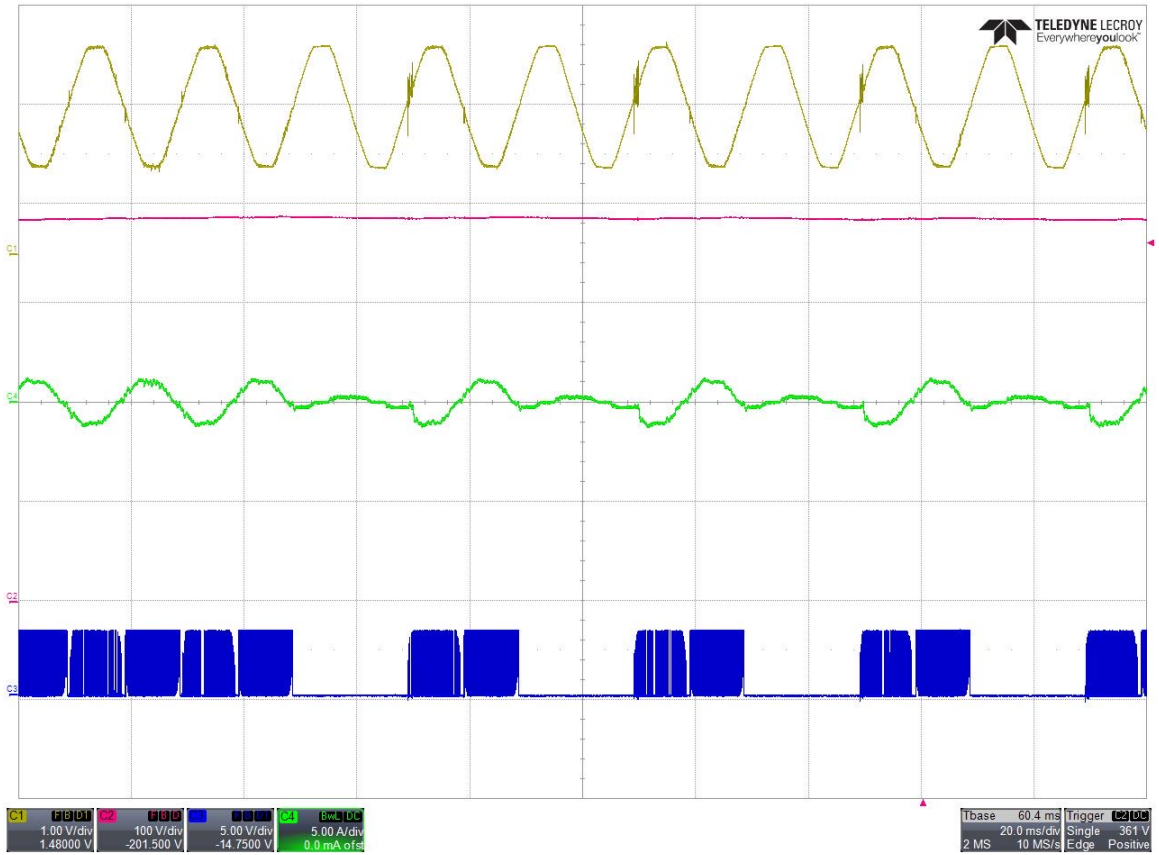
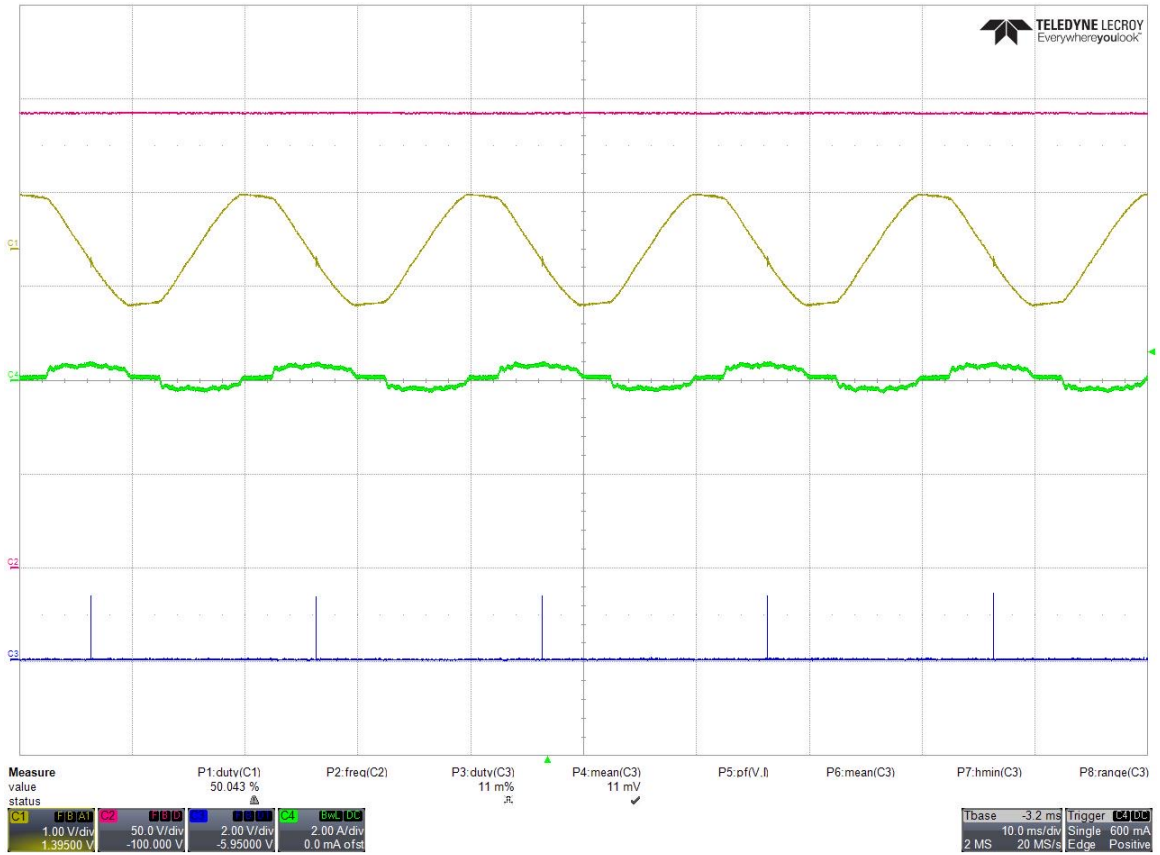
Burst Mode



