LSI/CSI

APPLICATION NOTE 301

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A UNIVERSAL POWER CONTROL CIRCUIT FOR APPLIANCES

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The growing demand among appliance manufacturers for advanced electronic control circuitry in AC operated appliances has generated the development of a new series of circuits (by LSI/CSI) which can be utilized in a wide variety of appliance applications.

At the heart of a basic AC power control system using phase angle variation for triac control of delivered power, the circuits described contain on-board LED drivers to indicate each of the ten distinct power levels which are available. Unique design features include the use of input/output ports to minimize both pin count and package size and the fact that the ten individual phase angle outputs are contained in mask programmable ROM. This allows the circuits to be customized with a single level mask change, if necessary, for specific applications.

While a major application for these circuits is the control of speed of AC universal motors, they will equally apply to the control of electrical heating elements. While some versions of the circuit accept mechanical momentary contact switched inputs, others are also capable of “Touch Control”; recognizing the human body’s capacitive coupling to AC ground.

Two versions of the circuit exist: one specifically designed for mechanical switch input control of motors (LS7310, LS7311); and one specifically designed for touch control of motors (LS7312 and LS7313). The LS7310 and LS7311 have built in pull-up resistors on the control inputs to allow single pole single throw switches to be used. The LS7312 and LS7313 have no internal resistors to allow for external sensitivity adjustments.

INTRODUCTION

This paper describes both the design and functions of a new AC power control integrated circuit intended for application in appliances.

Appliance manufacturers have been continuously increasing the content of electronics in their products of the past few years and the trend appears to be a continuing one. Microprocessors are used extensively in products ranging from electronic auto shutoff irons to vacuum cleaners. Very few dedicated AC power control circuits have been available to the industry which could be applied to a wide variety of appliance applications. The LS7310 was designed to be just such a device.

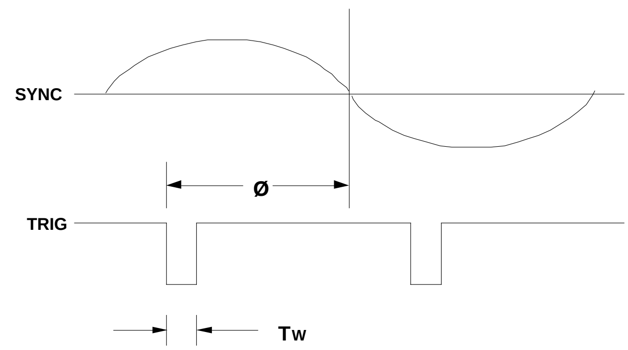

FIGURE 1. OUTPUT PHASE ANGLE, Ø

Control of AC power utilizing a power triac as the switching device is accomplished by controlling the phase angle point along each half of the sinewave at which the triac gate is activated. The earlier into the half-cycle that the triac gate is triggered, the more power is delivered to the load. Conversely, the later or closer to the end of the half-cycle that the gate is triggered, the less power delivered to the load.

For the purpose of clarity, half-cycles will be discussed. It should be understood, however, that what occurs in each half-cycle will also occur in each alternate half-cycle (i.e. the complete cycle).

The output phase angle of the LS7310 in relation to the AC line voltage is controlled by a phase-locked-loop. Almost all other comparable products use a zero-crossing-detection technique. The advantage of the phase-locked-loop over the zero-crossing-detection is that the PLL approach exactly synchronizes all internal timings to the AC input resulting in identical control for all ICs and leaves no DC component in the triggered triac current so that they can be efficiently used for inductive loads such as motors, transformers, etc. The circuits based on zero-crossing-detection principle leave a DC component in the triac output rendering them unsuitable for inductive-load applications.

In its design, the LS7310 can address anyone of 85 separate points or phase angles along the curve of a half cycle ranging from a minimum of 41° to a maximum of 159° (refer to angle Ø in Figure 1). This represents a “duty cycle” variation from 23% to 88%. The 85 points or phase angles are contained in a mask-programmable ROM on-board the chip. This ROM can be changed using a single mask to provide different output power levels, if required.

