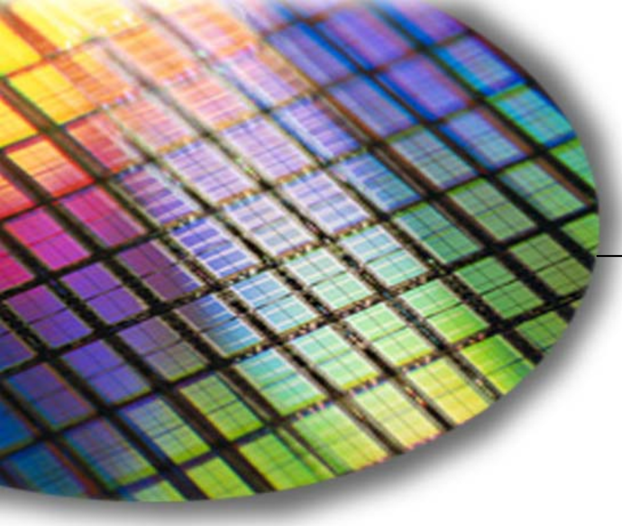


The World Leader in High-Performance Signal Processing Solutions

Calibrating the ADE7758 for Watt, VAR, RMS and VA measurements

CF based calibration - Integrator off

August, 2003

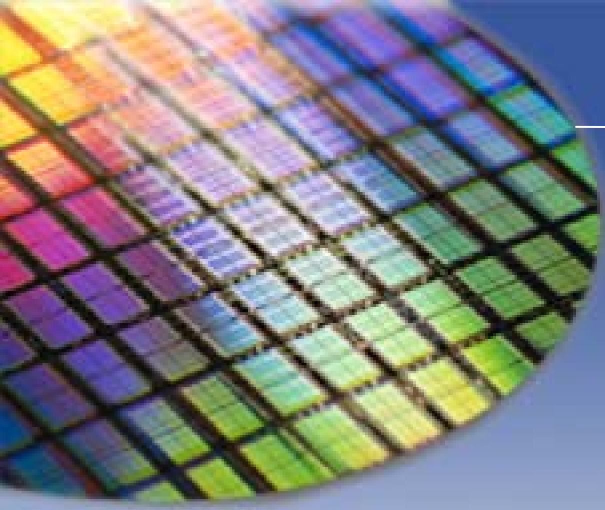
ANALOG DEVICES

Calibration Procedure Overview

- **Watt-Hour calibration**
  - **Gain Calibration**
  - **Phase Calibration**
  - **Offset Calibration**
- **Reactive Power**
  - **Gain Calibration**
  - **Offset Calibration**
- **IRMS**
  - **Offset Calibration**
- **VRMS**
  - **Offset Calibration**
- **Apparent Power Calibration**
  - **Gain Calibration**

Note: This presentation is designed to use APCF, VARCF & VACF to calibrate the meter.

A reduced calibration time can be realized if a full digital calibration is used in combination with the Line Cycle Accumulation Mode.



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Watt-Hour Calibration

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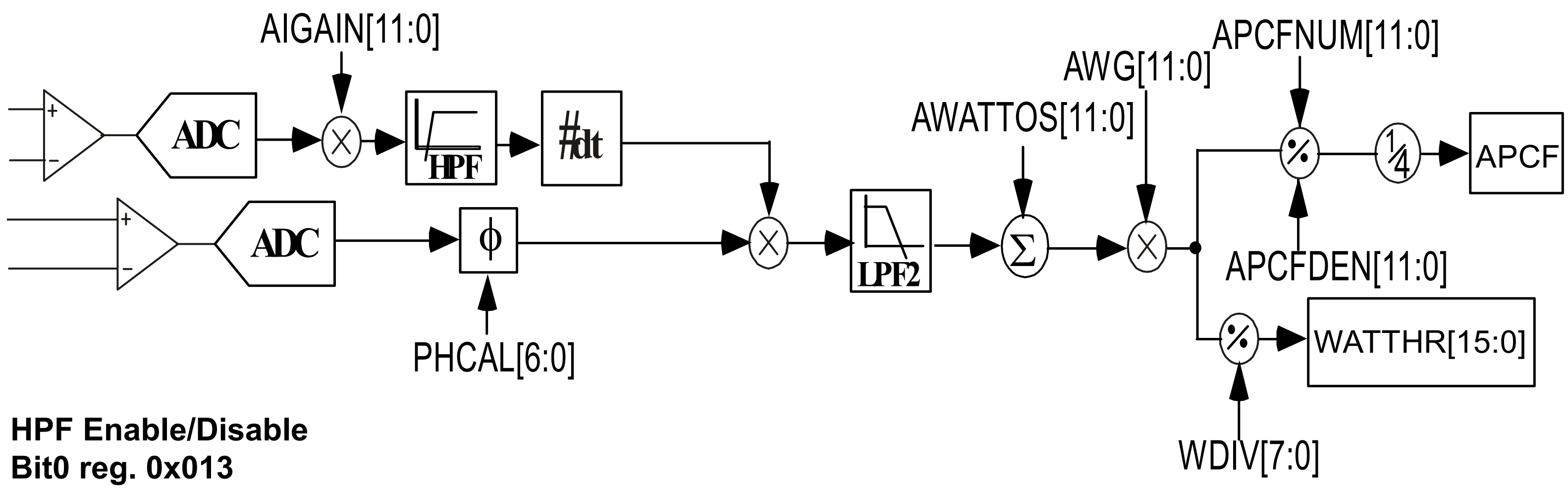
ADE7758 (Phase A) Watt-hour signal path