Low Load



No Load

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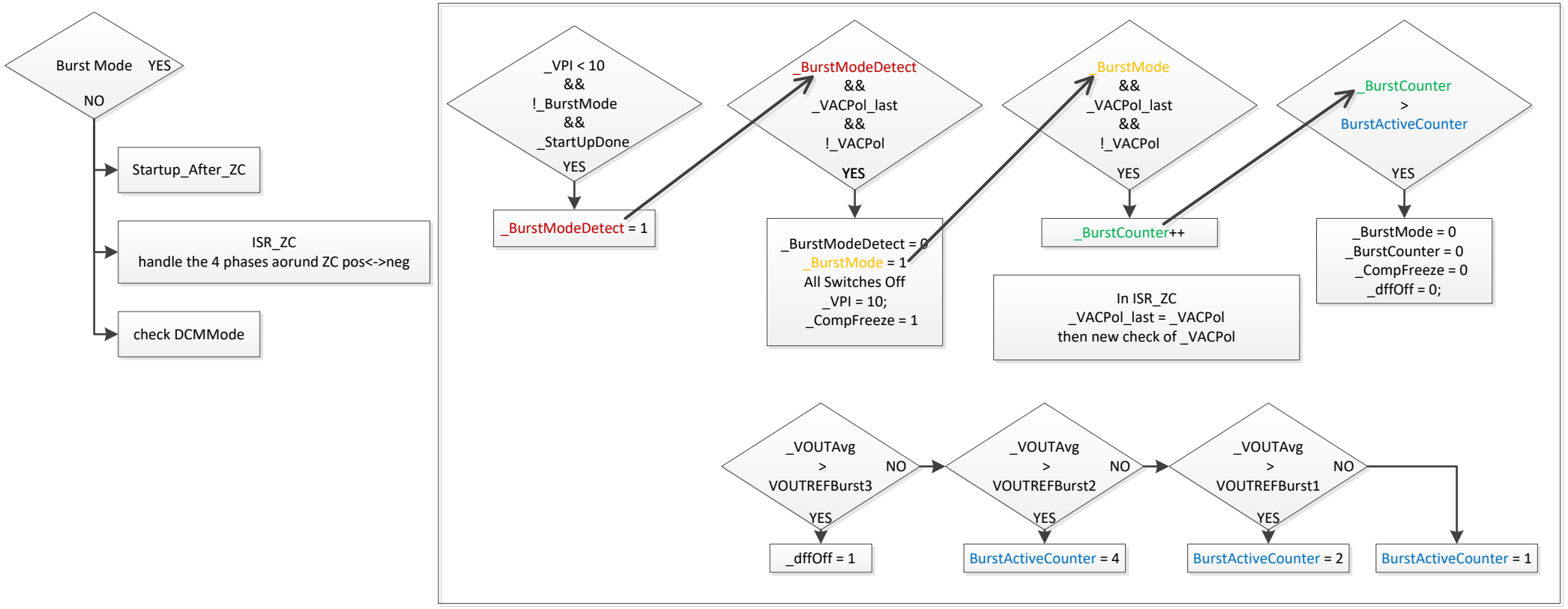
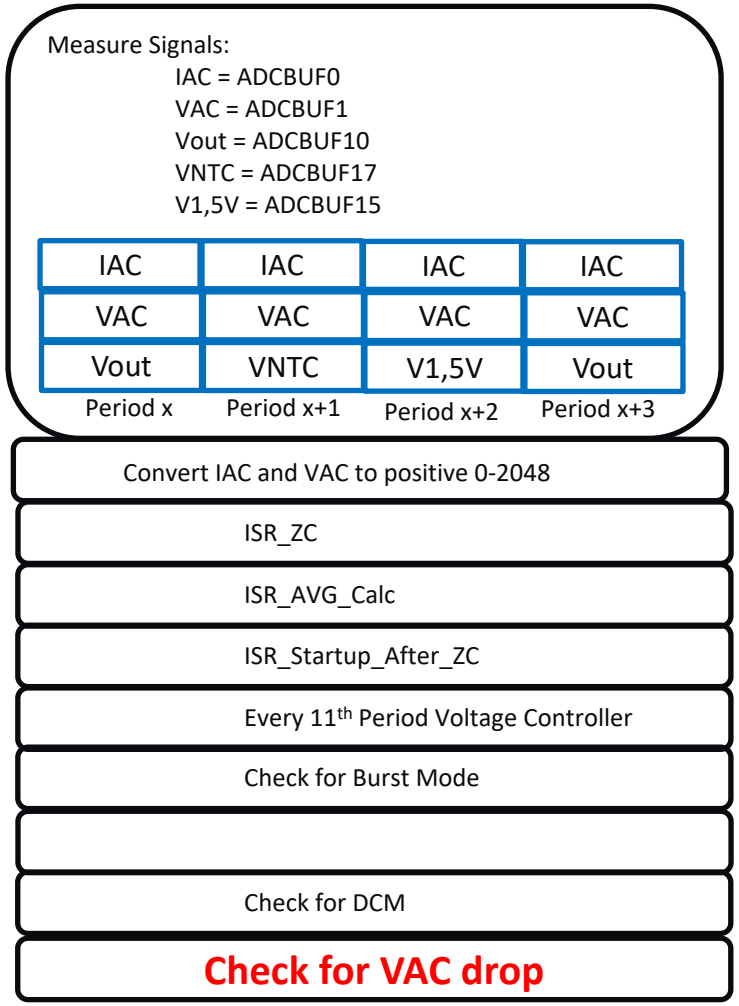
Burst Mode



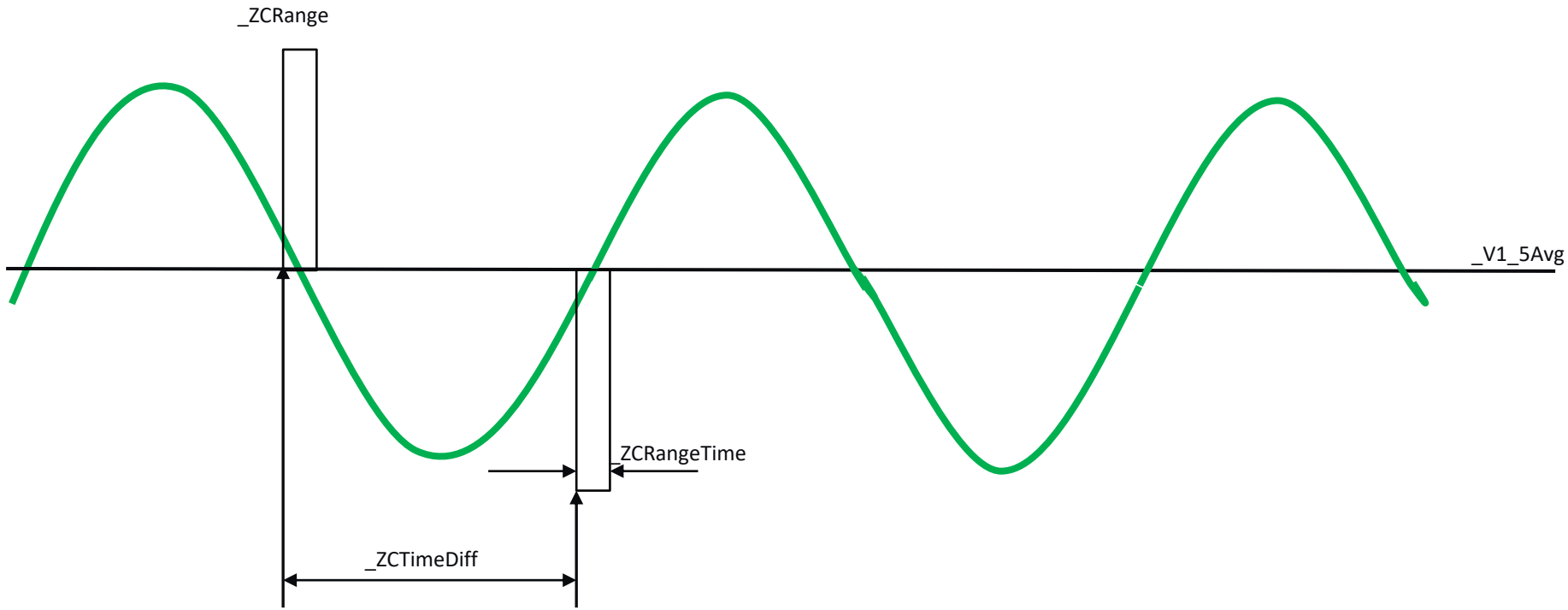
Burst Mode test called in ISR avery switching period

