IL19006

THREE PHASE POWER/ENERGY METERING IC WITH INSTANTANEOUS PULSE OUTPUT

FEATURES

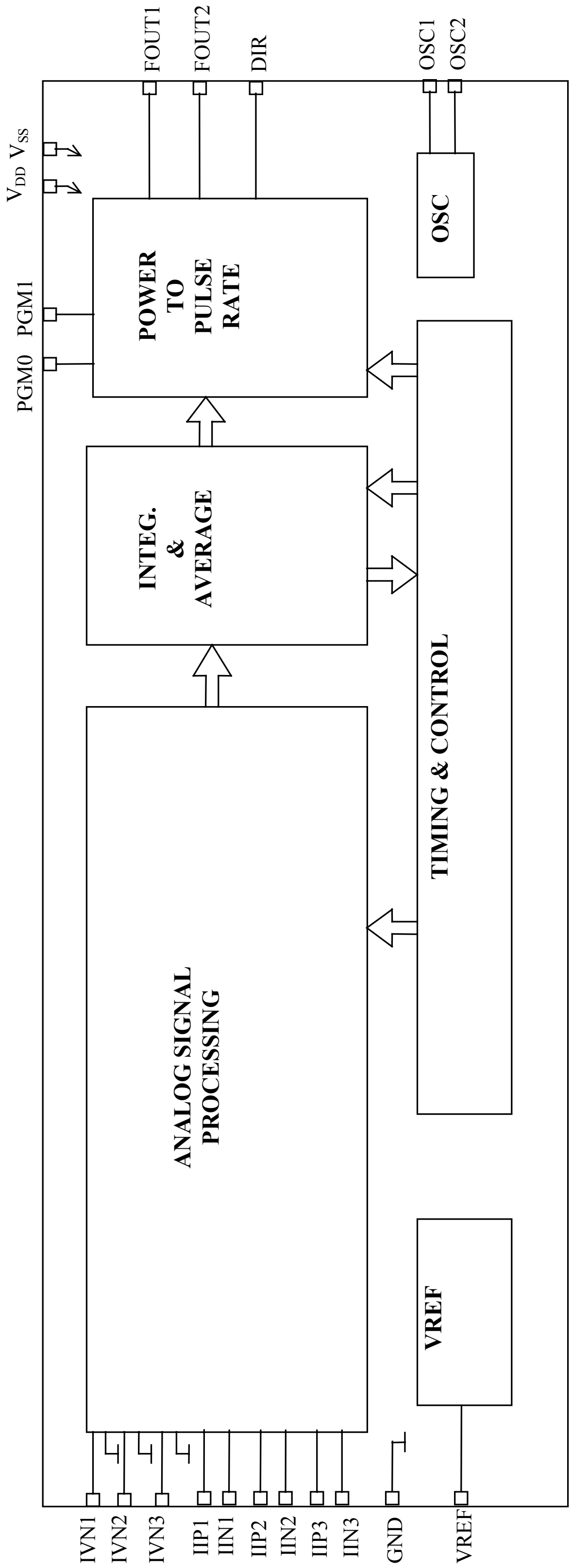
- Output frequency represents the absolute sum of energy on all three phases
- Performs one, two or three phase power and energy measurement
- Meets the IEC 521/1036 Specification requirements for Class 1 AC Watt hour meters
- Operates over a wide temperature range
- Current transformers for sensing
- Excellent long term stability
- Easily adaptable to different signal levels
- Precision voltage reference on-chip
- Pin selectable pulse rates
- Support tamper detection

FUNCTIONAL DESCRIPTION:

The IL19006 Three Phase Power/Energy metering integrated circuit generates a pulse rate output, the frequency of which is proportional to the absolute power consumption. The IL19006 performs the calculations of active power.
The method of calculation takes the power factor into account.
Energy consumption is determined by the power measurement being integrated over time.
The output of this universal three phase power/energy metering integrated circuit, is ideally suited for applications such as residential and industrial energy metering and control.