HPF Enable/Disable
Bit0 reg. 0x013
Default – Enabled

Integrator Enable/Disable
Bit7 reg. 0x0D
Default – Disabled

LPF2: Enable/Disable
Bit1 reg. 0x13
Default - Enabled

APCF: Enable/Disable
Bit 2 reg. 0x13
Default - Disabled

Step 1: Enable APCF Pulses Bit 2 reg. 0x13 – Set to 0

Step 2: Disable Phase B & C contribution to APCF Bit 3, Bit 4 reg. 0x16 – Set to 0

Watt-Hour Calibration Procedure

- **Gain Calibration**
  - Set APCFNUM(0x45) & APCFDEN(0x46) to the default values to perform a coarse adjustment on the imp/kWh ratio.
  - Measure %error in APCF from Reference Meter (Ib, PF=1.0)
  - Calculate AWG (0x2A) adjustment
- **Phase Calibration**
  - Measure %error in APCF from Reference Meter (Ib, PF=0.5)
  - Calculate phase error & compensate with APHCAL (0x3F)
- **Offset Calibration**
  - Measure %error in APCF from Reference Meter (Imin, PF=1.0)
  - Calculate offset error & compensate with AWATTOS (0x39)
- **Repeat for Phase B & C**

Watt-Hour GAIN Calibration

- **Use gain calibration for:**
  - **Meter to meter gain adjustment & APCF output rate calibration**
  - **Wh/LSB constant**

- **APCF gain adjustment:**

$$APCF = APCF_{initial} \times \frac{APCFNUM[11:0]}{APCFDEN[11:0]} \times \left(1 + \frac{xWG[11:0]}{2^{12}}\right)$$

- **xWATTHR Gain adjustment:**

$$xWATTHR = xWATTHR_{initial} \times \frac{1}{WDIV[7:0]} \times \left(1 + \frac{xWG[11:0]}{2^{12}}\right)$$

Watt-Hr calibration: Estimating APCFNUM & APCFDEN (1)

- Determine $APCF_{expected}$ & $APCF_{nominal}$ from the meter design
- For a meter design with
  - 3200 imp/kWh; Itest = 10A; Vtest = 240V; Line freq = 50Hz; PF=1

$$APCF_{\text{expected}} = \frac{3200 \times 10 \times 240}{1000 \times 3600} \times Cos(\phi) = 2.1333 Hz$$

Watt-Hr calibration: Estimating APCFNUM & APCFDEN (2)

- **$APCF_{nominal}$ is determined by the signal amplitude on the current & voltage inputs when Itest & Vtest are applied.**
  - **For our example we will assume that**
    - Vtest = 1/2 CH2 FS input
    - Itest = 1/12 CH1 FS input
- **APCF = ~ 16kHz when one phase has full scale inputs.**

$$APCF_{nominal} = 16kHz \times \frac{1}{2} \times \frac{1}{12} = 667\,Hz$$

- **Measure the APCF frequency with APCFNUM=APCFDEN=xWG=WDIV=0 on a sample set of meters to find the best value for your design**

Watt-Hr calibration:
Estimating APCFNUM & APCFDEN (3)

- **Calculate the APCFDEN with this equation from the ADE7758**

$$APCF_{expected} = APCF_{nominal} \times \frac{APCFNUM[11:0]}{APCFDEN[11:0]} \times \left(1 + \frac{xWG[11:0]}{2^{12}}\right)$$

- **First, do a coarse adjustment of the APCF output frequency and therefore use only APCFDEN. (xWG = 0 & APCFNUM = 0)**

$$APCFDEN = INT\left(\frac{APCF_{nominal}}{APCF_{expected}}\right) = INT\left(\frac{667}{2.1333}\right) = 313$$

- **Note: A zero “0” written to the APCFNUM/APCFDEN/xWG register is forced to “1” to avoid a divide by “0”.**

Watt-Hr calibration:
Measure CF error and calculate the xWG setting

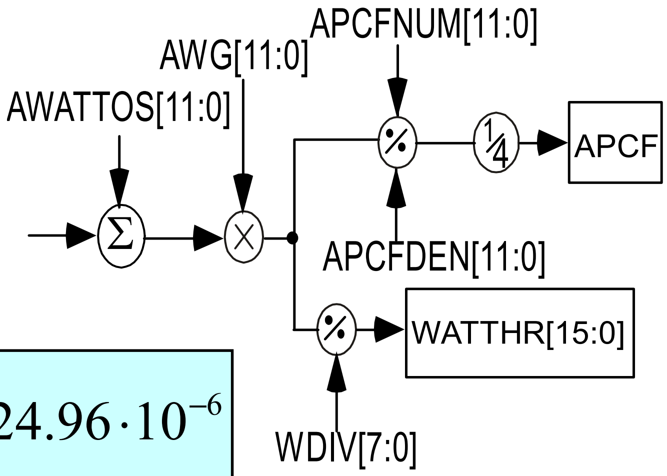
- With the meter at Itest & Vtest, measure the error in CF.
  - For example: CF error = -3.07%
- One lsb change in xWG (12 bits) changes the WATTHR register by 0.0244% and therefore APCF by 0.0244%.
- Use only the xWG adjustment to perform the fine adjustment (meter to meter) and have previously
  - Set APCFDEN = 313 and APCFNUM = 0 (actually = 1).

