

The World Leader in High-Performance Signal Processing Solutions



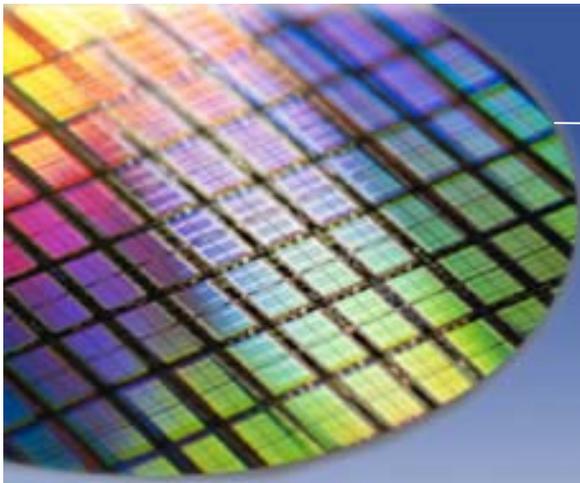
# Calibrating the ADE7754 for Watt, RMS and VA measurements

Feb 17, 2003



# Agenda

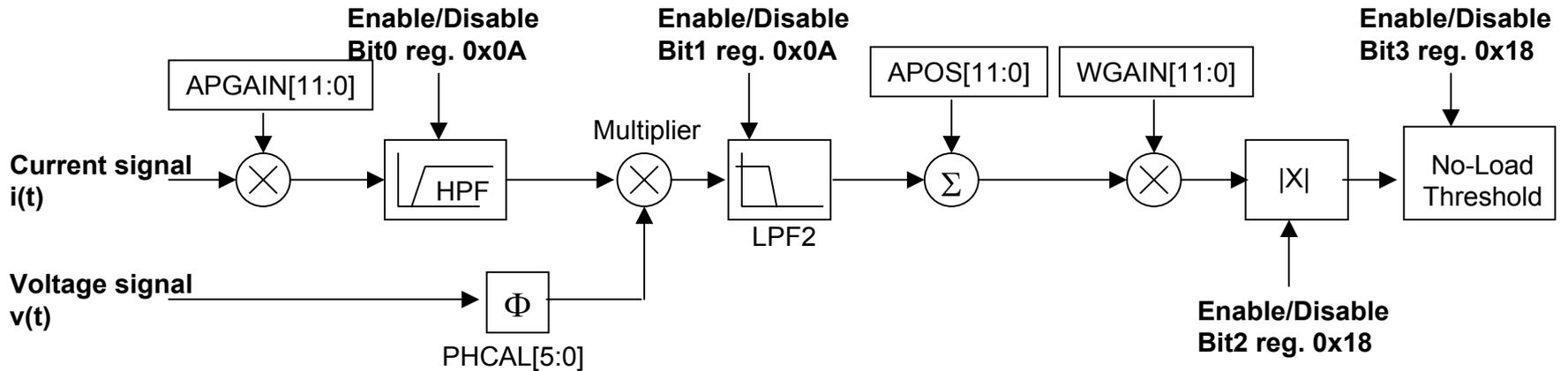
- ◆ **Watt-hour Calibration**
  - Signal path and functionality
  - Gain calibration
  - Offset Calibration
  - Phase calibration
- ◆ **RMS Calibration**
  - Signal path and functionality
  - Offset Calibration
- ◆ **VA-hour Calibration**
  - Signal path and functionality
  - Gain calibration
- ◆ **Reactive Energy**
  - Theory of Operation
  - ADE7754 implementation



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# Watt-Hour Calibration

# ADE7754 Watt-hour signal path

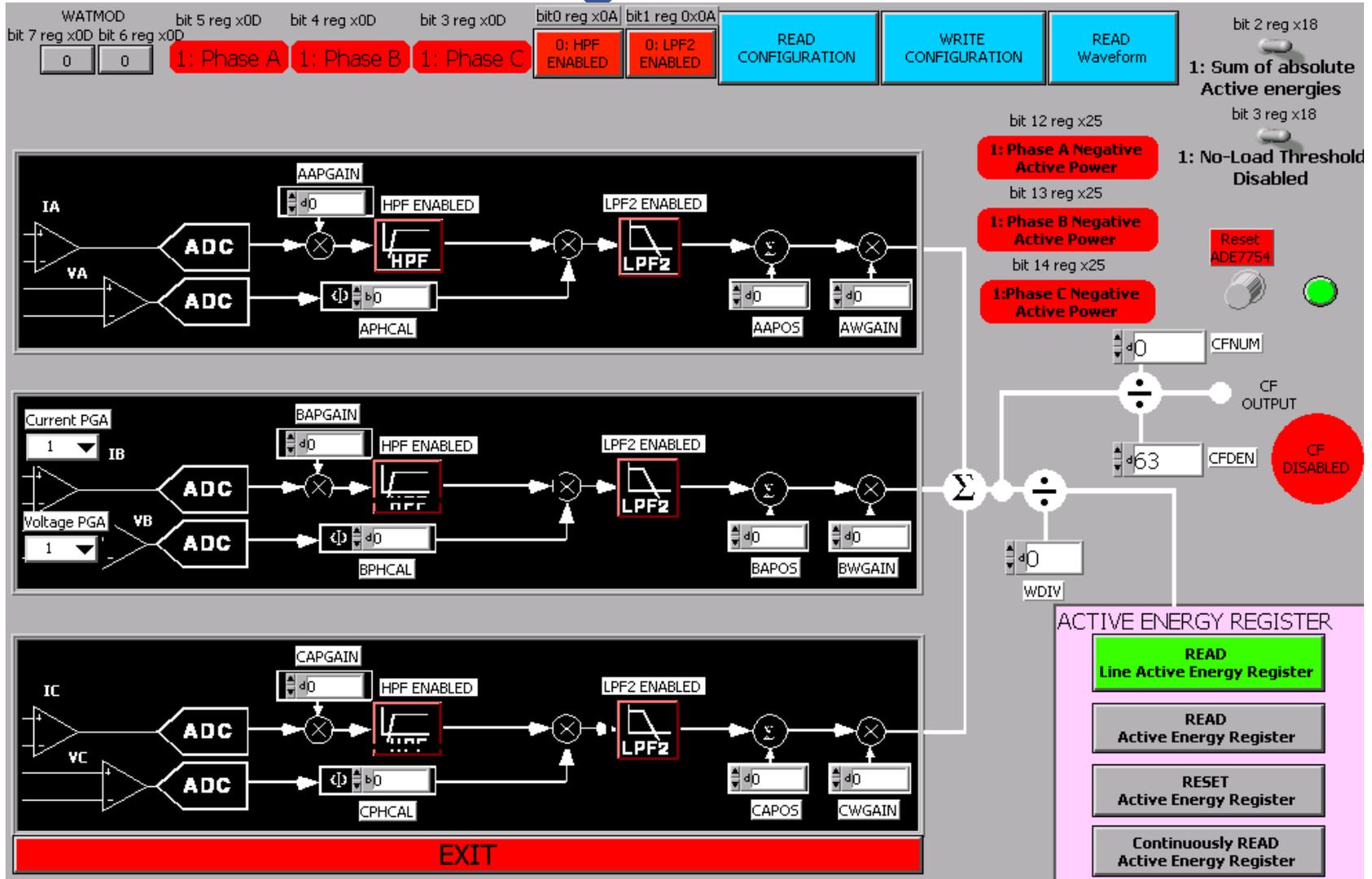


The screenshot shows the configuration interface for the ADE7754. At the top, there are several control bits and their states:

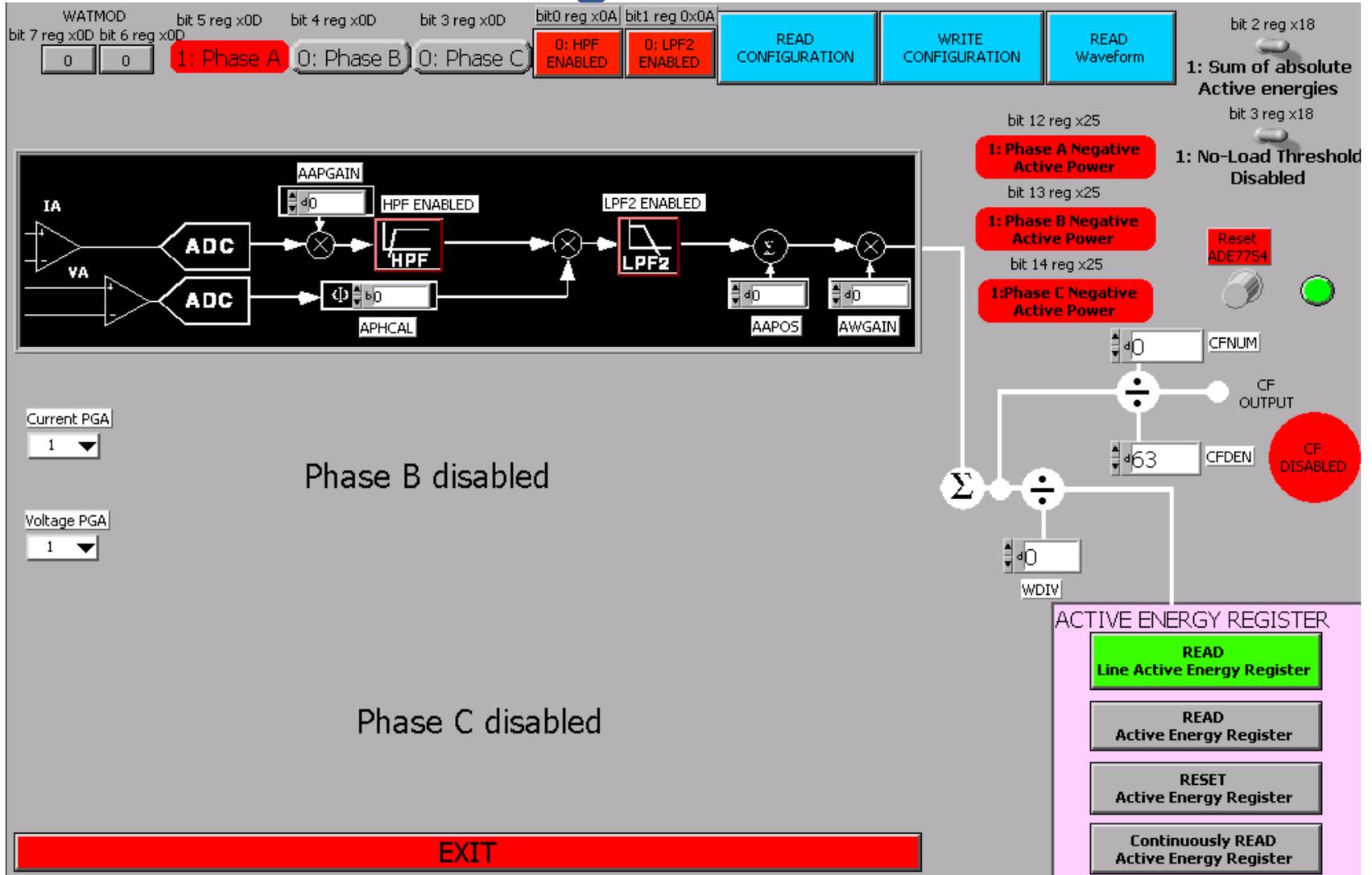
- WATMOD**: bit 7 reg x0D (0), bit 6 reg x0D (0)
- Phase Selection**: bit 5 reg x0D (1: Phase A), bit 4 reg x0D (0: Phase B), bit 3 reg x0D (0: Phase C)
- Filter States**: bit 0 reg x0A (0: HPF ENABLED), bit 1 reg 0x0A (0: LPF2 ENABLED)
- Buttons**: READ CONFIGURATION, WRITE CONFIGURATION, READ Waveform
- Other Bits**: bit 2 reg x18 (1: Sum of absolute Active energies), bit 12 reg x25 (1: Phase A Negative Active Power), bit 13 reg x25 (1: Phase B Negative Active Power), bit 14 reg x25 (1: Phase C Negative Active Power)
- Reset**: Reset ADE7754 (green indicator)
- CFNUM**: bit 3 reg x18 (1: No-Load Threshold Disabled)

Below the configuration interface is a detailed block diagram of the signal path, mirroring the one above. It shows the **IA** and **VA** inputs, **ADC** converters, **AAPGAIN**, **HPF**, **PHCAL**, **LPF2**, **AAPOS**, **AWGAIN**, and the final **|X|** block.

# Total Watt-hour Signal Path



# Total Watt-hour Signal Path



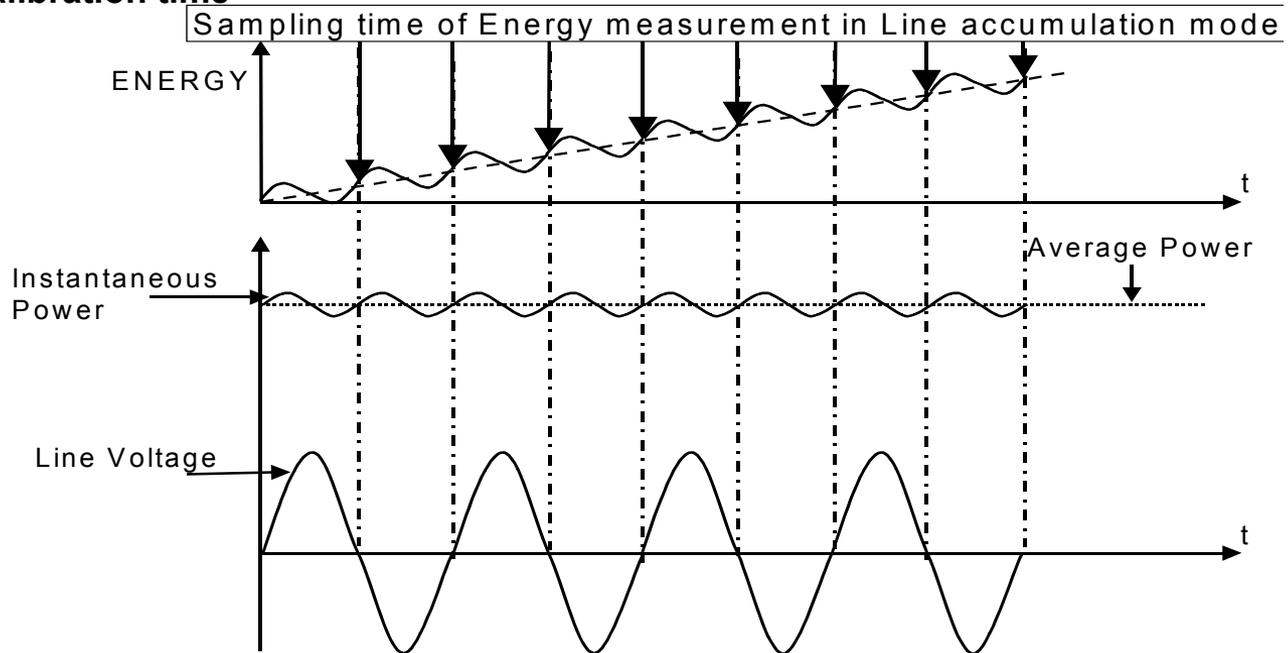


# Total Watt-hour Signal Path

- ◆ **2 independent Total Watt-Hour signal paths:**
  - **AENERGY**
  - **LAENERGY (accurate if only one phase is selected)**
- ◆ **Bit3-5 of WATMODE register (0x0D) select input phases for AENERGY register and CF pulse output**
- ◆ **Bit0-2 of WATMODE register (0x0D) select input phases for LAENERGY register**
- ◆ **Frequency output CF generated based on AENERGY configuration**
  - **Bit2 of OPMODE register (0x0A) enable/disable CF output**
- ◆ **Under same conditions:  $AENERGY = LAENERGY/4$**
- ◆ **Reverse active power information per phase available in bitC-E of CFNUM register (0x25)**

# LAENERGY accumulation

- ◆ **Principle: Accumulation of the Active Energy over N half line cycles (<65535)**
  - If bit A of IRQMASK register (0x0F) is set => IRQ goes Low when finished
- ◆ **Benefits:**
  - Cancel the ripple frequency effect (2 x line freq) in Energy Measurement
  - Shorten calibration time



# LAENERGY configuration

- ◆ Bit4-6 of MMODE Register (0x0B) select input phases for ZX count
- ◆ LINCYC register (0x13) define the # of half line cycles
- ◆ Bit0-2 of WATMODE register (0x0D) select input phases for LAENERGY register

The screenshot displays the configuration interface for the ADE7754. At the top left is a 'Reset ADE7754' button. The central area features two large gauges: 'Line Active Energy' (ranging from 0 to 200,000) and 'Line Apparent Energy' (ranging from 0 to 50,000). Between these gauges is a toggle for 'Active or Reactive' (bit 5 reg 0x0C), currently set to '0: Active'. To the left of the gauges is a yellow box for 'Line active energy accumulation' with phase selection bits 2, 1, and 0 (all set to '1: Phase A ON', '1: Phase B ON', and '1: Phase C ON' respectively). To the right is a yellow box for 'Line apparent energy accumulation' with phase selection bits 2, 1, and 0 (all set to '1: Phase A ON', '1: Phase B ON', and '1: Phase C ON' respectively). Above the gauges is a cyan box for 'Phase selection for ZX detection for Line accumulation' with bits 4, 5, and 6 (all set to '1: Phase A ON', '1: Phase B ON', and '1: Phase C ON' respectively). On the far right, a 'Line Accumulation # of Half Line Cycles' field is set to 65535. At the bottom are four buttons: 'READ CONFIGURATION', 'WRITE CONFIGURATION', 'READ', and 'EXIT'. Red arrows from the text above point to the bit settings in the cyan and yellow boxes, and the 'Line Accumulation' field.