The IL19006 Three Phase Power/Energy metering integrated circuit is a CMOS mixed signal Analog/Digital integrated circuit, which performs three phase power/energy calculations over a range of 1000:1, to an overall accuracy of better than Class 1.
The integrated circuit includes all the required functions for 3-phase power and energy measurement such as oversampling A/D converters for the voltage and current sense inputs, power calculation and energy integration. Internal offsets are eliminated through the use of cancellation procedures.
The IL19006 generates pulses, the frequency of which is proportional to the power consumption. Two frequency outputs (FOUT1 and FOUT2) are available. The pulse rate follows the instantaneous power measured.

BLOCK DIAGRAM



ILA19006

ABSOLUTE MAXIMUM RATINGS*

Parameter	Symbol	Min	Max	Unit
Supply Voltage	V_{DD} -V_{SS}	-0.3	6.0	V
Current on any Pin	I_{PIN}	-150	+150	mA
Storage Temperature	T_{STG}	-40	+125	°C
Operating Temperature	T_O	-40	+85	°C
Current at any pin	I_p	-100	100	mA

* Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only. Functional operation of the device at these or any other conditions above those indicated in the operation sections of this specification, is not implied. Exposure to Absolute Maximum Ratings for extended periods may affect device reliability.

ELECTRICAL CHARACTERISTICS

(V_{DD}=2.5V, V_{SS}=-2.5V, over the temperature range -10°C to +70°C, unless otherwise specified.)

Parameter	Symbol	Min	Typ	Maxf	Uni	Condition
Operating Temperature Ranges	T_O	-25		+85	^{0}C	
Supply Voltage	V_{DD}-V_{SS}	4.5		5.5	V	
Supply Current	I_{DD}			15	mA	
Nonlinearity of Power Calculation		-0.3		+0.3	%	1%-100% of rated power
Current Sensor Inputs (Differential)						
Input Current Range	I_{II}	-25		+25	μA	Peak value
Voltage Sensor Inputs (Asymmetric)						
Input Current Range	I_{IV}	-25		+25	μA	Peak value
Pins FOUT1, FOUT2, DIR Output Low Voltage Output High Voltage	 V_{OL} V_{OH}	 V_{DD}-1		 V_{SS}+1	 V V	 I_{OL}=5 mA I_{OH}=-2 mA
Pulse Rate: FOUT1	fp	10		1160 3000	Hz Hz	Specified linearity Min and max limits
FOUT2						User selectable
Oscillator	Recommended crystal: TV colour burst crystal, f=3.5795 MHz					
Pin VREF Ref. Current Ref. Voltage	 -I_R V_R	 45 1.1	 50	 55 1.3	 μA V	With R = 24 kΩ connected to V_{SS} Referred to V_{SS}

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PIN DESCRIPTION

Pin	Designation	Description
16	GND	Ground
6	VDD	Positive Supply Voltage
14	VSS	Negative Supply Voltage
17	IVN1	Analog Input for Voltage: Phase 1
20	IVN2	Analog Input for Voltage: Phase 2
3	IVN3	Analog Input for Voltage: Phase 3
19	IIN1	Inputs for current sensor-: Phase 1
18	IIP1	
2	IIN2	Inputs for current sensor : Phase 2
1	IIP2	
5	IIN3 .	Inputs for current sensor: Phase 3
4	IIP3	
10	OSC1	Connections for crystal or ceramic resonator
11	OSC2	(OSC1=Input; OSC2=Output)
7	FOUT1	Pulse rate outputs
8	FOUT2 .	
9	DIR	Direction indicator
12	PGM0	FOUT2 Frequency select pins
13	PGM1	
15	VREF	Connection for current setting resistor

Note: arrangement of pins according to analog SA9605A (Sames)