$$xWG = -\frac{APCF_{error}}{0.0244\%} = -\frac{-3.07\%}{0.0244\%} = 126$$

Watt-Hour GAIN calibration: Wh/LSB calibration

- **When APCF is calibrated, xWATTHR registers will have the same Wh/lsb from meter to meter, if the meter constant and the APCFNUM/APCFDEN ratio remain the same.**

$$Wh/lsb = \frac{1}{4 \times \frac{APCF_{const}}{1000} \times \frac{APCFDEN}{APCFNUM} \times \frac{1}{WDIV}}$$



For the example above:

$$Wh/lsb = \frac{1}{4 \times \frac{3200}{1000} \times \frac{313}{1} \times \frac{1}{1}} = \frac{1}{40064} = 24.96 \cdot 10^{-6}$$

To change the Wh/LSB constant, Change WDIV: If WDIV = 500, Wh/LSB = 0 .1248

Watt-Hour PHASE Calibration (1)

- **Use phase calibration for:**
  - **Compensation of phase shift from CT to CT**

- **Measure CF_{error} at Ib and PF=0.5 Inductive**

$$Phase\ Error(°) = -\text{Arcsin}\left(\frac{CF_{error}}{\sqrt{3}}\right)$$

Eq. 6

- **ADE7758 provides phase calibration for each Phase:**
  - **ADE7758's phase calibration is a time delay with different weights in the positive & negative direction**

$$+Delay = xPHCAL\ register \times 1.2\mu s$$
$$-Delay = xPHCAL\ register \times 2.4\mu s$$

xPHCAL[6:0] Dynamic range: +1.36° & -2.72° at 50Hz;

Note: Most CTs have Phase Lead – and because the ADE7758 PHCAL is introduced into the voltage channel, PHCAL will typically be negative, therefore we will focus on negative delays

Watt-Hour PHASE Calibration (2)

$$Phase\ Correction\left(°\right) = Delay \times 360° \times \frac{1}{Period\left(s\right)} = xPHCAL \times 2.4\mu s \times 360° \times \frac{1}{Period\left(s\right)}$$

- **Period can be measured with ADE7758's PERIOD (0x10) register**
  - **Note: LCYCMODE [bit 7] needs to equal 1 to get PERIOD**

Period (s) = PERIOD register x 9.6µs

$$Phase\ Correction\left(°\right) = xPHCAL \times 2.4\mu s \times 360° \times \frac{1}{PERIOD \times 9.6\mu s}$$

$$Phase\ Correction\left(°\right) = -Phase\,Error$$

$$xPHCAL \times \frac{2.4\mu s}{9.6\mu s} \times \frac{360°}{PERIOD} = \text{Arcsin}\left(\frac{Error}{\sqrt{3}}\right)$$

$$\Rightarrow xPHCAL\ \ \text{Register} = \text{Arcsin}\left(\frac{Error}{\sqrt{3}}\right) \times \frac{9.6\mu s}{2.4\mu s} \times \frac{PERIOD\ \text{Register}}{360°}$$

Eq. 7

Watt-Hour PHASE Calibration: Example

- **A 50Hz meter, measures 0.215% error at Ib & PF=0.5 Inductive**

$$Phase\ Error(°) = -\text{Arcsin}\left(\frac{0.00215}{\sqrt{3}}\right) = -0.07°$$

From Eq. 6

- **At 50Hz the PERIOD register = 2083d**

$$xPHCAL\ \text{ Register} = -0.07° \times \frac{9.6\mu s}{2.4\mu s} \times \frac{2083}{360°}$$

$$xPHCAL\ \text{ Register} = -1.62 \Rightarrow -2$$

Watt-Hour OFFSET Calibration (1)

- **Use power offset calibration for:**
  - **Outstanding performance over wide dynamic range (1,000:1)**
- **Measure CF_{error} at Imin & PF=1**

$$APCF_{measured} = (LPF) \times \frac{CLKIN}{4} \times \frac{1}{2^{27}} \times \frac{APCFNUM}{APCFDEN} \quad \text{eq. 1}$$

$$APCF_{expected} = \left(LPF + \frac{xWATTOS}{2^{4}} \right) \times \frac{CLKIN}{4} \times \frac{1}{2^{27}} \times \frac{APCFNUM}{APCFDEN} \quad \text{eq. 2}$$

- **Let Q represent the timing for simplification of the equation**

$$Q = \frac{CLKIN}{4} \times \frac{1}{2^{25}} \times \frac{1}{4}$$

Watt-Hour OFFSET Calibration (2)

Therefore

$$APCF_{measured} = (LPF) \times Q \times \frac{APCFNUM}{APCFDEN} \quad and \quad LPF = \frac{APCF_{measured}}{Q \times \frac{APCFNUM}{APCFDEN}}$$

Substituting LPF into eq 2

$$APCF_{expected} = \left(\frac{APCF_{measured} \times \frac{APCFDEN}{APCFNUM}}{Q} + \frac{xWATTOS}{2^4} \right) \times Q \times \frac{APCFNUM}{APCFDEN}$$

$$APCF_{expected} = APCF_{measured} + \frac{xWATTOS \times Q}{2^4} \times \frac{APCFNUM}{APCFDEN}$$

Watt-Hour OFFSET Calibration (3)