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The LS7310 is designed to output ten separate power levels. The specific phase angles chosen are applicable to the control of a universal AC motor as shown in Table 1.

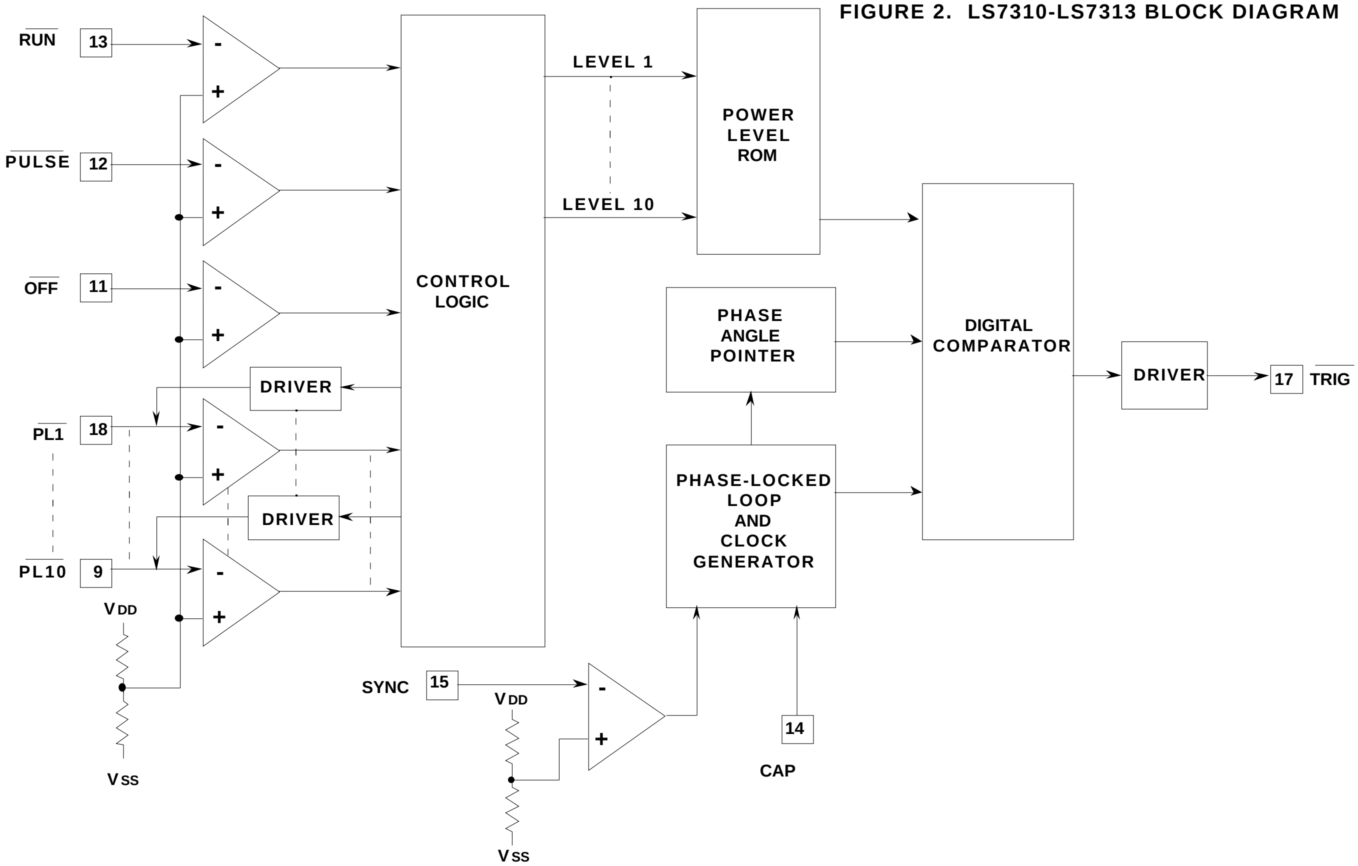
Speed Position	Output RMS Voltage	Conduction Angle
1	73	78.2
2	81	86.0
3	88	93.4
4	94	100.3
5	99	106.7
6	103	112.3
7	107	119.0
8	111	126.7
9	115	136.7
10	118	148.6

TABLE 1

The ten power levels are referred to as speed positions. The conduction angles range from 78.2˚ to 148.6˚, which represents an output RMS voltage to the load that ranges from 73V RMS to 118V RMS.