FUNCTIONAL DESCRIPTION

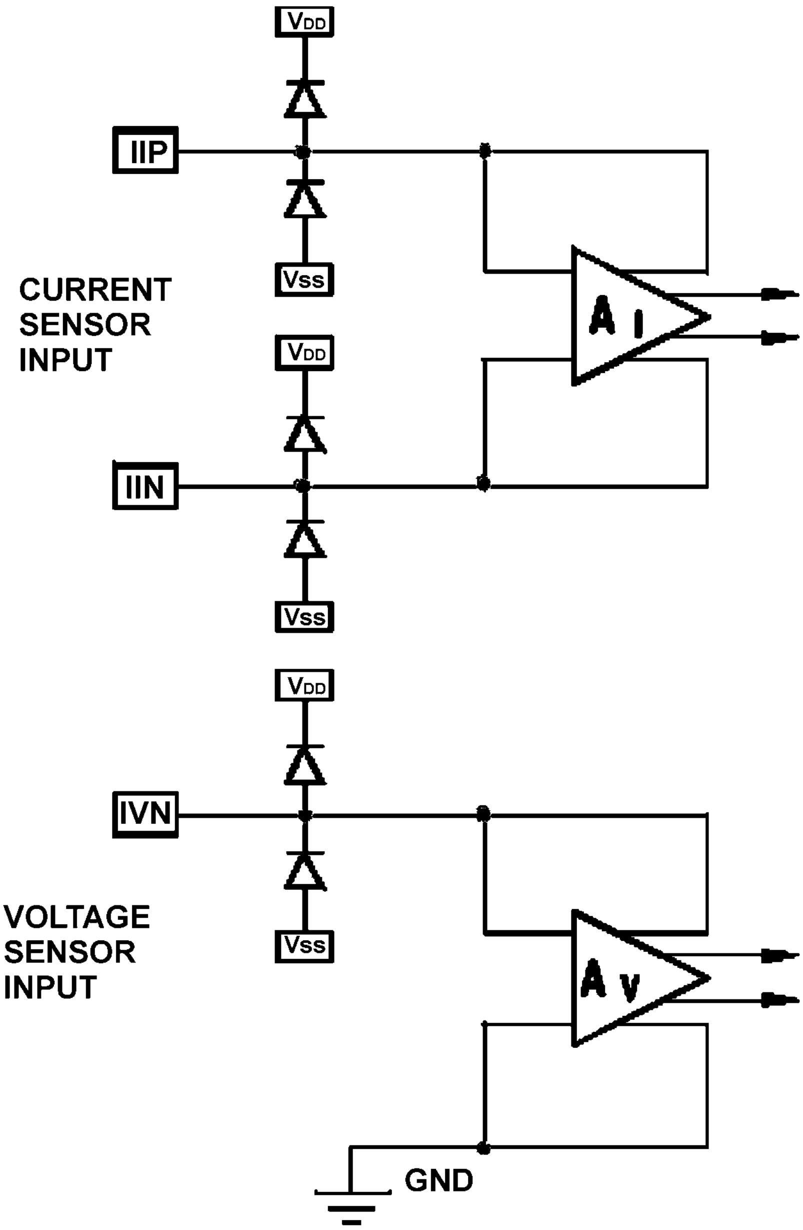
The IL19006 is a CMOS mixed signal Analog/Digital integrated circuit, which performs three phase power/energy calculations over a range of 1000:1, to an overall accuracy of better than Class 1.
The IL19006 in both DIP-20 and SOIC-20 package options is functionally similar to the SA9105E and SA9105F with the advantage of no external loop capacitors.
The integrated circuit includes all the required functions for 3-phase power and energy measurement such as oversampling A/D converters for the voltage and current sense inputs, power calculation and energy integration. Internal offsets are eliminated through the use of cancellation procedures.
The IL19006 generates pulses, the frequency of which is proportional to the power consumption. Two frequency outputs (FOUT1 and FOUT2) are available. The pulse rate follows the instantaneous power measured.

1. Power Calculation

In the Application Circuit (Figure 1), the mains voltages from Line 1, Line 2 and Line 3, are converted to currents and applied to the voltage sense inputs IVN1, IVN2 and

IVN3.
The current levels on the voltage sense inputs are derived from the mains voltage (3 x 230 VAC) being divided down through voltage dividers to 14V. The resulting input currents into the A/D converters are 14μA through the resistors R_{15}, R_{16} and R_{17}.
For the current sense inputs the voltage drop across the current transformers terminating resistors are converted to currents of 16μA for rated conditions, by means of resistors R_8, R_9 (Phase 1); R_{10}, R_{11} (Phase 2); and R_{12}, R_{13} (Phase 3).
The signals providing the current information are applied to the current sensor inputs: IIN1, IIP1; IIN2, IIP2; and IIN3, IIP3.
In this configuration, with the mains voltage of 3 x 230 V and rated currents of 80A, the output frequency of the IL19006 energy metering integrated circuit at FOUT1 is 1.16kHz. In this case 1 pulse will correspond to an energy consumption of 3 x 18.4 kW/1160Hz = 47.6 Ws.
The output frequency at FOUT1 and FOUT2 represents the absolute sum of the energy measured on all three phases, regardless of the direction of energy flow through the current sensors. This measurement method will assist meter manufacturers to circumvent meter tampering by reversal of the phases.