ADC0 ISR every PWM Period (66kHz)



MICROCHIP

ADC0 ISR every PWM Period (66kHz)



vacDrop = 1 if: _ZCTimeDiff < min period of 55Hz/65Hz
_ZCTimeDiff > max period of 45Hz/55Hz
_ZCRangeTime > 800µs (53 * 66kHz period) ?? low voltage with slower ZC ramp ??

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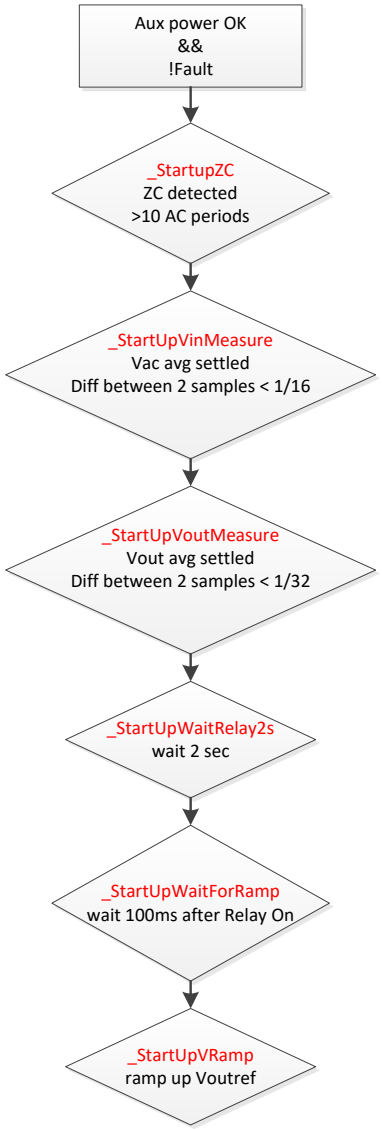
Startup Structure



Startup Flags:

_StartupZC
_StartUpVinMeasure
_StartUpVoutMeasure

_StartUpWaitRelay2s
_StartUpWaitForRamp

_StartUpIRamp
_StartUpVRamp
_StartUpDone

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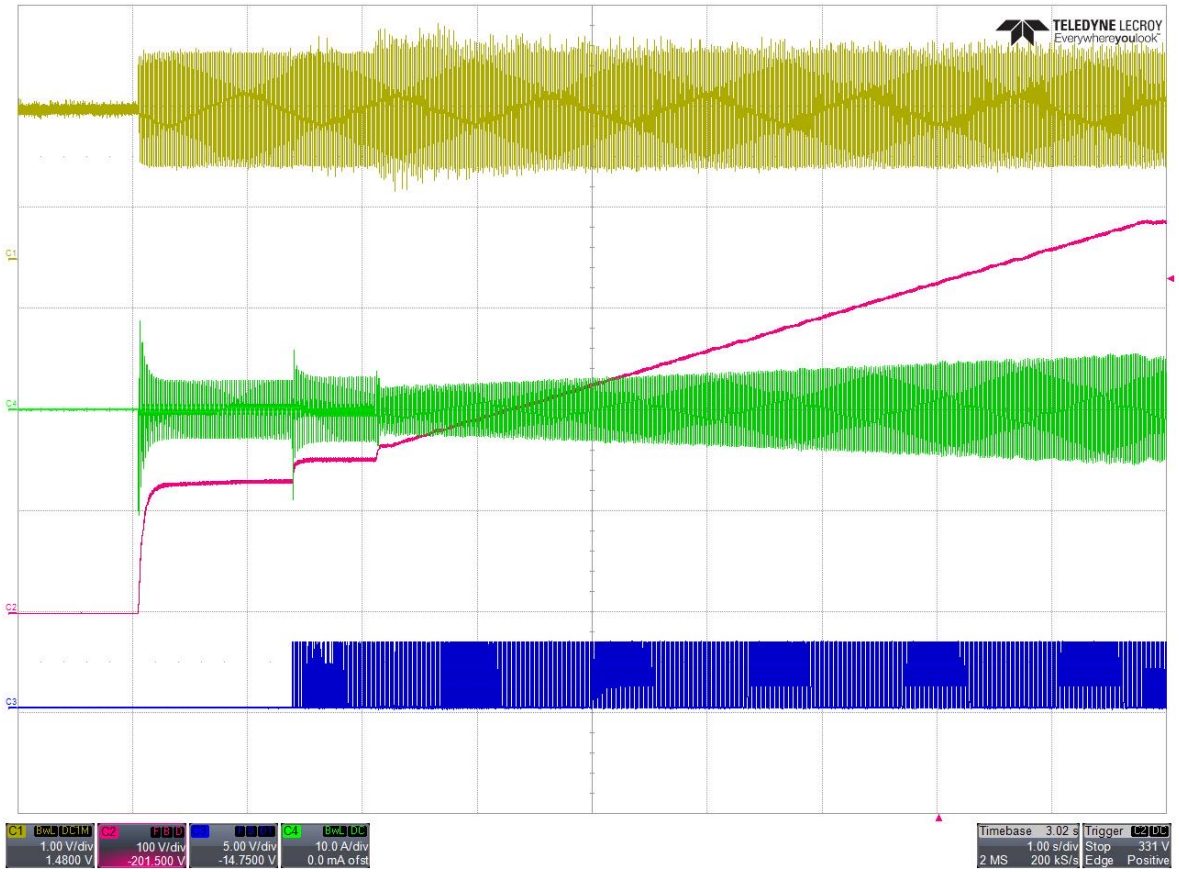
Startup Low Line