# Watt-Hour GAIN Calibration

## ◆ Gain calibration:

- Meter to meter gain adjustment
- Phase to phase input gain matching
- Pulse output rate
- Wh/LSB constant

## ◆ CF gain adjustment:

$$CF = CF_{initial} \times \frac{CFNUM[11:0]}{CFDEN[11:0]} \times \left( 1 + \frac{WGAIN[11:0]}{2^{12}} \right)$$

## ◆ AENERGY/LAENERGY Gain adjustment:

$$AENERGY = AENERGY_{initial} \times \frac{1}{WDIV[11:0]} \times \left( 1 + \frac{WGAIN[11:0]}{2^{12}} \right)$$

# Relationship between CF and LAENERGY

$$CF (Hz) = \frac{LAENERGY}{4 \times Accumulation Time(s)} \times \frac{CFNUM}{CFDEN} \times WDIV \times \left(1 + \frac{WG}{2^{12}}\right) \quad \text{Eq. 1}$$

**With**

$$Accumulation time(s) = \frac{LINCYC[15:0] \times Line Period}{2 \times \# \text{ of phase selected}} \quad \text{Eq. 2}$$

- ◆ **Line Period can be read from the ADE7754: Period register (0x07)**  
Phase input selected with Bit0-1 and 4-6 of MMODE register (0x0B)  
Bit weight: 2.4μs/LSB at CLKIN=10MHz ( $T_{CLKIN}/24$ )

$$Line Period(s) = Period Register \times 2.4 \cdot 10^{-6}$$

# Conversion of AENERGY value to Wh

- ◆ **AENERGY is an Energy register**
  - **One constant is sufficient to convert it to Wh**

$$Wh = AENERGY \times Wh/LSB \text{ constant}$$

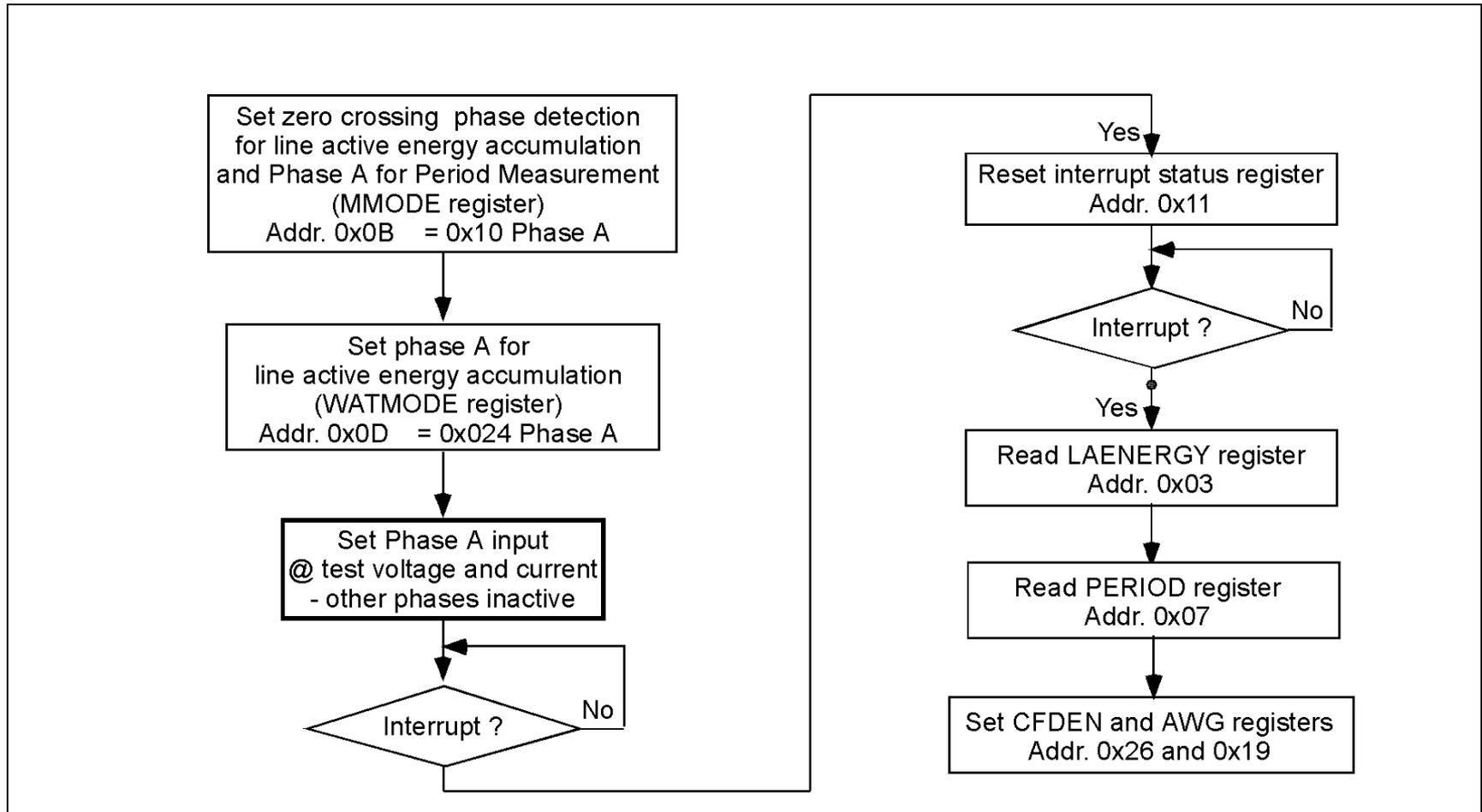
- **To calibrate Wh/LSB constant:**
  - ◆ **Known integration time**
  - ◆ **Known Load ( $W = V \times I$ )**
- **Wh/LSB constant can be determined with LAENERGY test:**

$$Wh/LSB \text{ constant} = \frac{W \times \text{Accumulation time}(s) / 3600}{LAENERGY / 4}$$

Eq. 3

Where Accumulation time is given by Eq. 2

# Watt-Hour GAIN calibration example: Procedure



# Watt-Hour GAIN calibration example: Configuration

	Phase A	Phase B	Phase C
<b>MMODE (0x0B)</b>	<b>0x10</b>	<b>0x21</b>	<b>0x42</b>
<b>WATMODE (0x0D)</b>	<b>0x24</b>	<b>0x12</b>	<b>0x09</b>
<b>LINCYC (0x13)</b>	<b>0d200</b>		
<b>MASK (0x0F)</b>	<b>0x0400</b>		

# Watt-Hour GAIN calibration example: CF calibration

- ◆ Gain adjustment by comparison with expected CF frequency
  - With 3200 imp/kWh ;  $I_{test} = 10A$  ;  $V_{test} = 240V$  ; Line freq = 50Hz

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

- ◆ ADE7754 CF frequency:

- ◆ LAENERGY = 38760 with LINCYC = 200
- ◆ Period register = 8336 => Accumulation time = 2.0006s

$$CF(Hz) = \frac{38760 \times 2}{4 \times 8336 \times 2.4 \cdot 10^{-6} \times 200} = 4843.45Hz \quad \text{From Eq. 1}$$

- ◆ Gain adjustment: CFDEN, WGAIN

$$CFDEN = INT \left( \frac{4843.45}{2.1333} \right) = 2270$$

$$WGAIN = \left( \frac{\frac{2.1333}{4843.45} - 1}{\frac{2.1333}{2270}} \right) \times 2^{12} = -1$$

# Watt-Hour GAIN calibration example: Wh/LSB calibration

- ◆ When CF is calibrated, AENERGY and LAENERGY registers will give the same value from design to design

$$LAENERGY = 38760 \times \left(1 - \frac{1}{2^{12}}\right) = 38751$$

With  $I_{test} = 10A$  ;  $V_{test} = 240V$  and accumulation time = 2s

- ◆ Wh/LSB constant from previous test:

$$Wh/LSB = \frac{240 \times 10 \times 8336 \times 2.4 \cdot 10^{-6} \times 200}{3600 \times 38751 / 4} = 0.2753 \cdot 10^{-3} Wh/LSB \quad \text{From Eq. 3}$$

# Watt-Hour OFFSET Calibration

- ◆ Offset calibration for:
  - Outstanding performances over wide dynamic range (10,000:1)
- ◆ 2 measurements at PF=1 needed:
  - Nominal current for reference:  $I_1$
  - Lowest current specified for correction:  $I_2$

$$Energy\ Offset = \frac{LAENERGY_2 \times I_1 - LAENERGY_1 \times I_2}{I_1 - I_2}$$

Eq. 4

# Watt-Hour OFFSET Calibration

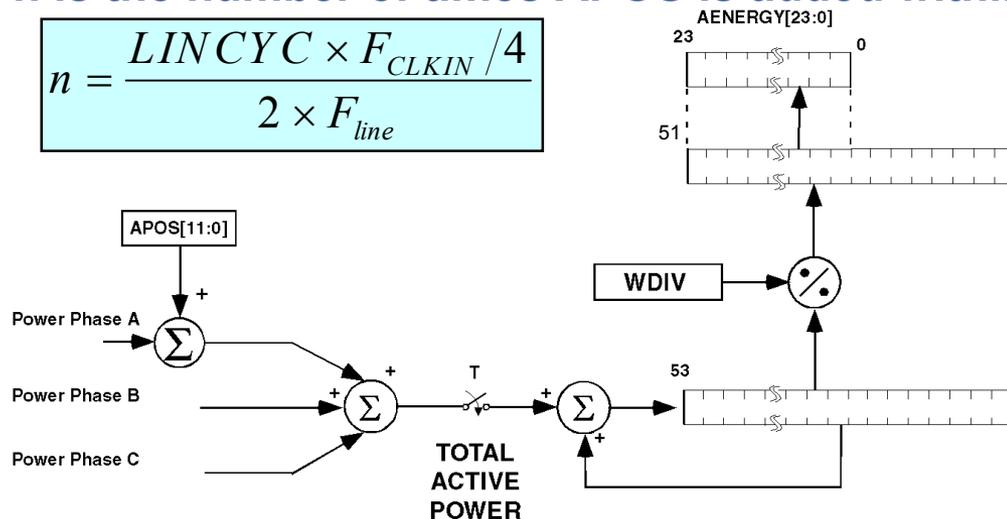
- ◆ ADE7754 provides Active Power offset correction per phase
  - APOS is added each time the Total active power is accumulated in AENERGY (every CLKIN/4)

$$LAENERGY \text{ Offset} = \frac{n \times APOS}{2^{28}}$$

Eq. 5

Where n is the number of times APOS is added within a period of time

$$n = \frac{LINCYC \times F_{CLKIN} / 4}{2 \times F_{line}}$$



# Watt-Hour OFFSET calibration: Example

- ◆ At 10A, with LINCYC=200: LAENERGY=38751
- ◆ At 10mA, with LINCYC=200 => LANERGY≈39
  - 1 LSB variation at this level => 2.5% error
  - LINCYC is too small to make an accurate offset compensation
- With LINCYC=10320 at 10mA => LANERGY=2041=LAENERGY<sub>2</sub>
  - ◆ 1 LSB variation represents .05% error
  - ◆ At 10A: LAENERGY=1999528=LAENERGY<sub>1</sub>

$$\text{Energy Offset} = \frac{2041 \times 10 - 1999528 \times 0.01}{10 - 0.01} = 41$$