2. Analog Input Configuration
The current and voltage sensor inputs are illustrated below.
These inputs are protected against electrostatic discharge through clamping diodes, in conjunction with the amplifiers input configuration.
The feedback loops from the outputs of the amplifiers A_I and A_V generate virtual shorts on the signal inputs. Exact duplications of the input currents are generated for the analog processing circuitry.



3. Electrostatic Discharge (ESD) Protection

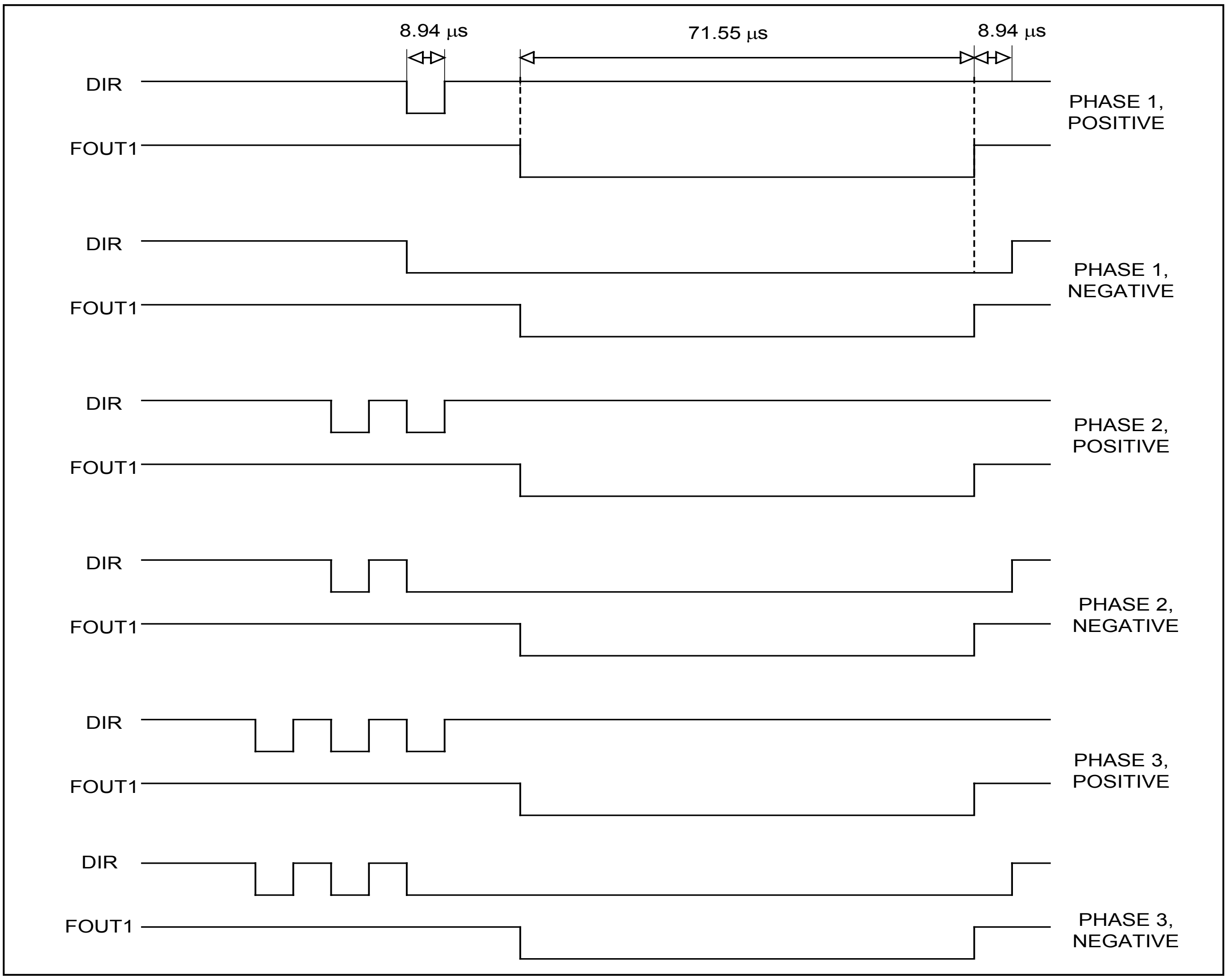
The IL19006 integrated circuit's inputs/outputs are protected against ESD.