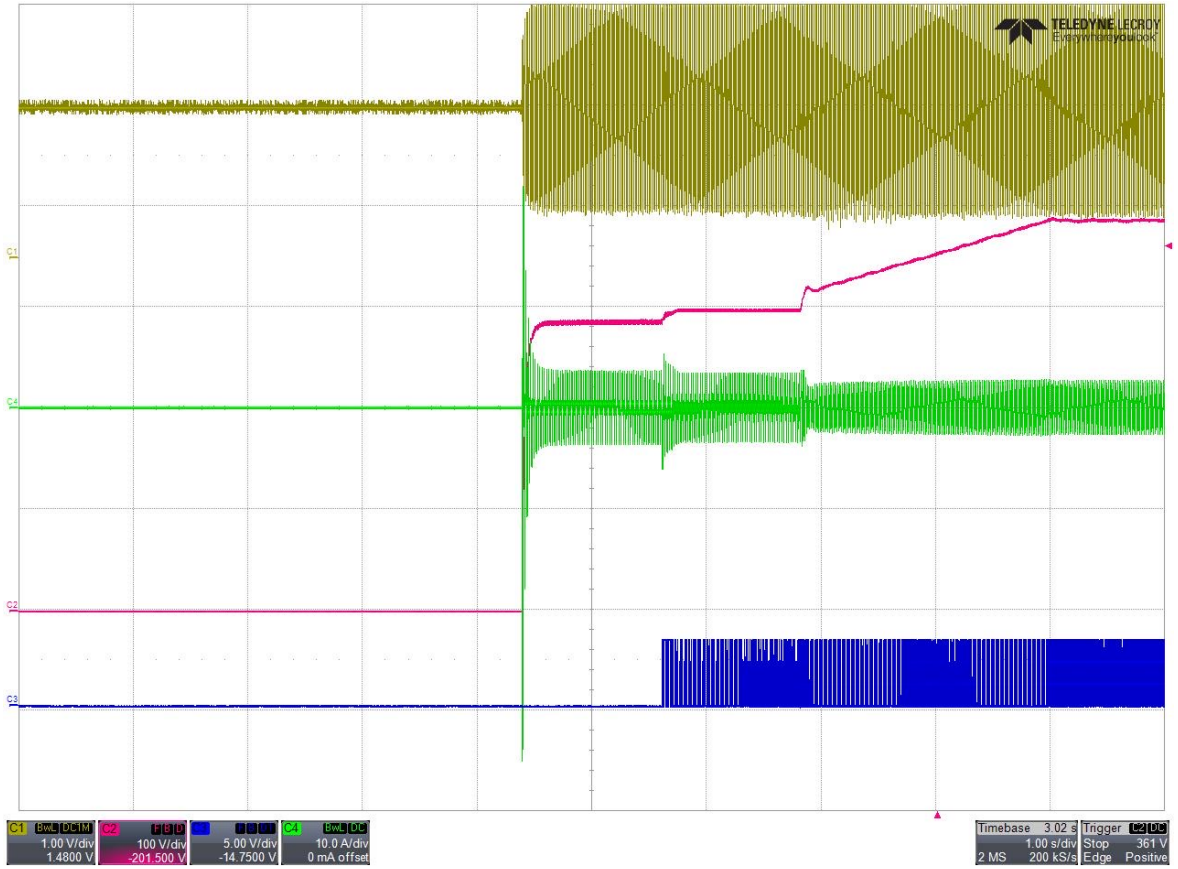
- **Electronic Load 1A**



MICROCHIP

Startup High Line

- **Electronic Load 1A**



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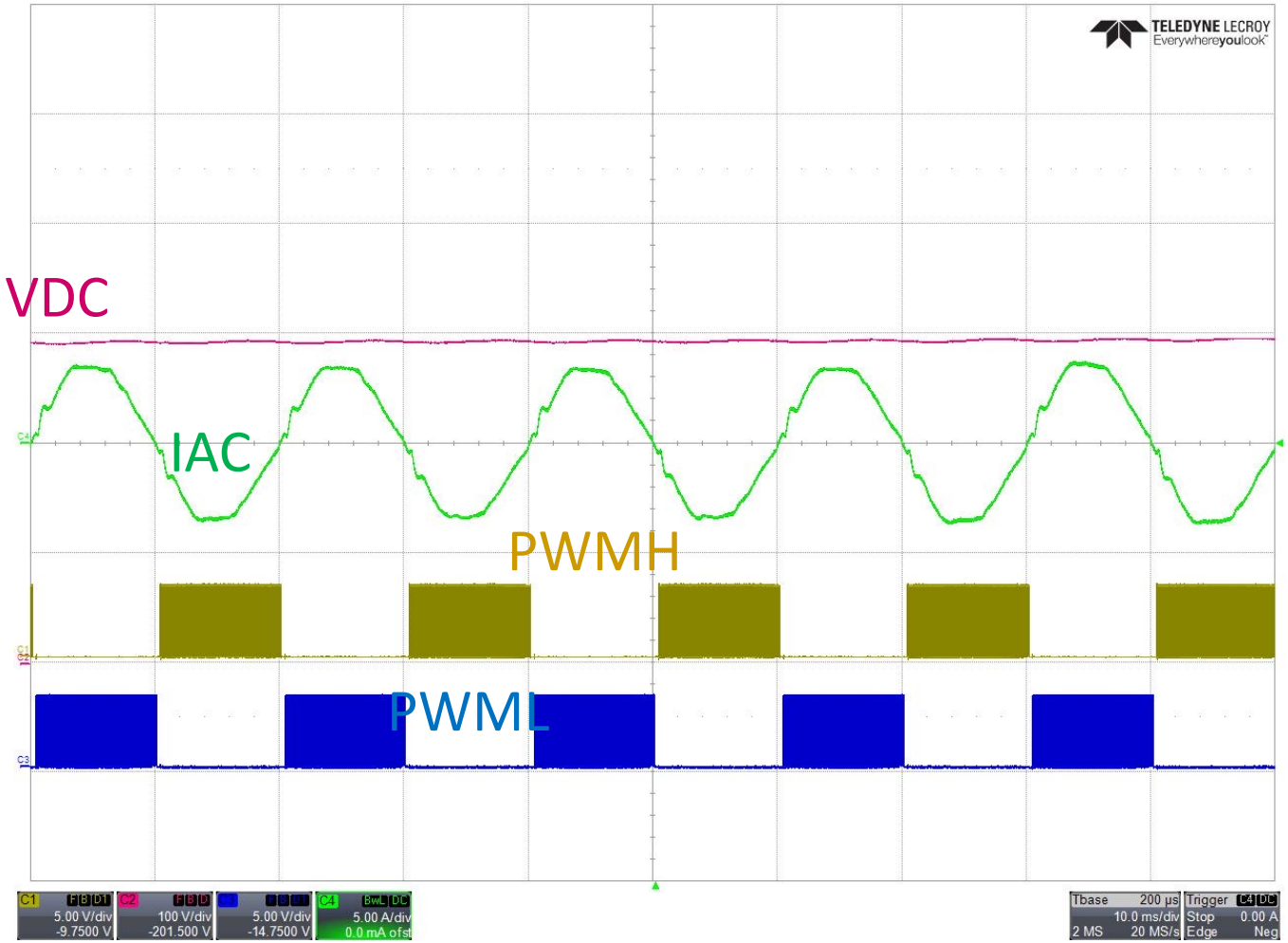
Startup during Ramp