From Eq. 4

- ◆  $n = 10320 \times \text{Line Period} / 2 / (\text{CLKIN} / 4) = 258082560$

$$APOS = -\frac{\text{Energy Offset} \times 2^{28}}{n} = -\frac{41 \times 2^{28}}{258082560} = -43$$

From Eq. 5

# Watt-Hour PHASE Calibration

## ◆ Phase calibration for:

- Compensation of phase shift from CT to CT

## ◆ 2 Measurements needed:

- Nominal current @ PF=1: W1
- Nominal current @ PF=0.5 Inductive Load: W2

$$Error = \frac{W_2 - W_1/2}{W_1/2}$$
$$Phase\ Error(^{\circ}) = -\text{Arcsin}\left(\frac{Error}{\sqrt{3}}\right)$$

Eq. 6

# Watt-Hour PHASE Calibration

- ◆ **ADE7754 provides phase calibration per phase:**

- **ADE7754's phase calibration is a time delay:**

$$Delay = PHCAL \text{ register} \times 1.2 \mu s$$

$$Phase \text{ Correction} (^{\circ}) = Delay \times 360^{\circ} \times \frac{1}{Period (s)}$$

**Dynamic range: +/-0.34° at 50Hz**

- **Period can be measured with ADE7754's Period register**

$$Period (s) = PERIOD \text{ register} \times 2.4 \mu s$$

$$Phase \text{ Correction} (^{\circ}) = -Phase \text{ Error}$$

$$\Rightarrow PHCAL \text{ Register} = \text{Arcsin} \left( \frac{Error}{\sqrt{3}} \right) \times \frac{PERIOD \text{ Register} \times 2}{360^{\circ}}$$

Eq. 7

# Watt-Hour PHASE Calibration: Example

- ◆ At 10A, PF=1 ; 50Hz with LINCYC=200
  - PF=1: LAENERGY=38751
  - PF=0.5 Inductive: LAENERGY = 19442

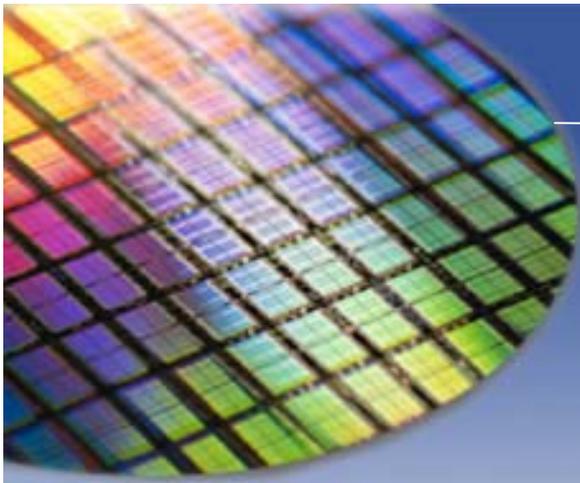
$$Error = \frac{19442 - 38751/2}{38751/2} = 0.344\%$$

$$Phase\ Error(^{\circ}) = -\text{Arcsin}\left(\frac{0.00344}{\sqrt{3}}\right) = -0.11^{\circ}$$

From Eq. 6

$$PHCAL\ Register = 0.11 \times \frac{8336 \times 2}{360^{\circ}} = 5$$

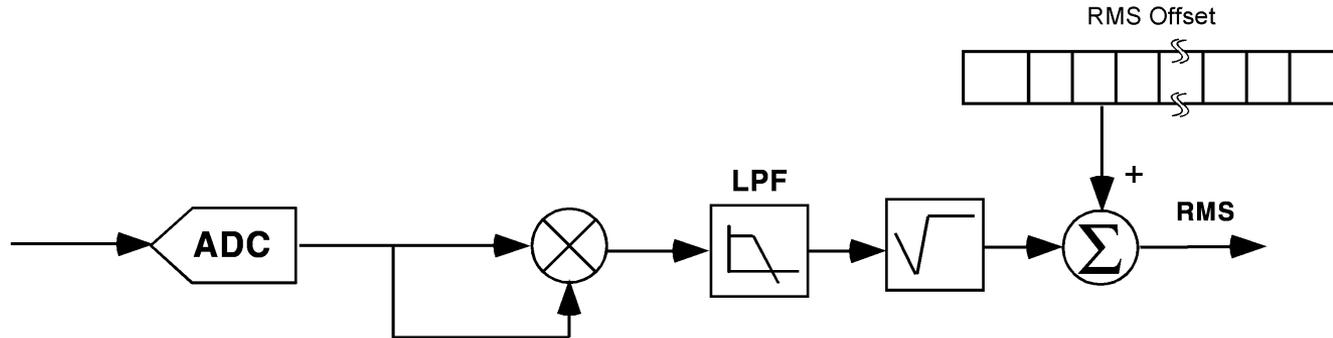
From Eq. 7



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# RMS Calibration

# ADE7754 RMS: Theory of operation



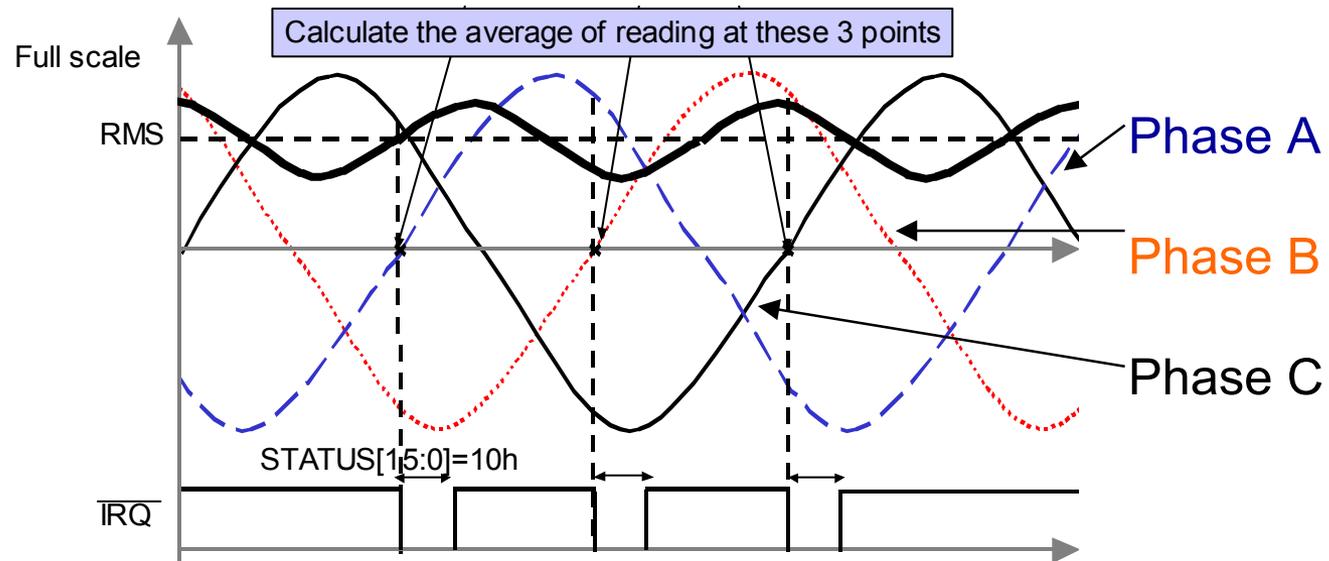
- ◆ The input is squared in a digital multiplier

$$v^2(t) = \sqrt{2} \cdot V \sin(\omega t) \times \sqrt{2} \cdot V \sin(\omega t) = V^2 - V^2 \cdot \cos(2\omega t)$$