Solving for WATTOS:

$$xWATTOS = \left(APCF_{expected} - APCF_{measured}\right) \times \frac{2^4}{Q} \times \frac{APCFDEN}{APCFNUM} \quad \text{eq. 3}$$

%error equation:

$$\%APCF_{error} = \frac{APCF_{measured} - APCF_{expected}}{APCF_{expected}}$$

$$APCF_{expected} - APCF_{measured} = -\left(\%APCF_{error} \times APCF_{expected}\right)$$

Substituting into eq 3

$$xWATTOS = -\left(\%APCF_{error} \times APCF_{expected}\right) \times \frac{2^4}{Q} \times \frac{APCFDEN}{APCFNUM}$$

Watt-Hour OFFSET Calibration (Summary)

- The resulting equation to determine xWATTOS is:

$$xWATTOS = -\left(\%APCF_{error} \times APCF_{expected}\right) \times \frac{2^4}{Q} \times \frac{APCFDEN}{APCFNUM}$$

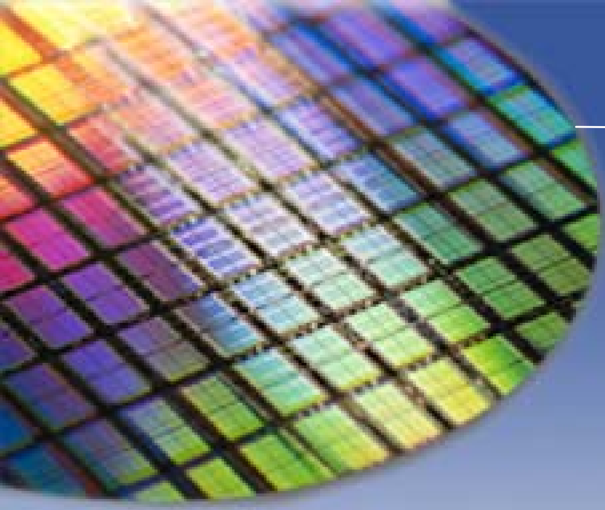
- Where:

$$Q = \frac{CLKIN}{4} \times \frac{1}{2^{25}} \times \frac{1}{4}$$

$$\%APCF_{error} = \frac{APCF_{measured} - APCF_{expected}}{APCF_{expected}}$$

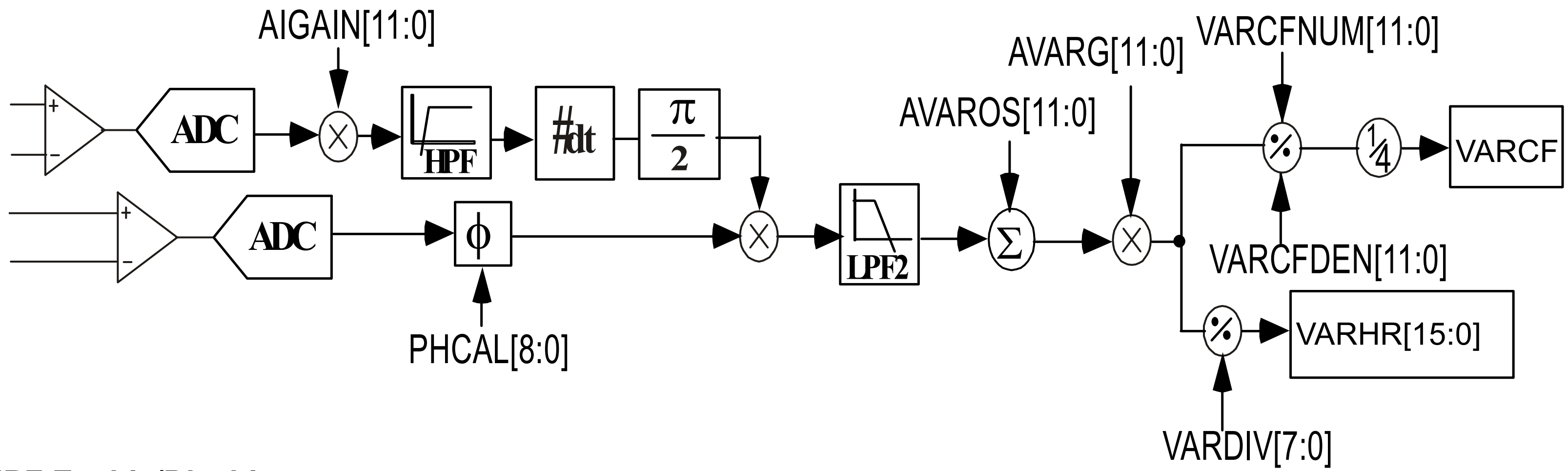
- The expected value is calculated or measured from the reference meter

$$APCF_{expected} = \frac{WattHr_{reference} \times \mathrm{MeterConstant}}{1000 \times 3600}$$



VAR-Hour Calibration

ADE7758 (Phase A) VAR-hour signal path



HPF Enable/Disable
Bit0 reg. 0x013
Default – Enabled

Integrator Enable/Disable
Bit7 reg. 0x0D
Default – Disabled

LPF2: Enable/Disable
Bit1 reg. 0x13
Default - Enabled

VARCF: Enable/Disable
Bit 2 reg. 0x13
Default - Disabled

Step 1: Enable VARCF Pulses Bit 2 reg. 0x13 – Set to 0
Bit 7 reg. 0x15 – Set to 0

Step 2: Disable Phase B & C contribution to APCF
Bit 3, Bit 4 reg. 0x16 – Set to 0