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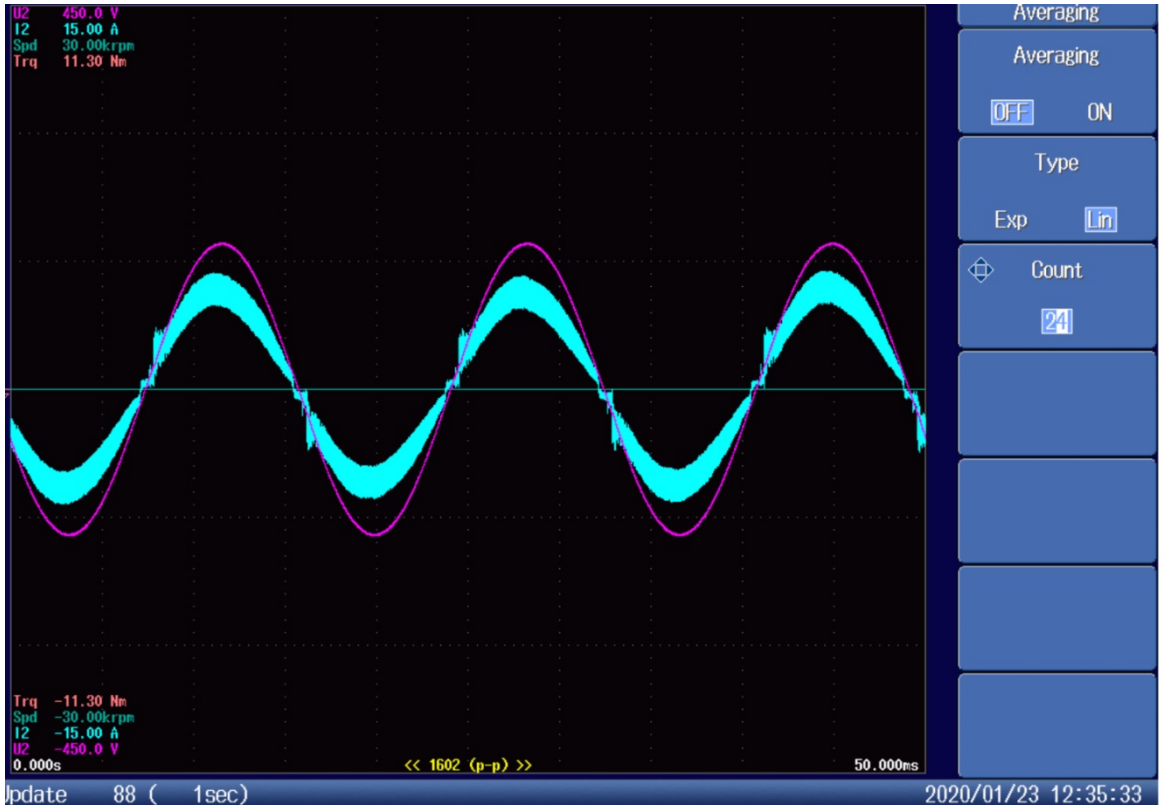
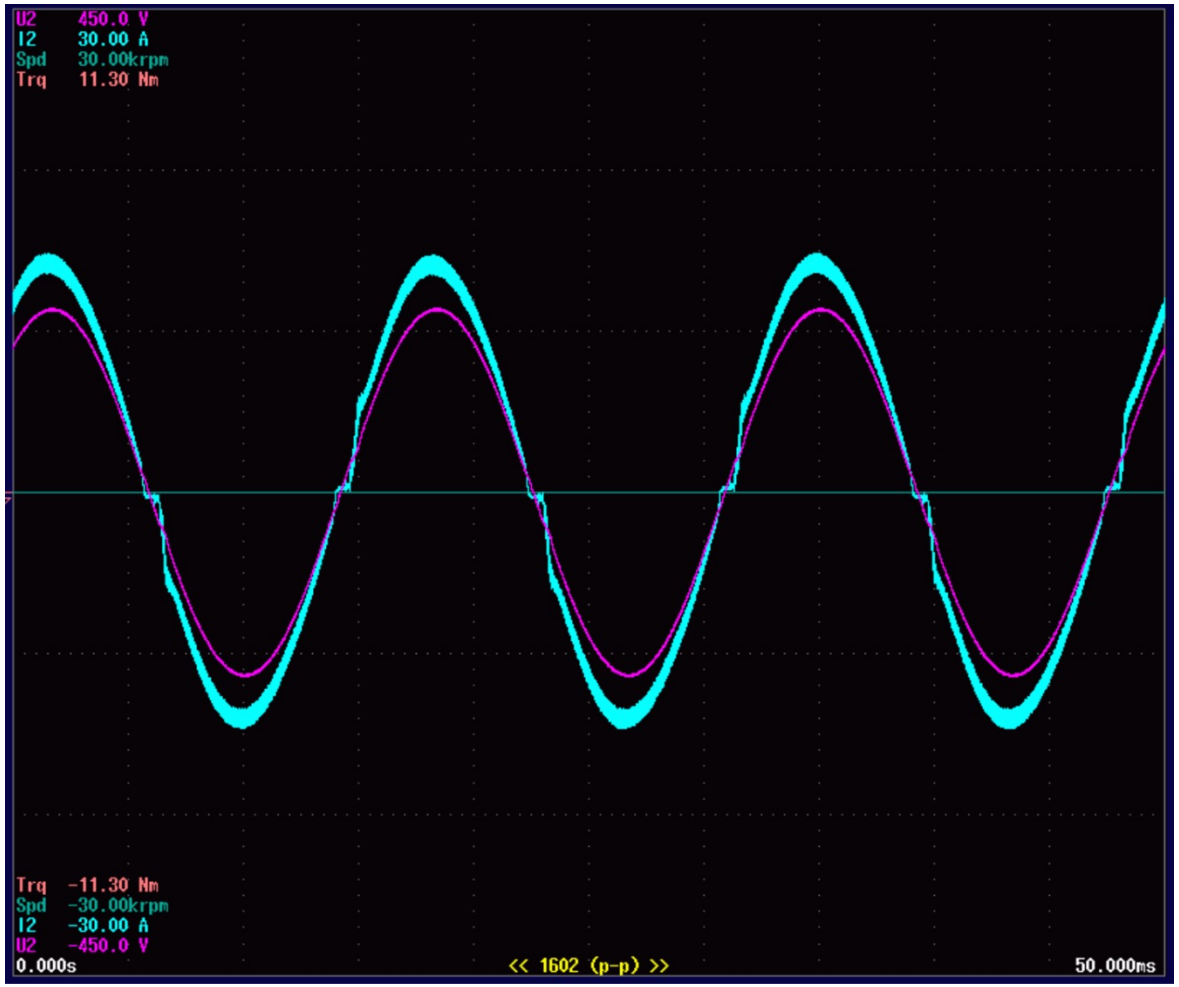
EFF & PF test results (Low Line)