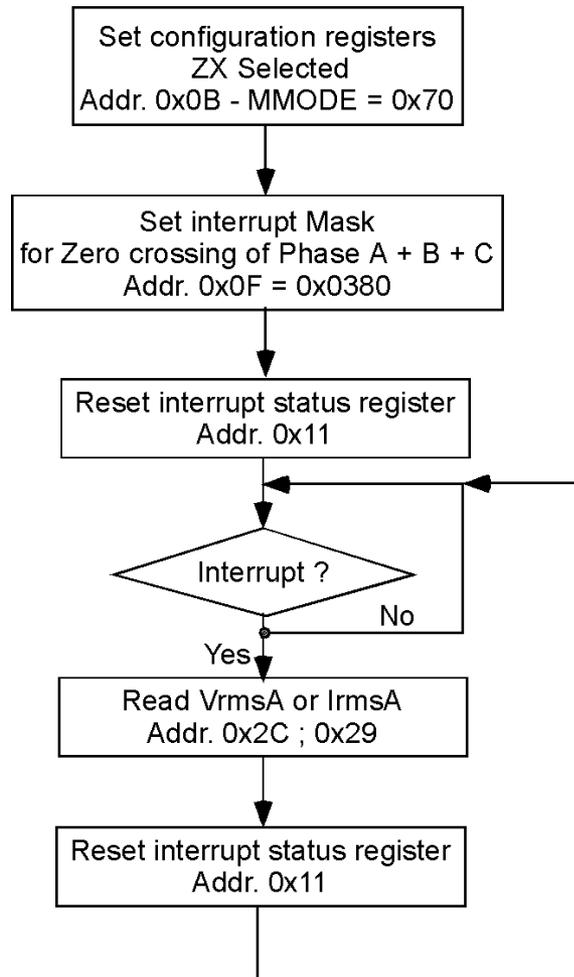
- ◆ The SQUARE of the RMS value is extracted from  $V^2(t)$  by an LPF
- ◆ The square root of the output of the LPF gives the true RMS value
- ◆ An offset correction is provided to cancel noise and offset contributions from the input

# ADE7754 RMS Register Reading

- ◆ Since the LPF is not perfect, ripple noise from  $2\omega$  term is present in the rms measurement
- ◆ Synchronize rms reading with zero crossings of voltage input from each phase to minimize this noise effect

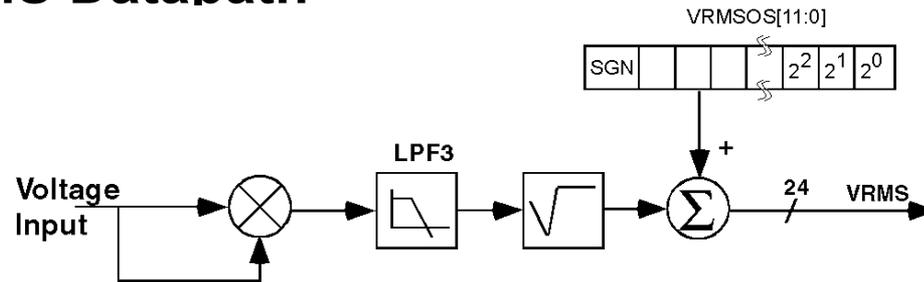


# ADE7754 RMS Reading Micro Routine Flowchart

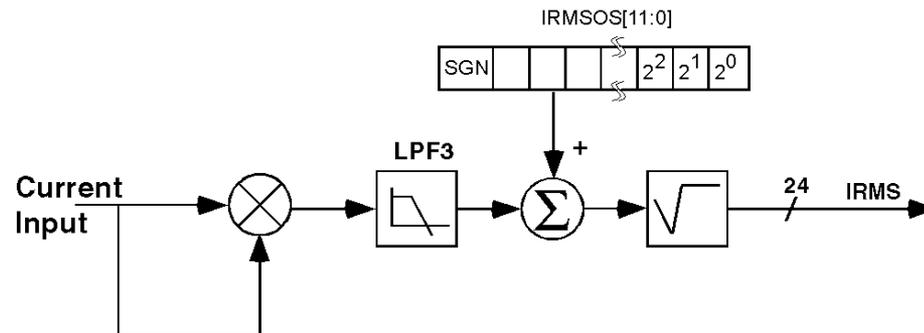


# RMS Signal Processing Datapaths for Voltage and Current Channels

## ◆ Voltage RMS Datapath



## ◆ Current RMS Datapath



# Voltage RMS Offset Compensation

- ◆ Voltage RMS compensation is performed after the square root:

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

where  $V_{rms0}$  is the rms measurement without offset correction

- ◆ Voltage rms calculation is linear from FS to FS/20
- ◆ To measure the  $V_{RMS}$  offset ( $VRMSOS$ ), measure rms values at two different voltage levels (e.g.  $V_{nominal}$  and  $V_{nominal}/10$ )

$$VRMSOS = \frac{1}{64} \times \frac{V_1 \times V_{rms2} - V_2 \times V_{rms1}}{V_2 - V_1}$$

Eq. 8

where  $V_{rms1}$  and  $V_{rms2}$  are rms register values without offset correction for input  $V_1$  and  $V_2$  respectively

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

# Current RMS Offset Compensation

- ◆ Current RMS compensation is performed before the square root:

$$I_{rms}^2 = I_{rms0}^2 + 32768 \times IRMSOS$$

where  $I_{rms0}$  is the rms measurement without offset correction

- ◆ 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  $I_{max}/100$ )

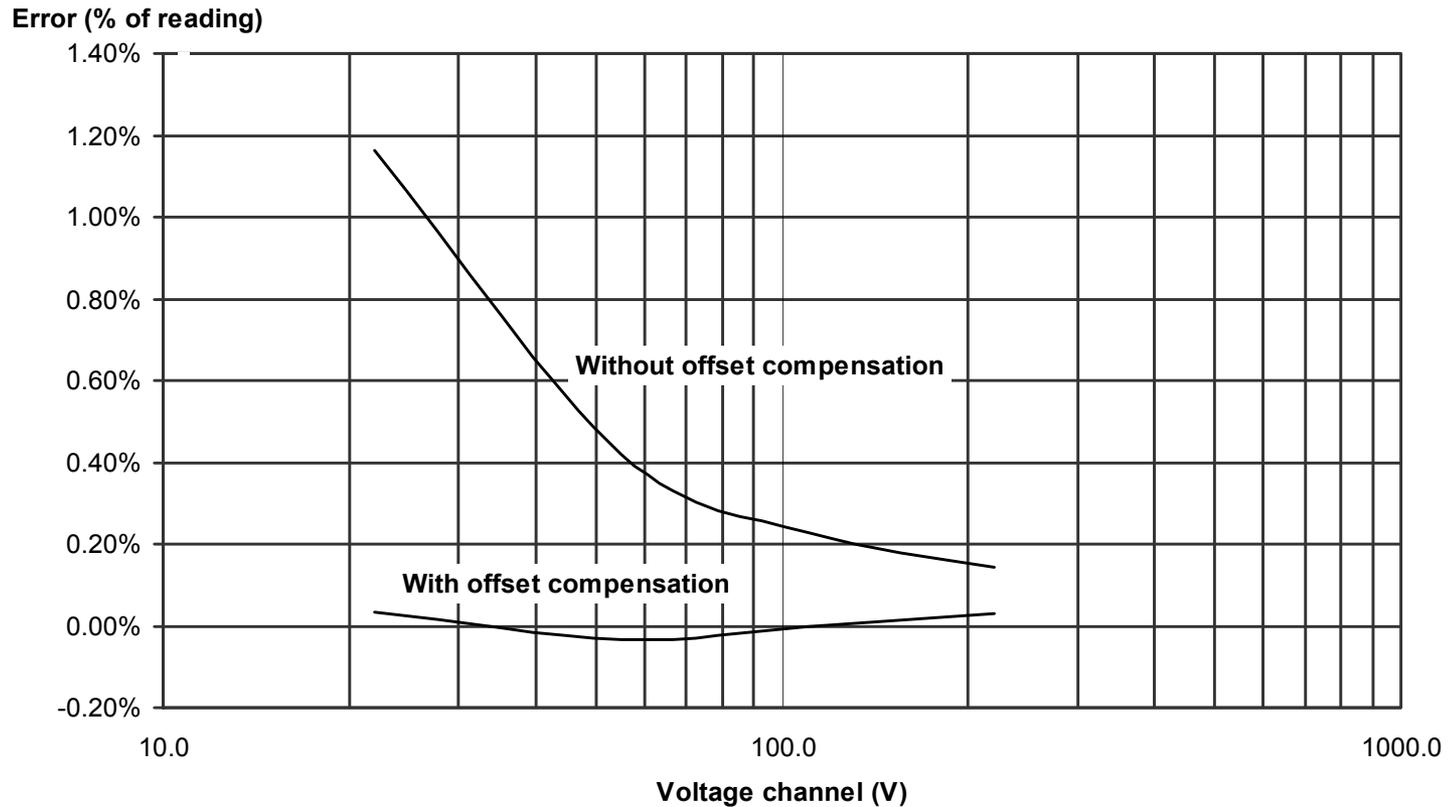
$$IRMSOS = \frac{1}{32768} \times \frac{I_1^2 \times I_{rms2}^2 - I_2^2 \times I_{rms1}^2}{I_2^2 - I_1^2}$$