VAR-Hour Calibration Procedure

- Gain Calibration
  - Set VARCFNUM(0x47) & VARCFDEN(0x48) the default values to perform a coarse adjustment on the imp/VARh ratio.
  - Measure %error in VARCF from Reference Meter (Ib, PF=0)
  - Calculate AVARG (0x2D) adjustment
- Offset Calibration
  - Measure %error in VARCF from Reference Meter (Imin, PF=0)
  - Calculate offset error & compensate with AVAROS (0x3C)
- Repeat for Phase B & C

VAR-Hour GAIN Calibration

- Use gain calibration for:
  - Meter to meter gain adjustment & VARCF output rate calibration
  - VARh/LSB constant

- VARCF gain adjustment:

$$VARCF = VARCF_{initial} \times \frac{VARCFNUM[11:0]}{VARCFDEN[11:0]} \times \left(1 + \frac{xVARG[11:0]}{2^{12}}\right)$$

- xVARHR Gain adjustment:

$$xVARHR = xVARHR_{initial} \times \frac{1}{VARDIV[7:0]} \times \left(1 + \frac{xVARG[11:0]}{2^{12}}\right)$$

VAR-Hr calibration: Determining VARCFNUM & VARCFDEN (1)

- Determine $VARCF_{expected}$ & $VARCF_{nominal}$ from the meter design.

- For a meter design with
  - 3200 imp/kVARh; Itest = 10A; Vtest = 240V; Line freq = 50Hz; PF=0

$$VARCF_{\text{expected}} = \frac{3200 \times 10 \times 240}{1000 \times 3600} \times Sin(\phi) = 2.1333 Hz$$

VAR-Hr calibration: Determining VARCFNUM & VARCFDEN (2)

- **$VARCF_{nominal}$ is determined by the signal amplitude on the current & voltage inputs when Itest & Vtest are applied.**
  - **For our example we will assume that**
    - Vtest = 1/2 CH2 FS input
    - Itest = 1/12 CH1 FS input (with PF=0)
- **CF = ~ 16kHz when one phase has full scale inputs.**

$$VARCF_{nominal} = 16kHz \times \tfrac{1}{2} \times \tfrac{1}{12} = 667\,Hz$$

- **Measure the VARCF frequency with VARCFNUM=VARCFDEN=xVARG=VARDIV=0 on a sample set of meters to find the best value for your design**

VAR-Hr calibration: Determining VARCFNUM & VARCFDEN (3)

- **Calculate the VARCFDEN with this equation from the ADE7758**

$$VARCF_{expected} = VARCF_{nominal} \times \frac{VARCFNUM[11:0]}{VARCFDEN[11:0]} \times \left(1 + \frac{xVARG[11:0]}{2^{12}}\right)$$

- **First, do a coarse adjustment of the VARCF output frequency and therefore use only VARCFDEN. (xVARG = 0 & VARCFNUM = 0)**

$$VARCFDEN = INT\left(\frac{VARCF_{nominal}}{VARCF_{expected}}\right) = INT\left(\frac{667}{2.1333}\right) = 313$$

- **Note: A zero “0” written to the VARCFNUM/VARCFDEN/xVARG register is forced to “1” to avoid a divide by “0”.**

VAR-Hr calibration: Measure VARCF error and calculate the xVARG setting

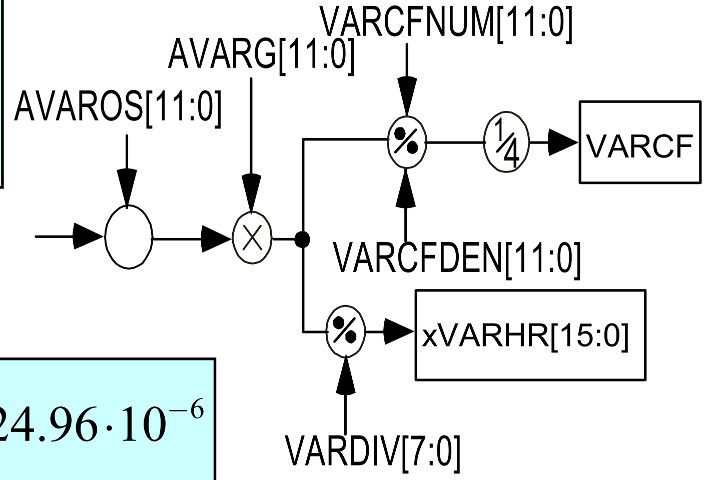
- **With the meter at Itest & Vtest, measure the error in VARCF.**
  - **For example: VARCF error = -4.05%**
- **One lsb change in xVARG (12 bits) changes the VARHR register by 0.0244% and therefore VARCF by 0.0244%**
- **Use only the xVARG adjustment to perform the fine adjustment (meter to meter) and have previously**
  - **Set VARCFDEN = 313 and VARCFNUM = 0 (actually = 1).**

$$xVARG = -\frac{VARCF_{error}}{0.0244\%} = -\frac{-4.05\%}{0.0244\%} = 165$$

VAR-Hour GAIN calibration: VARh/LSB calibration

- **When VARCF is calibrated, xVARHR registers will have the same VARh/lsb from meter to meter, if the meter constant and the VARCFNUM/VARCFDEN ratio remain the same.**

$$VARh/lsb = \frac{1}{4 \times \frac{VARCF_{const}}{1000} \times \frac{VARCFDEN}{VARCFNUM} \times \frac{1}{VARDIV}}$$