Urms2	121.07 V
Irms2	2.8298 A
P2	0.3385 kW
Urms4	378.47 V
Irms4	0.8775 A
P4	331.49 W
$\eta 3$	97.944 %
$\lambda 2$	0.9879



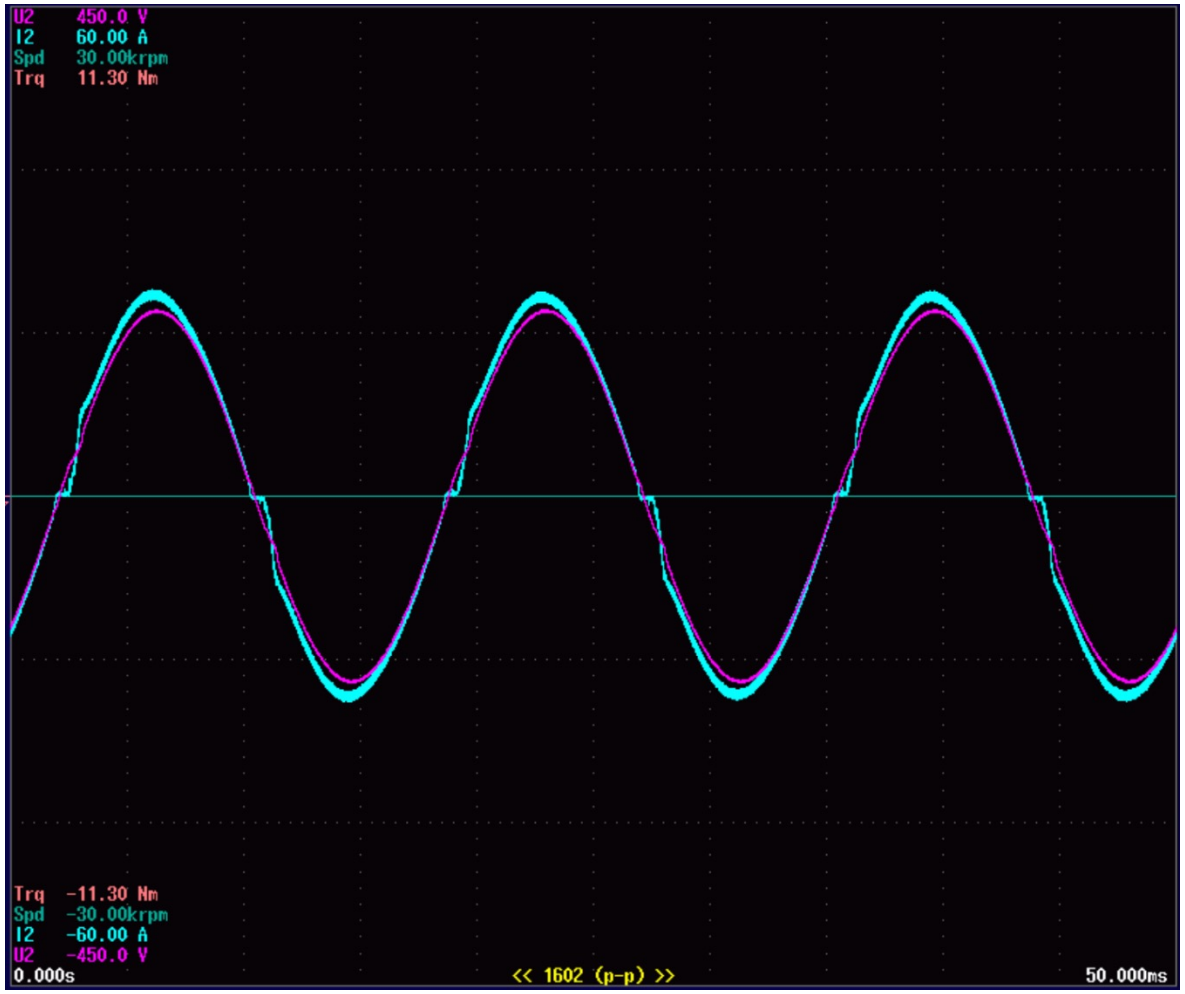
EFF & PF test results (Low Line)

Urms2	120.15 V
Irms2	9.973 A
P2	1.1959 kW
Urms4	377.97 V
Irms4	3.1097 A
P4	1.1750 kW
$\eta 3$	98.254 %
$\lambda 2$	0.9980



EFF & PF test results (Low Line)

Urms2	120.25 V
Irms2	17.168 A
P2	2.0609 kW
Urms4	377.03 V
Irms4	5.329 A
P4	2.0088 kW
η3	97.470 %
ff	
λ2	0.9983
F	



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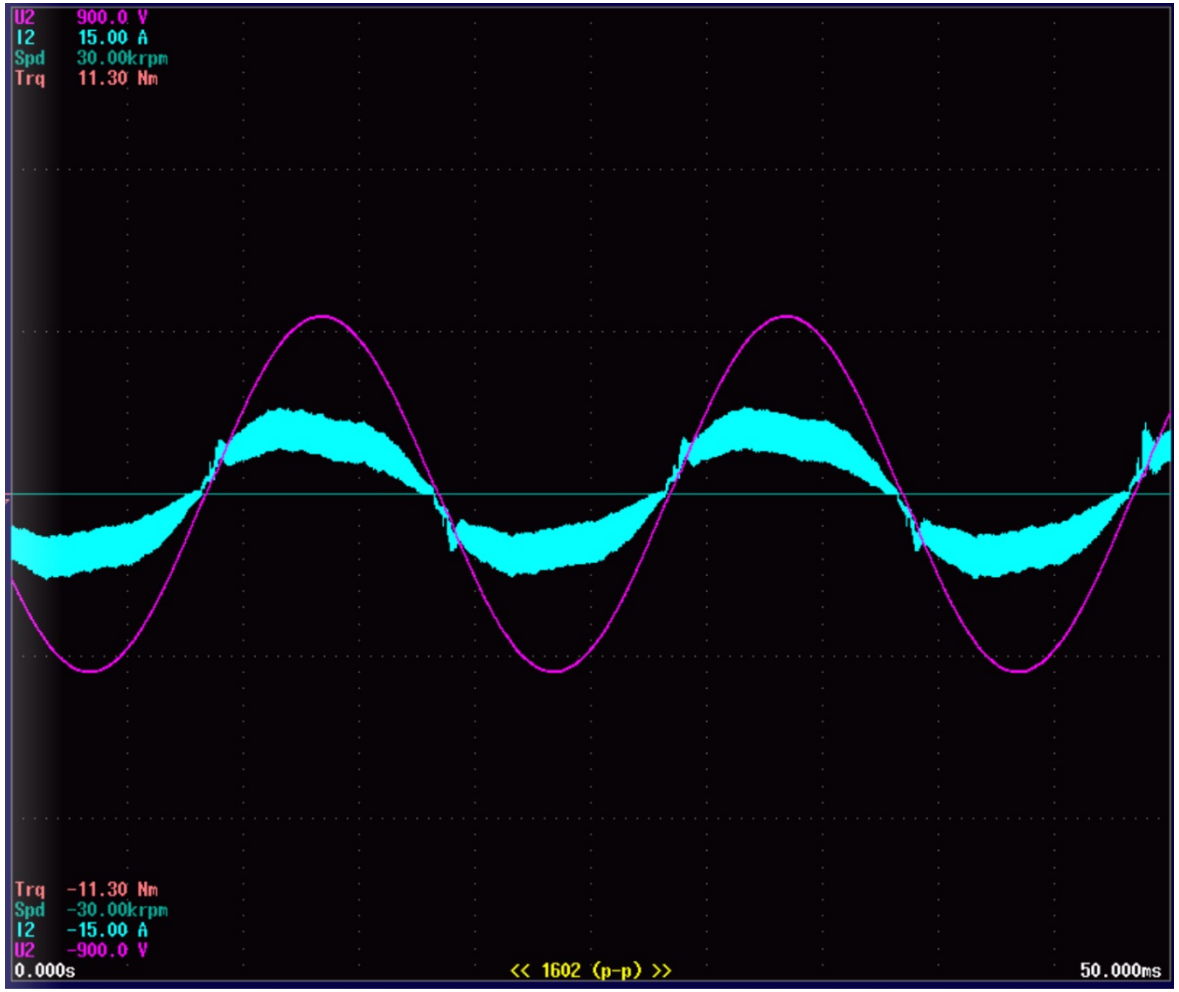
EFF & PF test results (High Line)