Eq. 9

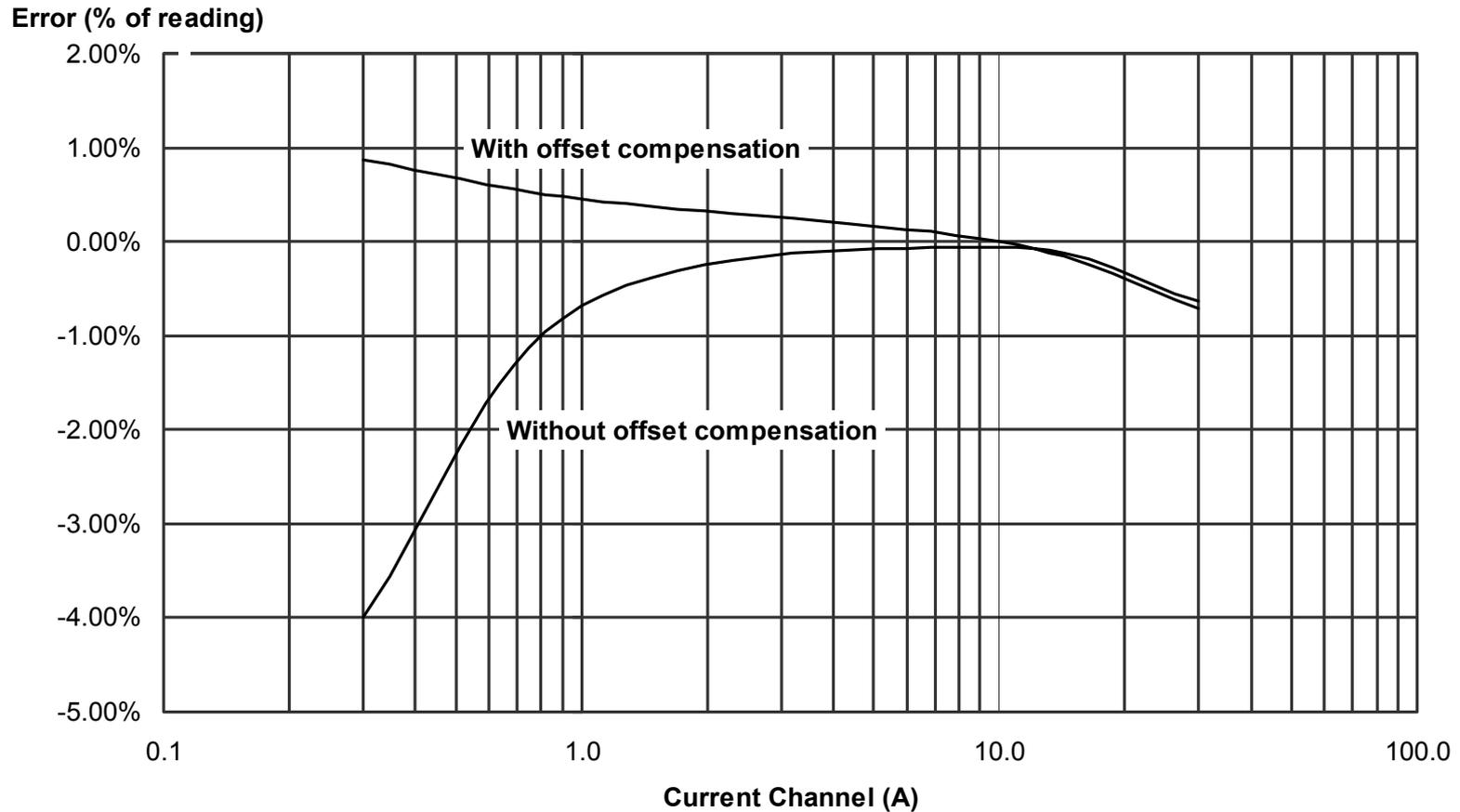
where  $I_{rms1}$  and  $I_{rms2}$  are rms register values without offset correction for input  $I_1$  and  $I_2$  respectively

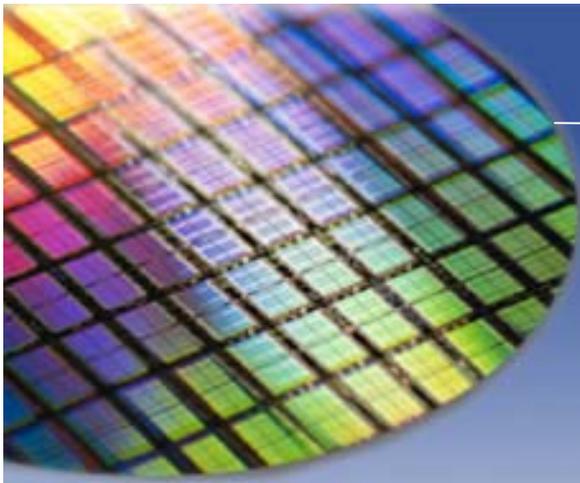
**Note:** To minimize noise, synchronize each reading with zero crossing of voltage input in each phase and take the average of these readings

# Voltage RMS offset correction: Example



# Current RMS offset correction: Example

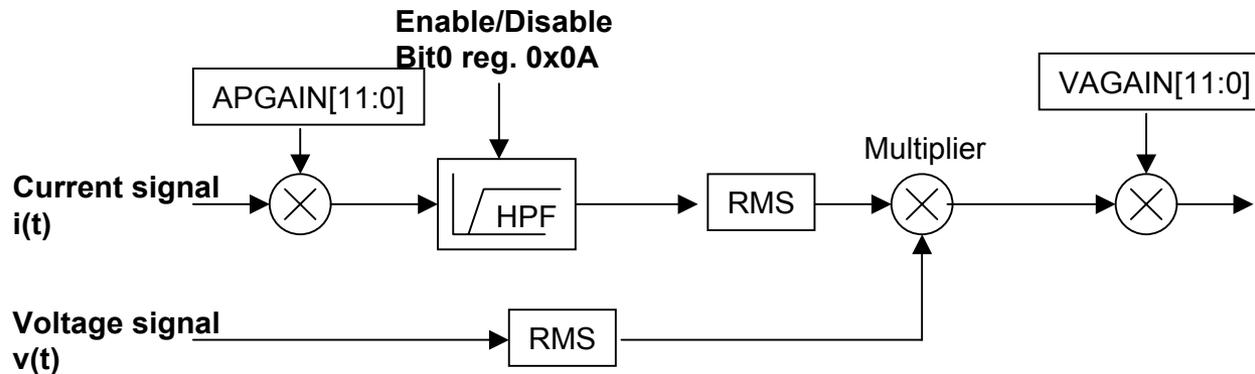




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# VA-Hour Calibration

# ADE7754 VA-Hour Signal Path



VAMOD bit 7 reg x0E bit 6 reg x0E bit 5 reg x0E bit 4 reg x0E bit 3 reg x0E bit0 reg 0x0A