4. Power Consumption

The overall power consumption rating of the IL19006 integrated circuit is less than 75mW with a 5V supply.

5. Pulse Output Signals

Waveforms displaying the DIR and FOUT1 signal information for each of the three phases are shown below.



These waveforms demonstrate how to establish the direction of energy flow as well as the phase from which the energy is measured. The direction of energy indicated on pin DIR is HIGH for POSITIVE energy flow and LOW for NEGATIVE energy flow, for the entire LOW period of the FOUT1 pulse. The phase to which the direction indication on the DIR pin refers can be ascertained by counting the number of falling edges on the DIR pin prior to the falling edge of the FOUT1 pulse. The supervision of the DIR pin can be accomplished with a μController.

Although FOUT1 has a fixed frequency output, the table below shows the various frequencies selectable for rated condition on FOUT2.

User Selectable Output Frequency		
PGM1	**PGM0**	**FOUT2 (Hz)**
0	0	5.11
0	1	3.83
1	0	2.55
1	1	N/A

The frequencies shown in the above table were chosen to allow a 4-3-2 scaling ratio for

rated conditions. This facility provides ease of interface with applications which use the same post divider with mechanical counter or unchanged microcontroller software for different current rated kWh meters.
For example, a meter manufacturer may wish to build meters for 3 system configurations with rated current loading of $80A_{RMS}$, $60A_{RMS}$ and $40A_{RMS}$. The rated line voltage is $230V_{RMS}$.

FOUT1 Frequency
Consider the case where FOUT1 is the output of the energy counting block. For each of the three rated conditions, the input current sensing resistors are chosen to ensure that $16\mu A_{RMS}$ flows into the current sensing pins.

Case 1 $I_L = 80A_{RMS}$
1 pulse on FOUT1 = (80*230*3)/1160 = 47.6Ws
Case 2 $I_L = 60A_{RMS}$
1 pulse on FOUT1 = (60*230*3)/1160 = 35.7Ws
Case 3 $I_L = 40A_{RMS}$
1 pulse on FOUT1 = (40*230*3)/1160 = 23.8Ws
The amount of energy represented by one pulse for each of the three cases is different.
In addition to changing the current sensing resistor network, the energy counting block must also be altered.

FOUT2 Frequency
Now consider the advantage of the user selectable frequency available on FOUT2. Again the input current sensing resistors must be chosen to ensure that 16µA RMS flows into the current sensing pins.

Case 1 $I_L = 80A_{RMS}$, PGM1 = 0 PGM0 = 0
1 pulse on FOUT2 = (80*230*3)/5.11 = 10.8kWs
Case 2 $I_L = 60A_{RMS}$, PGM1 = 0 PGM0 = 1
1 pulse on FOUT2 = (60*230*3)/3.83 = 10.8kWs
Case 3 $I_L = 40A_{RMS}$, PGM1 = 1 PGM0 = 0
1 pulse on FOUT2 = (40*230*3)/2.55 = 10.8kWs

The only changes which now have to be implemented to interface the device to different rated systems are: change the current sense resistors; and select the required PGM0 and PGM1.
No change to the post divider or micro-controller software is required if the FOUT2 pin is used as described.

TYPICAL APPLICATION
In the Application Circuit (Figure 1), the components required for a three phase power metering application are shown.
Terminated current sensors (current transformers) are connected to the current sensor inputs of the IL19006 through current setting resistors (R_8..R_{13}).