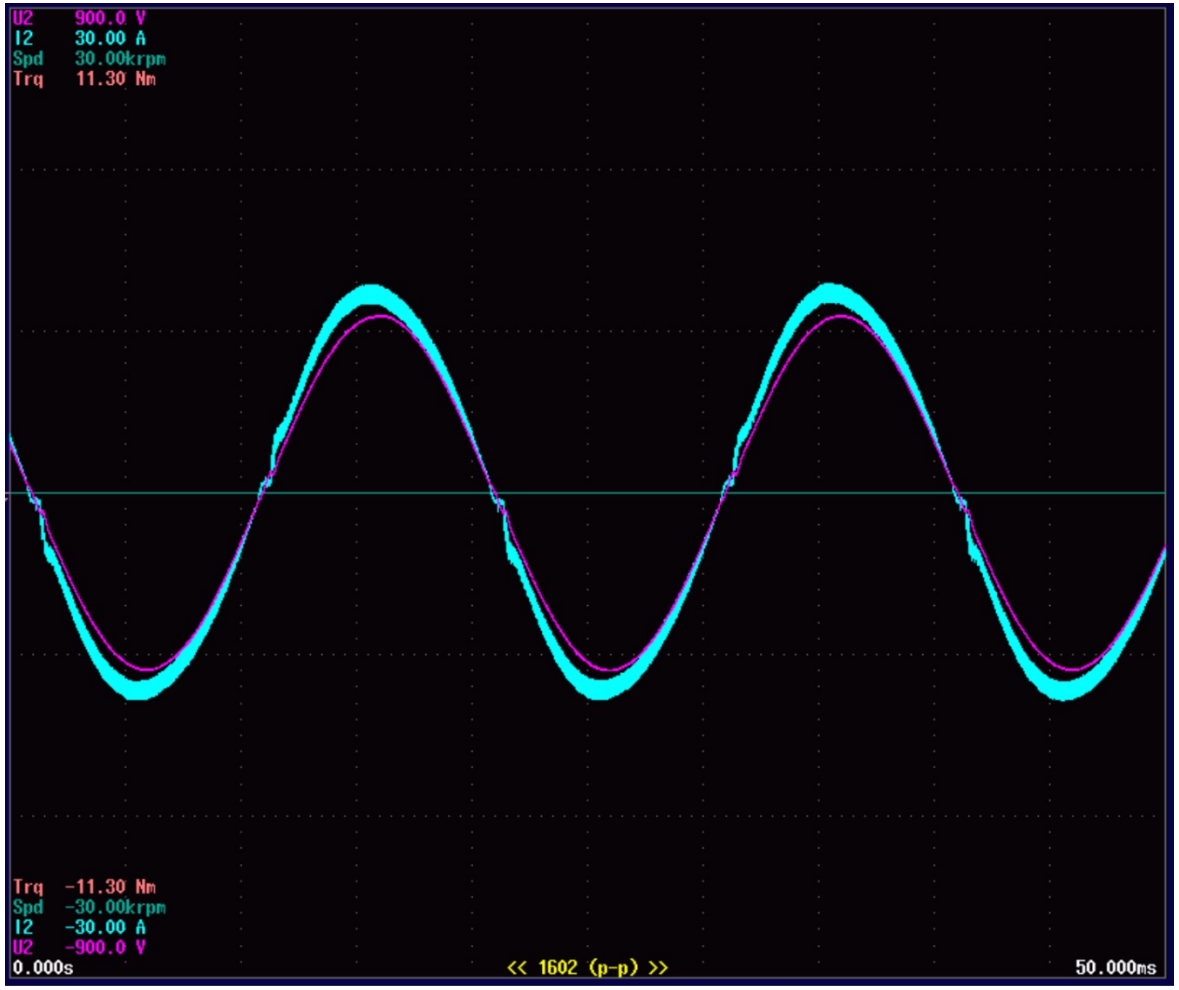
Urms2	231.85 V
Irms2	1.5283 A
P2	0.3346 kW
Urms4	378.46 V
Irms4	0.8714 A
P4	0.3293 kW
$\eta 3$	98.396 %
$\lambda 2$	0.9443



MICROCHIP

EFF & PF test results (High Line)

Urms2	231.17 V
Irms2	8.797 A
P2	2.0285 kW
Urms4	377.20 V
Irms4	5.329 A
P4	2.0100 kW
$\eta 3$	99.083 %
$\lambda 2$	0.9976