For the example above:

$$VARh/lsb = \frac{1}{4 \times \frac{3200}{1000} \times \frac{313}{1} \times \frac{1}{1}} = \frac{1}{40064} = 24.96 \cdot 10^{-6}$$

To scale the VARh/LSB constant, Change VARDIV: If VARDIV = 500, VARh/LSB = 0 .1248

VAR-Hour OFFSET Calibration (1)

- Use power offset calibration for:
  - Outstanding performance over wide dynamic range (1,000:1)
- Measure $VARCF_{error}$ at Imin & PF=0

$$VARCF_{measured} = (LPF) \times \frac{CLKIN}{4} \times \frac{1}{2^{27}} \times \frac{VARCFNUM}{VARCFDEN} \times \frac{202}{\left(PERIOD/4\right)}$$

$$VARCF_{expected} = \left(LPF + \frac{xVAROS}{2^{4}}\right) \times \frac{CLKIN}{4} \times \frac{1}{2^{27}} \times \frac{VARCFNUM}{VARCFDEN} \times \frac{202}{\left(PERIOD/4\right)}$$

- Let Q represent the timing for simplification of the equation

$$Q = \frac{CLKIN}{4} \times \frac{1}{2^{24}} \times \frac{202}{\left(PERIOD/4\right)} \times \frac{1}{4}$$

VAR-Hour OFFSET Calibration (2)

- The resulting equation to determine xVAROS is:

$$xVAROS = -\%VARCF_{error} \times VARCF_{expected} \times \frac{2^4}{Q} \times \frac{VARCFDEN}{VARCFNUM}$$

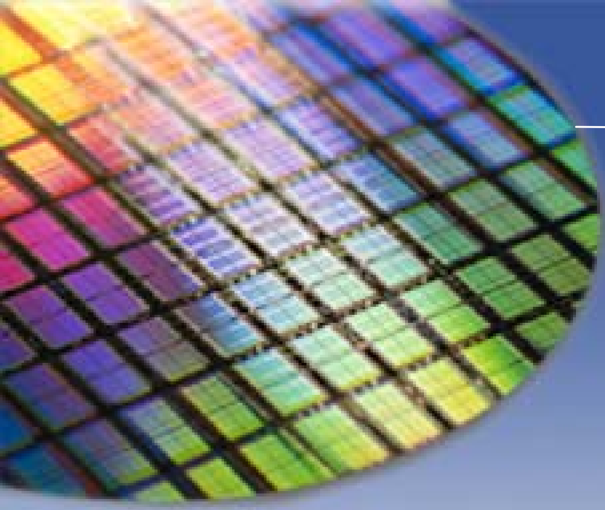
- Where:

$$Q = \frac{CLKIN}{4} \times \frac{1}{2^{24}} \times \frac{202}{\left(PERIOD/4\right)} \times \frac{1}{4}$$

$$\%VARCF_{error} = \frac{VARCF_{measured} - VARCF_{\text{expected}}}{VARCF_{\text{expected}}}$$

- The expected value is calculated of measured from the reference meter

$$VARCF_{expected} = \frac{VARHr_{reference} \times \text{MeterConstant}}{1000 \times 3600}$$

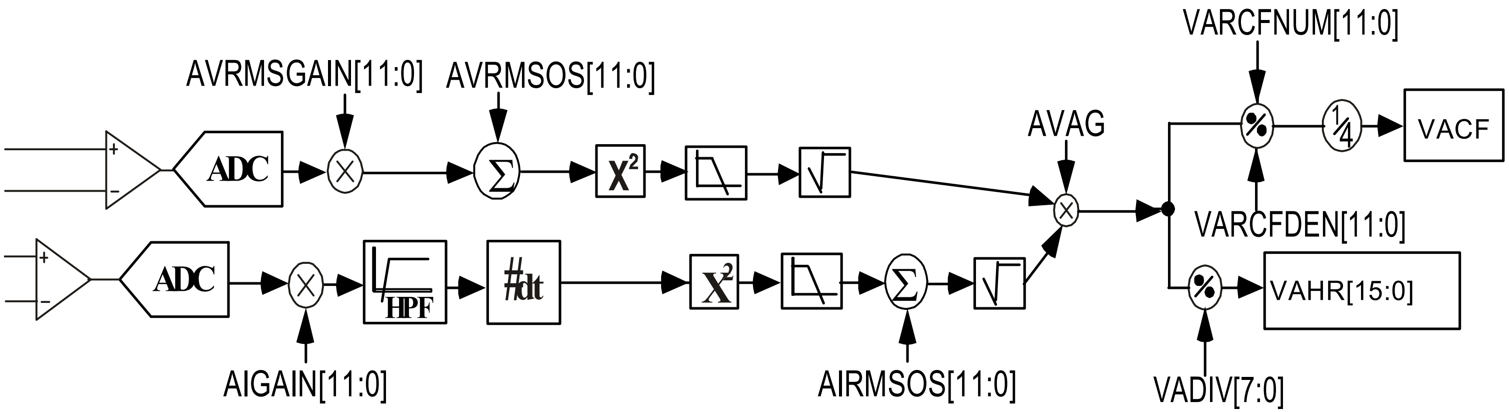


VA-Hour Calibration

VA-Hour Calibration Procedure

- Calibrate IRMS (for all phases)
- Calibrate VRMS (for all phases)
- Gain Calibration (phase A)
  - Repeat Gain Calibration for Phase B & C