0 0 1: Phase A 1: Phase B 1: Phase C 0: HPF ENABLED

READ CONFIGURATION WRITE CONFIGURATION READ Waveform

Reset ADE7754

Current PGA Voltage PGA ADC

IA VA

AAPGAIN HPF ENABLED HPF

AIRMSOS AVRMSOS

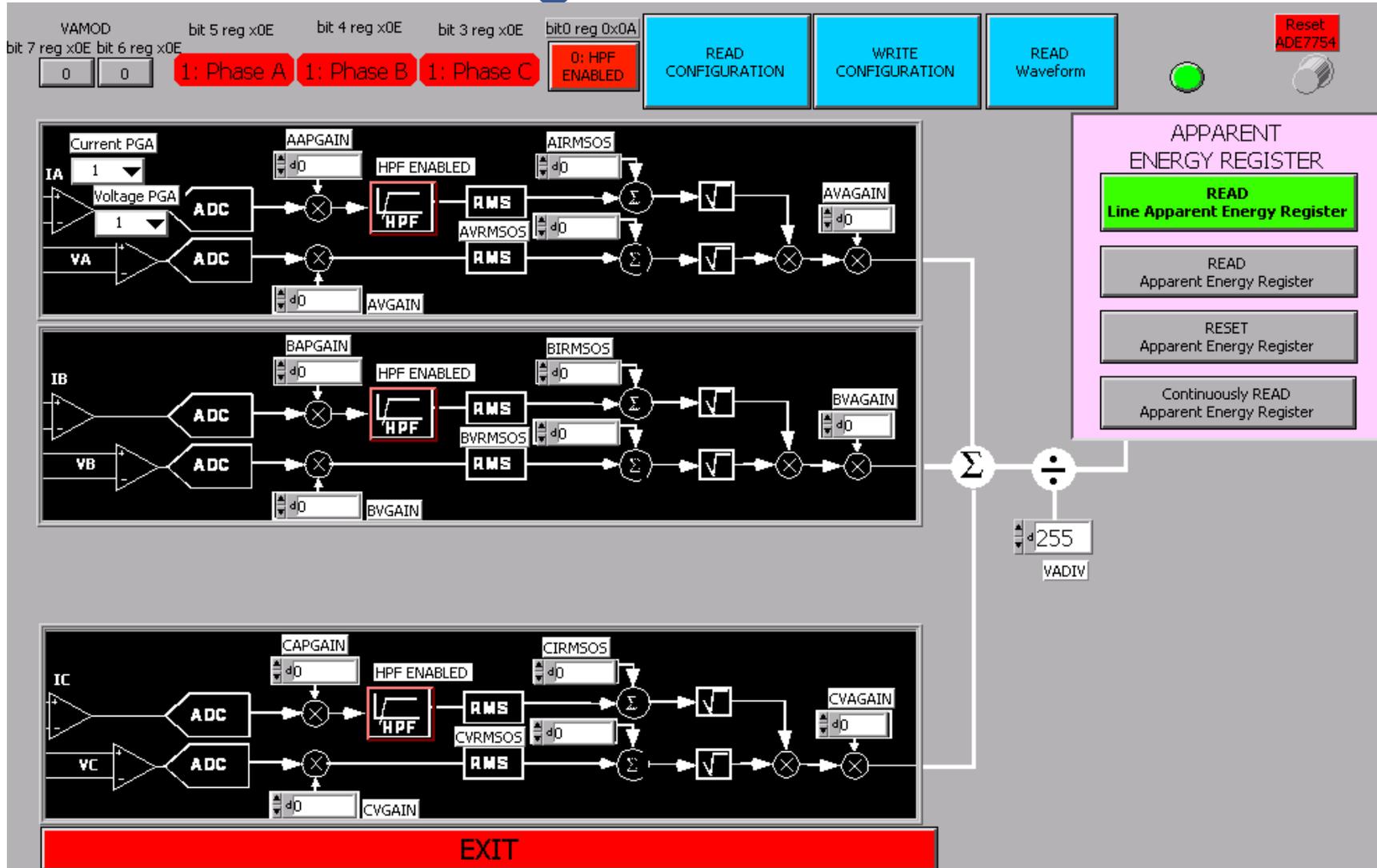
AVGAIN AVAGAIN

APPARENT ENERGY REGISTER

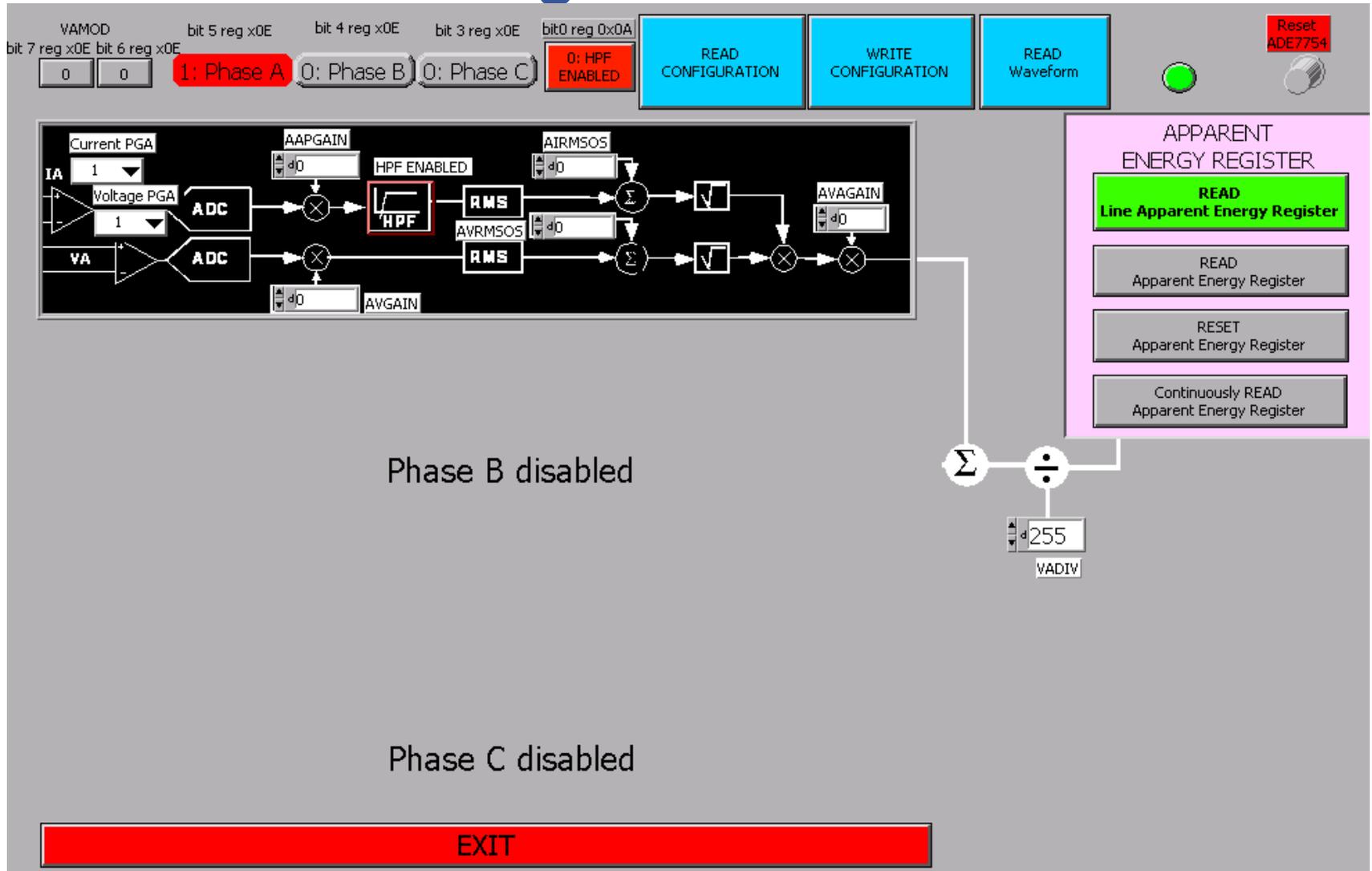
READ Line Apparent Energy Register

READ Apparent Energy Register

# Total VA-Hour Signal Path



# Total VA-Hour Signal Path



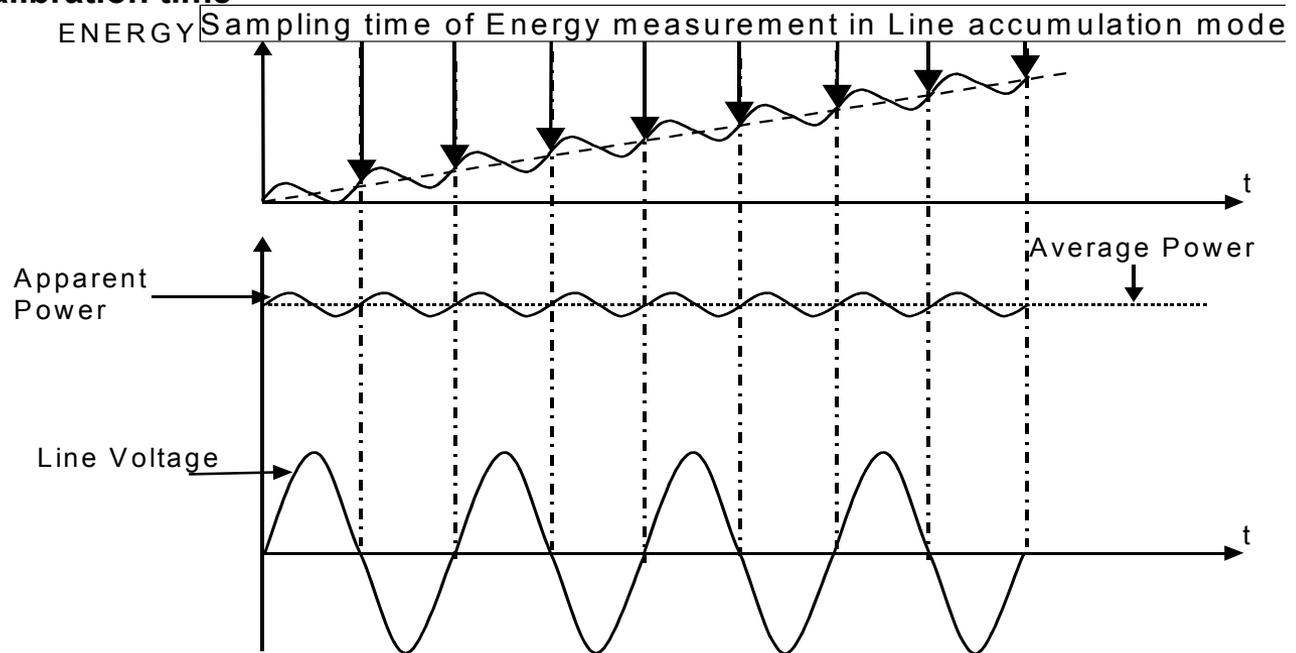


# Total VA-Hour Signal Path

- ◆ **2 independent Total Apparent hour signal paths:**
  - **VAENERGY**
  - **LVAENERGY (see VAR)**
- ◆ **Bit3-5 of VAMODE register (0x0E) select input phases for VAENERGY register**
- ◆ **Bit0-2 of VAMODE register (0x0E) select input phases for LVAENERGY register**

# LVAENERGY accumulation

- ◆ **Principle: Accumulation of the Apparent Energy over N half line cycles (<65535)**
  - If bit A of IRQMASK register (0x0F) is set => IRQ goes Low when finished
- ◆ **Benefits:**
  - Cancel the ripple frequency effect (2 x line freq) in Energy Measurement
  - Shorten calibration time



# LVAENERGY configuration

- ◆ Bit4-6 of MMODE Register (0x0B) select input phases for ZX count
- ◆ LINCYC register (0x13) define the # of half line cycles
- ◆ Bit0-2 of VAMODE register (0x0E) select input phases for LVAENERGY register

The screenshot displays the configuration interface for the ADE7754. Key elements include:

- Reset ADE7754**: A button with a refresh icon.
- Phase selection for ZX detection for Line accumulation**: A cyan box containing three red buttons: "1: Phase A ON", "1: Phase B ON", and "1: Phase C ON".
- Line Accumulation # of Half Line Cycles**: A numeric input field showing "65535".
- Line Active Energy**: A gauge with a scale from 0 to 200,000 and a digital display showing "0".
- Line Apparent Energy**: A gauge with a scale from 0 to 50,000 and a digital display showing "0".
- Active or Reactive bit5 reg 0x0C**: A toggle switch currently set to "0: Active".
- Line active energy accumulation Phase selection**: A yellow box with three red buttons: "1: Phase A ON", "1: Phase B ON", and "1: Phase C ON".
- Line apparent energy accumulation Phase selection**: A yellow box with three red buttons: "1: Phase A ON", "1: Phase B ON", and "1: Phase C ON".
- Control Buttons**: "READ CONFIGURATION", "WRITE CONFIGURATION", "READ", and "EXIT".