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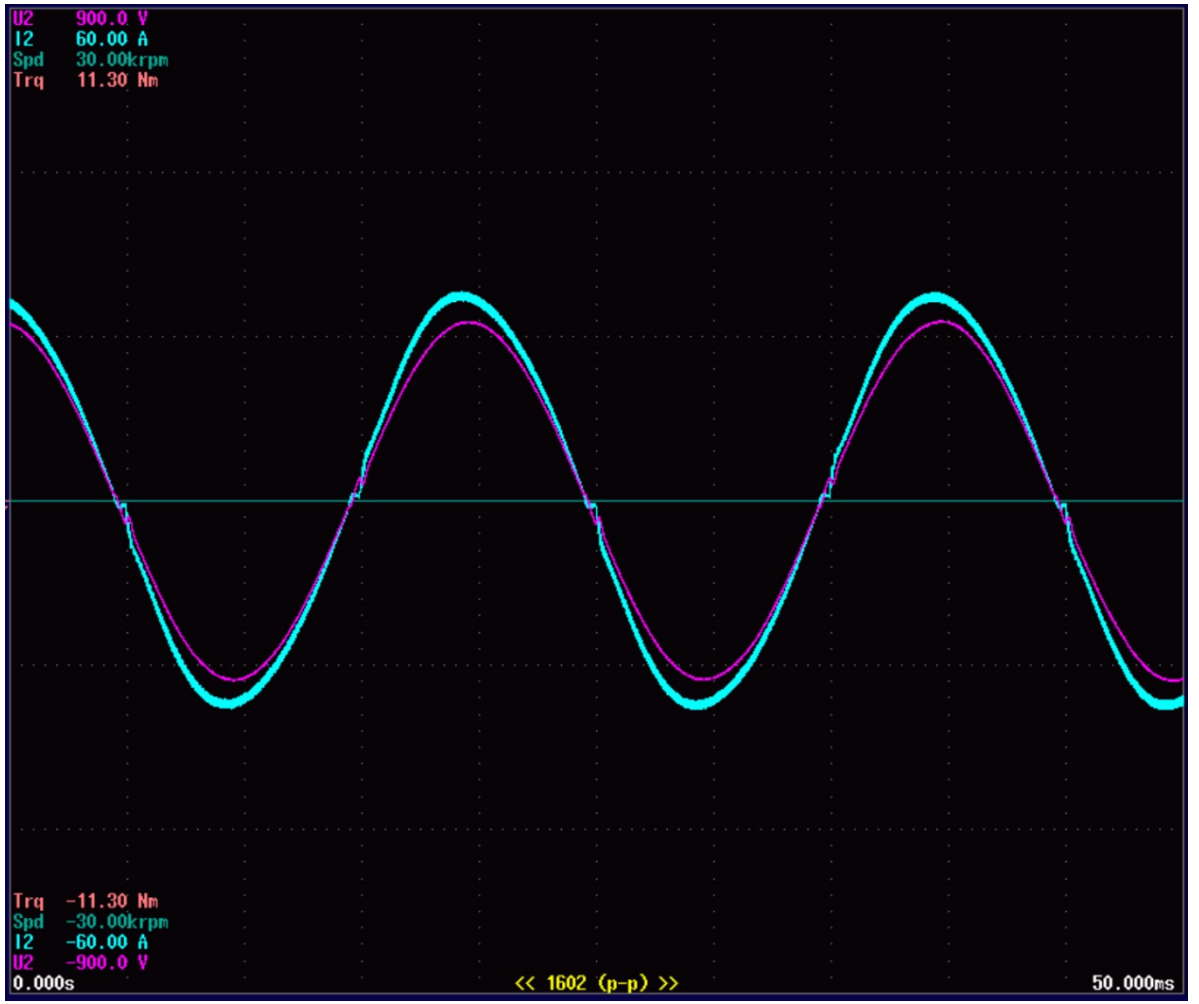
EFF & PF test results (High Line)

Urms2	230.01 V
Irms2	17.780 A
P2	4.0848 kW
Urms4	375.54 V
Irms4	10.728 A
P4	4.0287 kW
$\eta 3$	98.628 %
$\lambda 2$	0.9988



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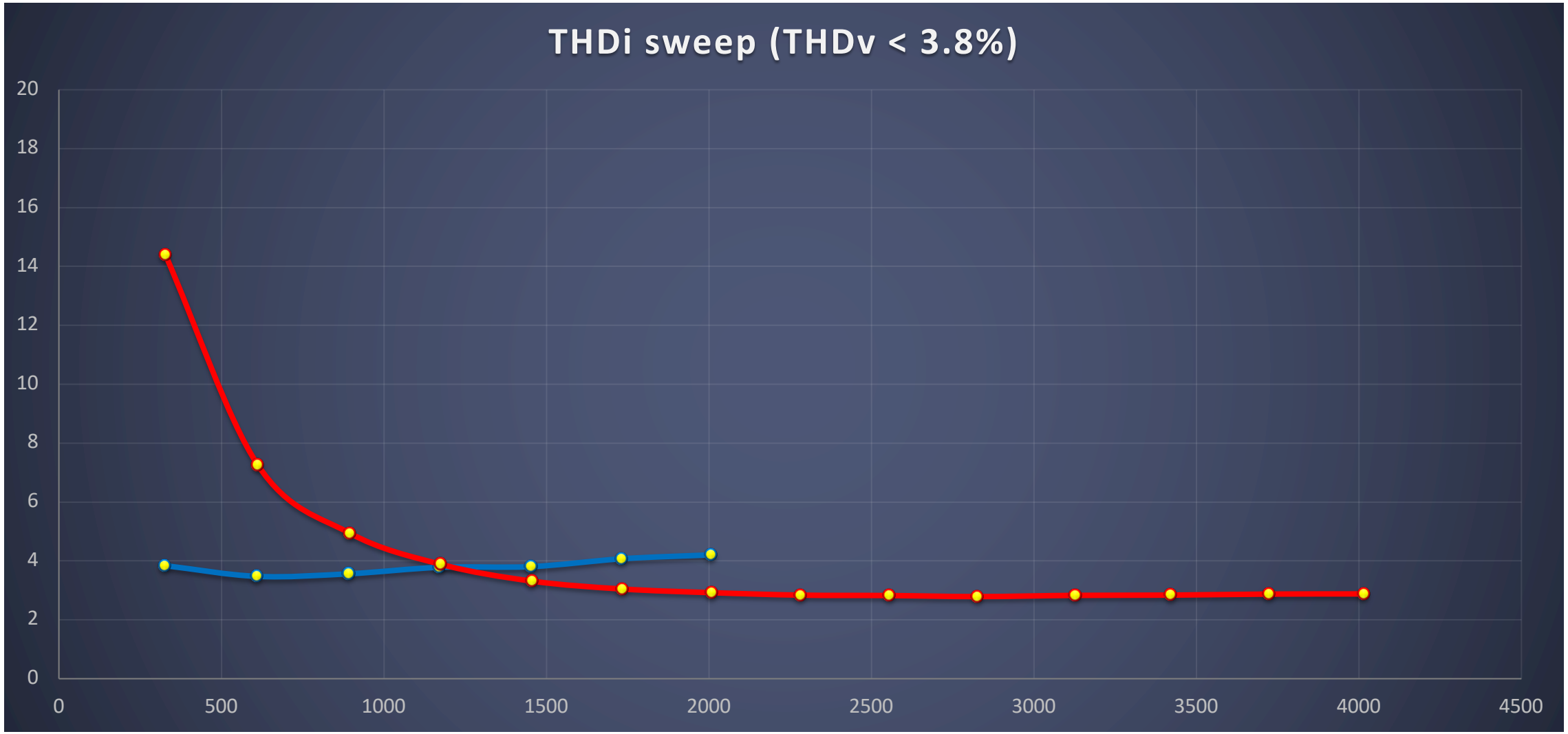
iTHD test results



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Thank you

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