The resistor values for standard operation are selected for an input current of 16μA into the IL19006, at the rated line current.
The values of these resistors are calculated as follows:

Phase 1:

$R_8 = R_9 = (I_{L1} / 16\mu A) * R_{18}/2$

Phase 2:

$R_{10} = R_{11} = (I_{L2} / 16\mu A) * R_{19}/2$

Phase 3:

$R_{12} = R_{13} = (I_{L3} / 16\mu A) * R_{20}/2$

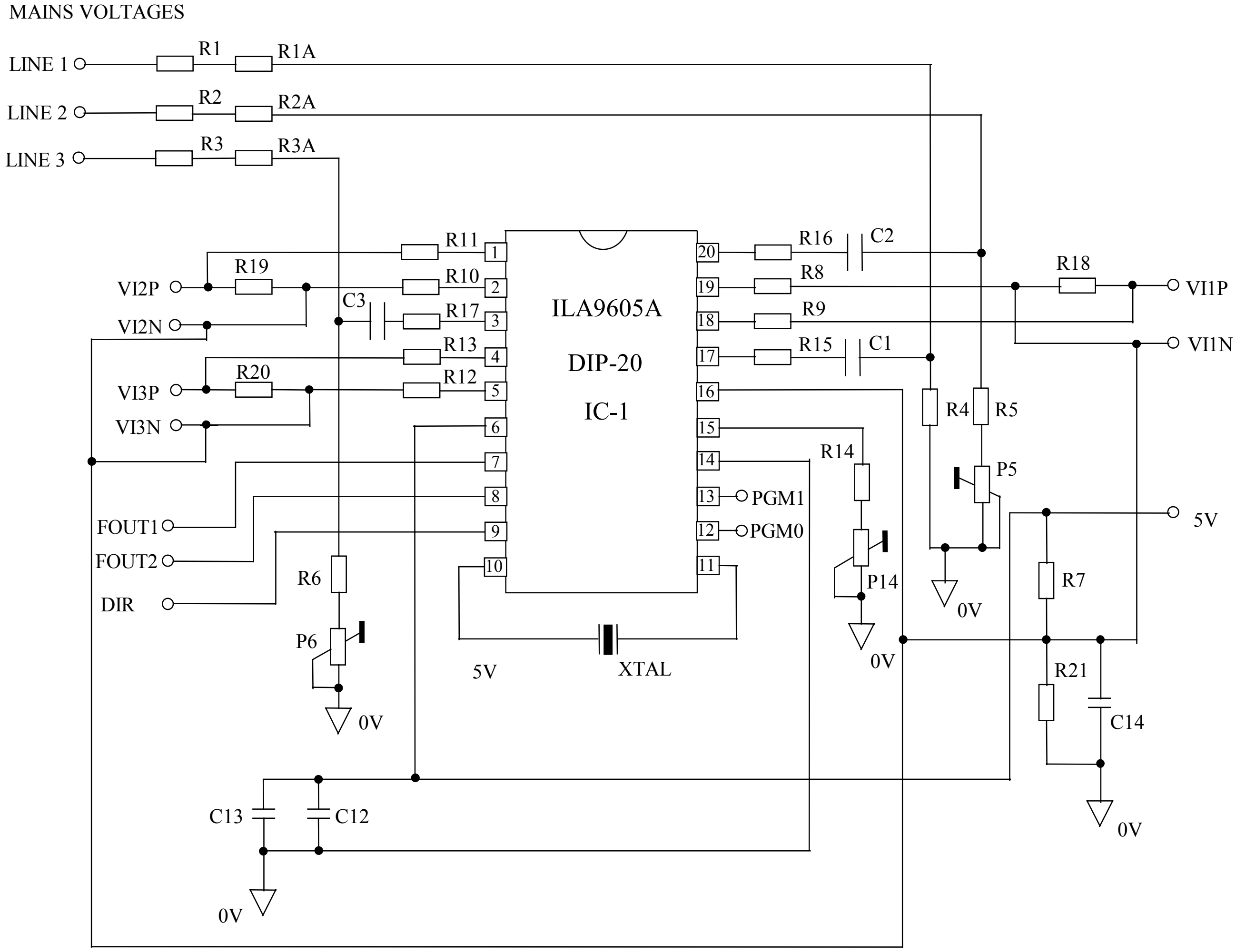
Where I_{LX} = Secondary CT current at rated conditions.
R_{18}, R_{19} and R_{20} = Current transformer termination resistors for the three phases.
R_1+R_{1A}, R_4 and R_{15} set the current for the phase 1 voltage sense input. R_2+R_{2A}, R_5+P_5 and R_{16} set the current for phase 2 and R_3+R_{3A}, R_6+P_6 and R_{17} set the current for phase 3. The values should be selected so that the input currents into the voltage sense inputs (virtual ground) are set to 14μA for rated line voltage. Capacitors C1, C2 and C3 are for decoupling and phase compensation.
$R_{14}+P_{14}$ defines all on-chip bias and reference currents. With $R_{14}+P_{14}$ = 24kW, optimum conditions are set. $R_{14}+P_{14}$ may be varied within ± 10% for calibration purposes. Any changes to R 14 + P 14 will affect the output quadratically
(i.e: ΔR = +5%, Δf = +10%).
The formula for calculating the Output Frequency (f) is given below:

$$f = 11.16 * FOUTX * \frac{FOSC}{3.5795 МГц} * \frac{(I_{I1} I_{V1}) + (I_{I2} I_{V2}) + (I_{I3} I_{V3})}{3 * I_R^2}$$

Where FOUTX = Nominal rated frequency (1160Hz)
FOSC = Oscillator frequency (2MHz ...... 4MHz)
I_{I1}, I_{I2}, I_{I3} = Input currents for current inputs (16μA at rated)
I_{V1}, I_{V2}, I_{V3} = Input currents for voltage inputs (14μA at rated)
I_R = Reference current (typically 50μA)

XTAL is a colour burst TV crystal (f = 3.5795 MHz) for the oscillator. The oscillator frequency is divided down to 1.78975 MHz on-chip, to supply the digital circuitry and the A/D converters.

Figure 1: Application Circuit for Three Phase Power/Energy Measurement.



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Parts List for Application Circuit: Figure 1

Item	Symbol	Description	Detail
1	IC-1	Integrated IL19006	DIP-20, SOIC-20
2	XTAL	Crystal, 3.5795 MHz	Colour burst TV
3	R1	Resistor, 200k, 1%, 1/4W	
4	R1A	Resistor, 180k, 1%, 1/4W	
5	R2	Resistor, 200k, 1%, 1/4W	
6	R2A	Resistor, 200k, 1%, 1/4W	
7	R3	Resistor, 200k, 1% , 1/4W	
8	R3A	Resistor, 180k, 1%, 1/4W	
9	R4	Resistor, 24k, 1%, 1/4W	
10	R5	Resistor, 22k, 1%, 1/4W	
11	R6	Resistor, 22k, 1%, 1/4W	
12	R7	Resistor, 820W, 1%, 1/4W	
13	R8	Resistor	Note 1
14	R9	Resistor	Note 1
15	R10	Resistor	Note 1
16	R11	Resistor	Note 1
17	R12	Resistor	Note 1
18	R13	Resistor	Note 1
19	R14	Resistor, 22k, 1%, 1/4W	
20	R15	Resistor, 1M, 1%, 1/4W	
21	R16	Resistor, 1M, 1%, 1/4W	
22	R17	Resistor, 1M, 1%, 1/4W	
23	R18	Resistor	Note 1
24	R19	Resistor	Note 1
25	R20	Resistor	Note 1
26	R21	Resistor, 820W, 1%, 1/4W	
27	P5	Potentiometer, 4.7k	Multi turn
28	P6	Potentiometer, 4.7k	Multi turn
29	P14	Potentiometer, 4.7k	Multi turn
30	C1	Capacitor, electrolytic, 1μF, 6V	Note 2
31	C2	Capacitor, electrolytic, 1μF, 6V	Note 2
32	C3	Capacitor, electrolytic, 1μF, 6V	Note 2
33	C12	Capacitor, 820nF	Note 3
34	C13	Capacitor, 100nF	
35	C14	Capacitor, 100nF	

Note 1: Resistor (R_8, R_9, R_{10}, R_{11}, R_{12} and R_{13}) values are dependant upon the selected values of the current transformer termination resistors R_{18}, R_{19} and R_{20}.
Note 2: Capacitor values may be selected to compensate for phase errors caused by the current transformers.
Note 3: Capacitor (C12) to be positioned as close to Supply Pins (V_{DD} & V_{SS}) of IC-1, as possible.

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