The width of the output pulse (Tw) of the LS7310 to the triac gate is 33µs. While this is sufficient for driving many motors, it may not be sufficient for all. In an inductive circuit, a phase shift exists between the current and voltage. The larger the motor inductance, the greater the phase shift. It is possible that because of this shift, there may not be current available to the triac at the point of triggering. To compensate for this, the circuit was designed with a bonding pad option to change the output pulse width. LS7311 will supply an output pulse width of 1ms for use with motors that are highly inductive. In all other respects the LS7311 is identical to the LS7310.

FIGURE 2. LS7310-LS7313 BLOCK DIAGRAM



CIRCUIT ORGANIZATION
INPUTS
The circuit contains 13 comparators which serve as control input sensing devices. Ten of these comparators (1 thru 10) are utilized as power level inputs. The remaining three control the output pulse to the triac. The ten power level input pins of the circuit are actually I/O ports. When the control logic circuitry senses an input at any one of the ten I/Os, it latches the appropriate output LED driver to indicate the particular power level that had been selected. At the same time, the control logic also addresses the power level ROM to select the appropriate phase angle. The switching of these pins between input and output functions minimizes both the number of pins required and the physical dimensions of the circuit package.

CONTROL LOGIC (CL)
The CL controls all the outputs as a function of input signals and generates all internal timing.

PHASE-LOCKED LOOP (PLL)
The PLL section synchronizes the internal clock frequency with the AC line frequency applied at the SYNC input. The PLL consists of a phase detector, a lead-lag filter network, a voltage-controlled oscillator (VCO) and an 11 stage binary counter. The phase detector senses the phase difference between the AC signal and the internal clock. Any difference in phase generates an error voltage which is filtered through the lead-lag filter network to remove any high frequency component and optimizes loop response. The filtered output is then applied to the VCO input whose frequency of oscillation is a function of the input voltage. The VCO output is fed down the 11 stage counter whose final output is a clock in phase with the input AC line voltage. The outputs from the intermediate stages of the 11 stage counter are used for different control functions.

PHASE-ANGLE POINTER (PAP)
The PAP keeps track of the delay at any instant from the AC zero-crossing point. It consists of a 7-stage binary counter, driven by a clock which is synchronous with the line frequency. The upper and the lower limits of 159˚ and 41˚ set up the boundary between which an output can be generated for triggering a triac. The upper boundary is necessary for proper triac triggering while the lower boundary insures proper operation of the external power supply.

POWER LEVEL ROM (PLR)
The PLR is a mask programmable ROM which may be programmed for any one of 85 Phase Angles ranging between 41˚ and 159˚. Receiving its address from the control logic circuit, it is capable of making one out of ten phase angle selections, which feeds it in turn, to a digital comparator.

DIGITAL COMPARATOR (DC)
The DC compares the data received from the PAP and the PLR and generates an output pulse when the two are equal.

OUTPUT DRIVER (OD)
The OD is an output buffer for enhancing the drive capability of the output pulse, generated by the DC.

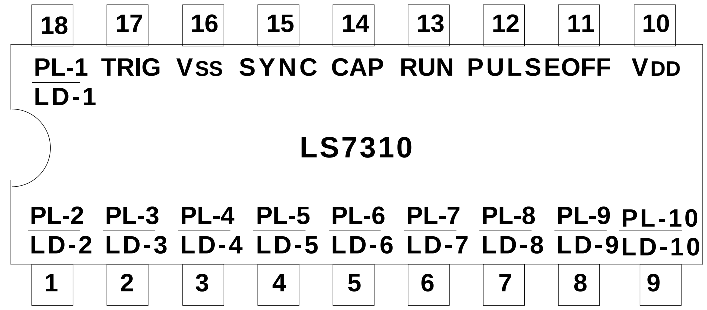


FIGURE 3

PIN DESCRIPTION
PIN 18 THRU PIN 9 (PL1 to PL10)
There are ten inputs/outputs for selecting 10 output phase angles (power levels). When no output power level is selected, PL1-PL10 all act as inputs. When a power level is selected by applying a logic zero at one of these inputs, in excess of 33ms, the selected input switches status to become an output in order to drive a display such as an LED.