Red arrows from the text above point to the "Phase selection for ZX detection" box, the "Line Accumulation" field, and the "Line apparent energy accumulation" box.

# VA-Hour GAIN Calibration

- ◆ Gain calibration for
  - Meter to meter gain adjustment
  - Phase to phase input gain matching
  - VAh/LSB constant

- ◆ VAENERGY/LVAENERGY Gain adjustment:

$$VAENERGY = VAENERGY_{initial} \times \frac{1}{VADIV[11:0]} \times \left( 1 + \frac{VAGAIN[11:0]}{2^{12}} \right) \text{Eq. 10}$$

# Conversion of VAENERGY value to VAh

- ◆ VAENERGY is an Energy register

- One constant is sufficient to convert it to VAh

$$VAh = VAENERGY \times VAh / LSB \text{ constant}$$

- To calibrate VAh/LSB constant:

- ◆ Known integration time
- ◆ Known Load ( $VA = V_{rms} \times I_{rms}$ )

- VAh/LSB constant can be determined with LVAENERGY test:

$$VAh / LSB \text{ constant} = \frac{VA \times \text{Accumulation time}(s) / 3600}{LVAENERGY}$$

Eq. 11

Where  $Line \ Period(s) = Period \ Register \times 2.4 \cdot 10^{-6}$



## **VA-Hour GAIN calibration example: Procedure**

- ◆ **Calibration of VA-Hour GAIN should be done after RMS offset corrections**
- ◆ **Calibration of VA-Hour GAIN can be done at the same time as Watt-Hour GAIN calibration**
  - **Program VAMODE and WATMODE to the same value**
  - **Read LAENERGY and LVAENERGY**

# VA-Hour GAIN calibration example: VAh/LSB calibration

## ◆ Calibration of VA-hour GAIN to get a pre-determined value

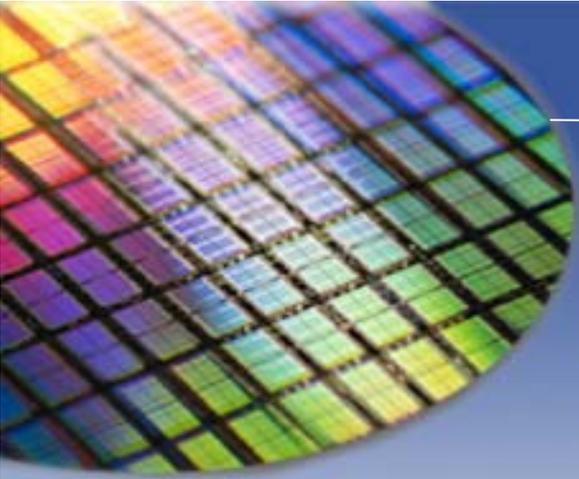
- V=240V ; I=10A ; 50Hz ; LINCYC = 200
- $LVAENERGY_{reference} = LVAENERGY_{phase A} = 10582$
- PERIOD register = 8336 => Accumulation time = 2.0006s

$$VAh/LSB \text{ constant} = \frac{240 \times 10 \times 2.0006}{3600 \times 10582} = 1.26 \cdot 10^{-4}$$

From Eq. 11

## ◆ Calibration of BVAGAIN to get to this value:

- $LVAENERGY_{phase B \text{ initial}} = 10558$
- With BVAGAIN=9 =>  $LVAENERGY_{phase B} = 10581$  From Eq. 10



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# Reactive Energy Measurement

# Reactive Power calculation (VAR)

- ◆ The reactive power is defined in the IEEE Standard Dictionary 100-1996 under the energy “magner” as:

$$\text{Reactive power} = \sum_{n=1}^{\infty} V_n \cdot I_n \cdot \sin(\varphi_n)$$

where  $V_n$  and  $I_n$  are respectively the voltage and current rms values of the  $n^{\text{th}}$  harmonics of the line frequency, and  $\varphi_n$  is the phase difference between the voltage and the current  $n^{\text{th}}$  harmonics.

Note:

$$\text{Active power} = \sum_{n=1}^{\infty} V_n \cdot I_n \cdot \cos(\varphi_n)$$

# Reactive Power calculation

- ◆ The implementation of the reactive power definition can be done by introducing a 90° phase shift on one channel at any frequency – Hilbert Transform

$$v(t) = \sqrt{2} \cdot V \cdot \sin(\omega t)$$

$$i(t) = \sqrt{2} \cdot I \cdot \sin(\omega t + \theta) \quad \Rightarrow \quad i'(t) = -\sqrt{2} \cdot I \cdot \cos(\omega t + \theta)$$

Hilbert transform

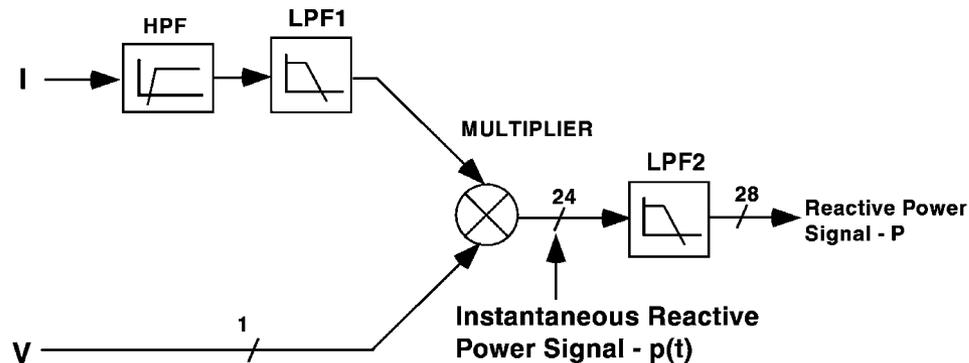
$$\text{VAR}(t) = v(t) \cdot i'(t) = V \cdot I \cdot \sin(\theta) - V \cdot I \cdot \sin(2\omega t + \theta)$$

Reactive Power is the DC part of the instantaneous reactive power:  $V \cdot I \cdot \sin(\theta)$

# ADE7754 Reactive Power: Theory of operation

- ◆ A low frequency low pass filter introduces a **89°** phase shift at any frequency

In the ADE7754, the Reactive Power calculation is processed by using a frequency Low-pass filter @ 2Hz (LPF1)



# Bit5 Register 0x0C = 0 LVAENERGY configuration

- ◆ Bit4-6 of MMODE Register (0x0B) select input phases for ZX count
- ◆ LINCYC register (0x13) define the # of half line cycles

The screenshot displays the configuration interface for the ADE7754. At the top left, a 'Reset ADE7754' button is visible. The central area features a cyan box titled 'Phase selection for ZX detection for Line accumulation' with three red buttons: '1: Phase A ON', '1: Phase B ON', and '1: Phase C ON'. To the right, a 'Line Accumulation # of Half Line Cycles' field is set to 65535. Below these are two meters: 'Line Active Energy' (range 0-200,000) and 'Line Apparent Energy' (range 0-50,000). A central toggle switch is set to '0: Active'. On the left and right sides, there are yellow panels for 'Line active energy accumulation' and 'Line apparent energy accumulation', each with three red buttons for Phase A, B, and C, all set to 'ON'. At the bottom, there are buttons for 'READ CONFIGURATION', 'WRITE CONFIGURATION', 'READ', and 'EXIT'.

# Bit5 Register 0x0C = 1 LVARENERGY configuration

- ◆ Reactive energy accumulated in LAENERGY
- ◆ Active energy accumulated in LVAENERGY
- ◆ Bit0-2 of WATMODE register (0x0D) select input phases for LAENERGY and LVAENERGY registers

The screenshot displays the configuration interface for the ADE7754. At the top left, a 'Preset ADE7754' button is visible. The central area features two large gauges: 'Line Reactive Energy' on the left and 'Line Active Energy' on the right. Above these gauges, a cyan box titled 'Phase selection for ZX detection for Line accumulation' contains three red buttons: '1: Phase A ON' (bit 4 reg x0B), '1: Phase B ON' (bit 5 reg x0B), and '1: Phase C ON' (bit 6 reg x0B). To the left of the gauges, a yellow box titled 'Line active energy accumulation Phase selection' contains three red buttons: '1: Phase A ON' (bit 2 reg x0D), '1: Phase B ON' (bit 1 reg x0D), and '1: Phase C ON' (bit 0 reg x0D). A pink box between the gauges is labeled 'Active or Reactive bit5 reg 0x0C' with a toggle switch set to '1: Reactive'. At the top right, a 'Line Accumulation # of Half Line Cycles' field shows the value '65535'. At the bottom, there are four buttons: 'READ CONFIGURATION' (blue), 'WRITE CONFIGURATION' (blue), 'READ' (green), and 'EXIT' (red).



# Reactive Energy Measurement

- ◆ Sign of Reactive Energy can be directly read from the LVARENERGY[23:0]
- ◆ The sign of LVARENERGY indicates inductive or capacitive loading
- ◆ Proposed Method to measure Reactive Energy and Power Factor including harmonics:

Using synchronous VAh and Wh data

$$\text{Varh} = \sqrt{(\text{VAh}^2 - \text{Wh}^2)} = \sqrt{(\text{LVAENERGY}^2 - \text{LAENERGY}^2)}$$

$$\text{PF} = \text{sign}(\text{LVARENERGY}) * \text{LAENERGY} / \text{LVAENERGY}$$