ADE7758 (Phase A) VA-hour signal Path



HPF Enable/Disable
Bit0 reg. 0x013
Default – Enabled

Integrator Enable/Disable
Bit7 reg. 0x0D
Default – Disabled

LPF2: Enable/Disable
Bit1 reg. 0x13
Default - Enabled

VACF: Enable/Disable
Bit 2 reg. 0x13
Default – Disabled
• VACF and VARCF share an output
Select Bit 7 reg. 0x15 for VA-hr pulses

Step 1: Enable VACF Pulses Bit 2 reg. 0x13 – Set to 0
Bit 7 reg. 0x15 – Set to 1

Step 2: Disable Phase B & C contribution to VACF
Bit 3, Bit 4 reg. 0x16 – Set to 0

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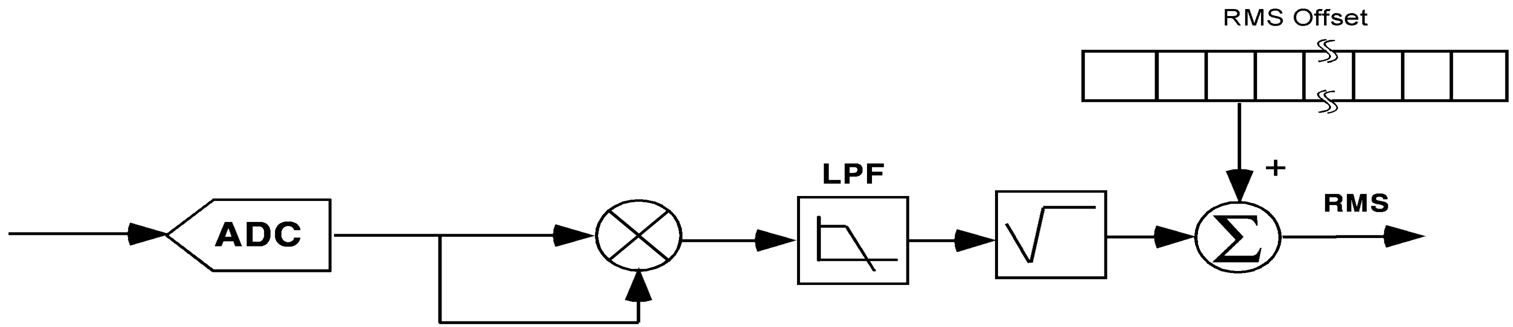
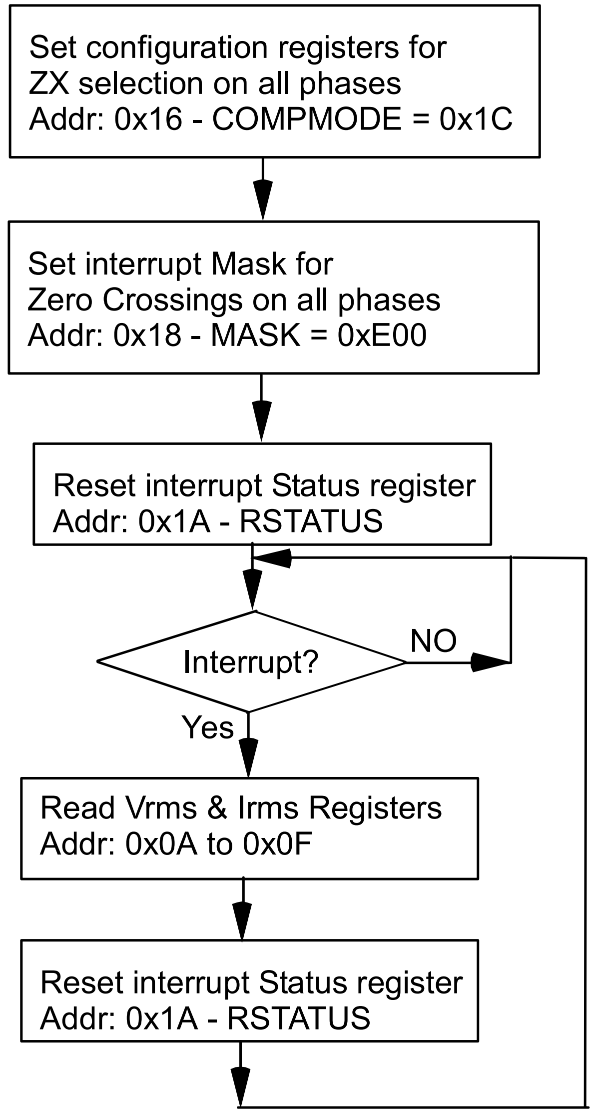
IRMS and VRMS Offset Calibration



- Use xIRMSOS and xVRMSOS for:
  - Canceling noise and offset contributions from the input
- Since the LPF is not perfect, ripple noise is present in the rms measurement
- Synchronize rms reading with zero crossings of voltage input from each phase to minimize this noise effect

RMS Offset Calibration Routine



IRMS Offset Calibration

- Current rms calculation is linear from FS to FS/100
- To measure the I_{RMS} offset (IRMSOS), measure rms values at two different current levels (e.g. I_{test} and $I_{max}/100$)

$$I_{rms}^{2} = I_{rms0}^{2} + 16,384 \times IRMSOS$$

  - Where I_{ms0} is the IRMS measurement without offset correction

$$IRMSOS = \frac{1}{16,384} \times \frac{I_1^2 \times I_{rms2}^{2} - I_2^2 \times I_{rms1}^{2}}{I_2^2 - I_1^2}$$