PIN 10 - VDD
Supply voltage negative terminal.

PINS 11, 12, 13 - OFF, PULSE & RUN, CONTROL INPUTS
These inputs are not I/O ports and do not have output LED indicators.

PIN 14 - CAP
The CAP input is for external component connection for the PLL filter capacitor.

PIN 15 - SYNC
The AC line frequency (50Hz/60Hz), when applied to this input, synchronizes all internal timings with the line frequency through a phase-locked-loop. The signal for this input is usually obtained from the line voltage through an RC filter. (See application schematic on Data Sheet.)

PIN 16 - TRIG
This output is a low level pulse of bonding pad variable duration, occurring every half-cycle of the SYNC input signal. The phase angles, Ø of the output in relation to the SYNC controls the power. The 10 levels of power correspond to the phase angles.

PIN 17 - VSS
Supply voltage positive terminal.

LOGIC PROTOCOL

ON A low level applied to this input in excess of 33ms starts the output at the selected phase angle.

OFF A low level applied to this input in excess of 33ms stops the output. The selected power level, however, remains unaffected.

PULSE A low level applied to this input turns the output on at the selected phase angle for as long as the level is apied.

PROTOCOL After a system power up, phase angle selection circuits are all cleared. To turn on the output, a power level is selected by applying one of the PL inputs followed by the application of the ON or the PULSE input. There are certain priorities incorporated in the input circuitry as follows:

1. If more than one PL input is applied simultaneously,* the input associated with the lowest power level will override the others independent of the sequence in which the inputs are removed.
2. If a PL input is appied simultaneously* with the RUN input, the former will override the latter.
3. If a PL input is applied along with the PULSE input, the PL input will override the PULSE input as long as the PL input is held active. If the PL input is discontinued while PULSE input is still active, the output will respond to the PULSE input upon the removal of the PL input.
4. If a PL input is applied along with the OFF input, the circuit will respond to both inputs simultaneously.
5. If the ON input is applied simultaneously* with the OFF input, the OFF input will override the ON input independent of their removal sequence.
6. The output power level can be altered in the ON state by applying a different PL input. It is not necessary to turn the output off before changing the power level.

***** Within 33ms of each other

VARIATIONS OF USE

While the circuit offers ten power output control levels, it is not necessary to use the circuit to its full capability. For example, in the case of a five speed hand mixer, only five of the I/O ports need be used. The specific five speeds may be selected from among the ten levels available. In such an application, the ON and OFF control input could also be ignored, using only the momentary input to control the ON/OFF function.

CONCLUSION

The flexibiltiy of programmable phase angle power control and the LED outputs, indicating addressed power levels, make this series of circuits ideally suited for controlling AC appliances. While it can serve as a motor speed control in air conditioners, vacuum cleaners, blenders, hand tools, food processors, etc., it can also serve as a basic power control for electric space heaters, electric blankets and incandescent lamp dimmer applications. Its economical effectiveness, when applied to motors, is the elimination of multiple-tapped windings that are used to achieve speed variation. A single winding will do.

In heater or lamp applications, only a single resistive element or filament is necessary to have multi-level control.

ADDENDUM

Since the original publication of this paper, LSI/CSI has added two ICs to this family of Power Controllers, LS7314 and LS7315.

These two Power Controllers are 16-Pin ICs which eliminate the ON and PULSE functions. When a PL is selected, the TRIG output immediately turns on with the appropriate phase angle reference to the SYNC input. TRIG pulses are 1ms wide (Tw).

LS7314 is designed for Touch Control and LS7315 is designed for Pushbutton Switch Control.