  - Where I_{ms1} and I_{rms2} are rms register values without offset correction for input I_1 and I_2 respectively

- To minimize noise, synchronize each reading with zero crossing of voltage input in each phase and take the average of these readings

VRMS Offset Calibration

- Voltage rms calculation is linear from FS to FS/20
- To measure the V_{RMS} offset (VRMSOS), measure rms values at two different current levels (e.g. $V_{nominal}$ and $V_{nominal}/20$)

$$V_{rms} = V_{rms0} + 64 \times VRMSOS$$

  - Where V_{ms0} is the VRMS measurement without offset correction

$$VRMSOS = 64 \times \frac{V_1 \times V_{rms2} - V_2 \times V_{rms1}}{V_2 - V_1}$$

  - Where V_{ms1} and V_{rms2} are rms register values without offset correction for input V_1 and V_2 respectively

- To minimize noise, synchronize each reading with zero crossing of voltage input in each phase and take the average of these readings

VA-Hour GAIN Calibration

- **Use gain calibration for:**
  - **Meter to meter gain adjustment & VACF output rate calibration**
  - **VAh/LSB constant**

- **VACF gain adjustment:**

$$VACF = VACF_{initial} \times \frac{VARCFNUM[11:0]}{VARCFDEN[11:0]} \times \left(1 + \frac{xVAG[11:0]}{2^{12}}\right)$$

- **xVAHR Gain adjustment:**

$$xVAHR = xVAHR_{initial} \times \frac{1}{VADIV[7:0]} \times \left(1 + \frac{xVAG[11:0]}{2^{12}}\right)$$

- **Note: VARCFNUM & VARCFDEN scale VACF**

VA-Hr calibration: Determining VARCFNUM & VARCFDEN (1)

- The VACF output on the same pin as the VARCF output and is scaled by VARCFNUM & VARCFDEN, therefore if the $VARCF_{const}$ and the $VACF_{const}$ are the same then the VARCFNUM & VARCFDEN values will be the same for the VACF output.
- Determine $VACF_{expected}$ & $VACF_{nominal}$ from the meter design.
- For a meter design with
  - 3200 imp/kVAWh ; Itest = 10A; Vtest = 240V; Line freq = 50Hz

$$VACF_{expected} = \frac{3200 \times 10 \times 240}{1000 \times 3600} = 2.1333Hz$$

VA-Hr calibration: Determining VARCFNUM & VARCFDEN (2)

- **$VACF_{nominal}$ is determined by the signal amplitude on the current & voltage inputs when Itest & Vtest are applied.**
  - **For our example we will assume that**
    - Vtest = 1/2 CH2 FS input
    - Itest = 1/12 CH1 FS input (with PF=1)
- **CF = ~ 16kHz when one phase has full scale inputs.**

$$VACF_{nominal} = 16kHz \times \tfrac{1}{2} \times \tfrac{1}{12} = 667\,Hz$$

- **Measure the VACF frequency with VARCFNUM=VARCFDEN=xVAG=VADIV=0 on a sample set of meters to find the best value for your design**

VA-Hr calibration: Determining VARCFNUM & VARCFDEN (3)

- **Calculate the VARCFDEN with this equation from the ADE7758**

$$VACF_{expected} = VACF_{nominal} \times \frac{VARCFNUM[11:0]}{VARCFDEN[11:0]} \times \left(1 + \frac{xVAG[11:0]}{2^{12}}\right)$$

- **First, do a coarse adjustment of the VACF output frequency and therefore use only VARCFDEN. (xVAG = 0 & VARCFNUM = 0)**

$$VARCFDEN = INT\left(\frac{VACF_{nominal}}{VACF_{expected}}\right) = INT\left(\frac{667}{2.1333}\right) = 313$$

- **Note: A zero "0" written to the VARCFNUM/VARCFDEN/xVAG register is forced to "1" to avoid a divide by "0".**

VA-Hr calibration: Measure VACF error and calculate the xVAG setting

- With the meter at Itest & Vtest, measure the error in VACF.
  - For example: VACF error = 1.67%
- One lsb change in xVAG (12 bits) changes the VAHR register by 0.0244% and therefore VACF by 0.0244%
- Use only the xVAG adjustment to perform the fine adjustment (meter to meter) and have previously
  - Set VARCFDEN = 313 and VARCFNUM = 0.

$$xVAG = -\frac{VACF_{error}}{0.0244\%} = -\frac{1.67\%}{0.0244\%} = -68$$

VA-Hour GAIN calibration: VAh/LSB calibration

- When VACF is calibrated, xVAHR registers will have the same VAh/lsb from meter to meter, if the meter constant and the VARCFNUM/VARCFDEN ratio remain the same.

$$VAh/lsb = \frac{1}{4 \times \frac{VACF_{const}}{1000} \times \frac{VARCFDEN}{VARCFNUM} \times \frac{1}{VADIV}}$$

For the example above:

$$VAh/lsb = \frac{1}{4 \times \frac{3200}{1000} \times \frac{313}{1} \times \frac{1}{1}} = \frac{1}{40064} = 24.96 \cdot 10^{-6}$$

To scale the VAh/LSB constant, Change VADIV: If VADIV = 500, VAh/LSB = 0 .1248