AN3939

SA828/838 Microprocessor Controlled PWM IC Family

Application Note

AN3939 - 3.2 January 1997

With the growing trend towards pulse width modulated AC motor drives, Mitel Semiconductor offers a fully digital, stand-alone PWM generator IC for use in motor drives and power supplies.

OVERVIEW

Several manufacturers have for some years been producing analog pulse width modulated (PWM) generator circuits for use in drive systems. These rely upon potentiometer control of parameters such as speed, acceleration and deceleration rates, pulse deletion and pulse delay (underlap) times. However, a growing demand has emerged in the drives market for digitally controlled drive units with direct keypad entry of operating parameters, and often with the ability to communicate with external computers/ controllers.

To this end, Mitel Semiconductor have produced a fully digital PWM generator IC family incorporating an industry standard microprocessor interface to produce full feature motor control with minimal hardware and software overhead whilst giving unprecedented stability, accuracy and speed range.

In addition, this low cost solution can be software configured to be used with the whole spectrum of power switches (including silent operation with fast switches).

PULSE WIDTH MODULATION TECHNIQUES

The process of pulse width modulation is shown in Fig.1. The required power waveform is compared to a triangular waveform of considerably higher frequency and slightly greater amplitude (*termed the carrier waveform).* The intersections of these two waveforms dictate the digital transitions of the PWM output.

The voltage swings of the digital PWM output are stepped up by a power switch stage (see later) before being fed to the machine. The inherent low-pass characteristic of the machine will filter out the high frequency components in the voltage waveform, leaving the desired sinusoidal current waveform only.

The SA8x8 family uses a very similar process to that described above, but differs in the sampling of the waveform, as shown in Fig.2. Since the devices use a digital implementation of the PWM process to increase stability, the waveform is sampled at the peak and trough of the triangular waveform. This is termed double edged regular sampling. The comparison of the two waveforms is still carried out on a continuous basis however. The SA828 has three such PWM channels working simultaneously to produce the required outputs for a three phase machine, each being transposed 120° from the next.

The process described above is *asynchronous.* That is, the carrier frequency is set independently and is therefore not necessarily a fixed multiple of the output frequency (which is varying). This allows easy interfacing of the SA828 to the power electronics.

The alternative approach - *synchronous PWM* - locks the carrier frequency to an exact integer multiple of the power frequency. This implies that the carrier frequency varies with the power frequency which would make interfacing to the power electronics considerably more difficult, and in some cases, impossible.

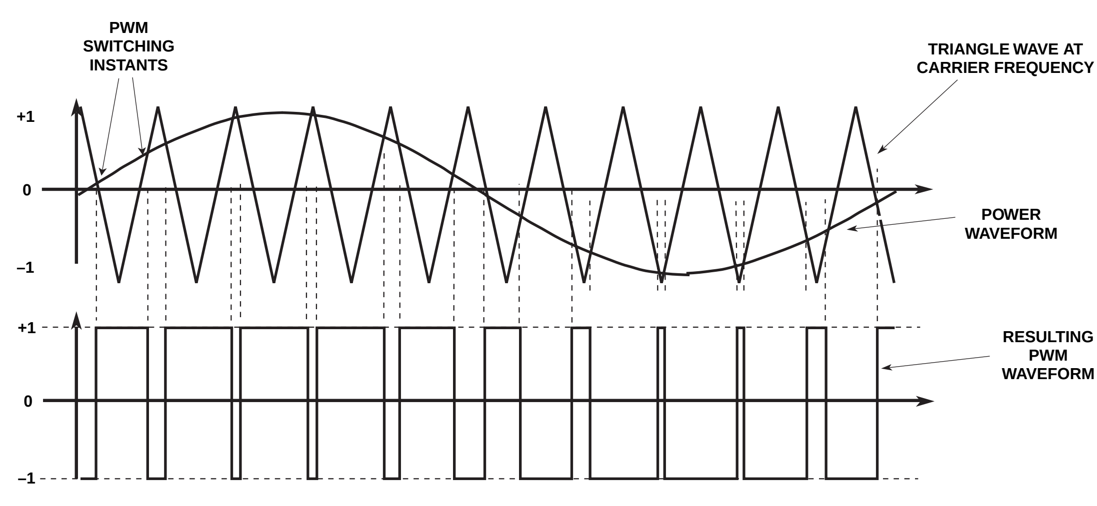

Fig.1: Natural PWM as used in analog implementation of the process

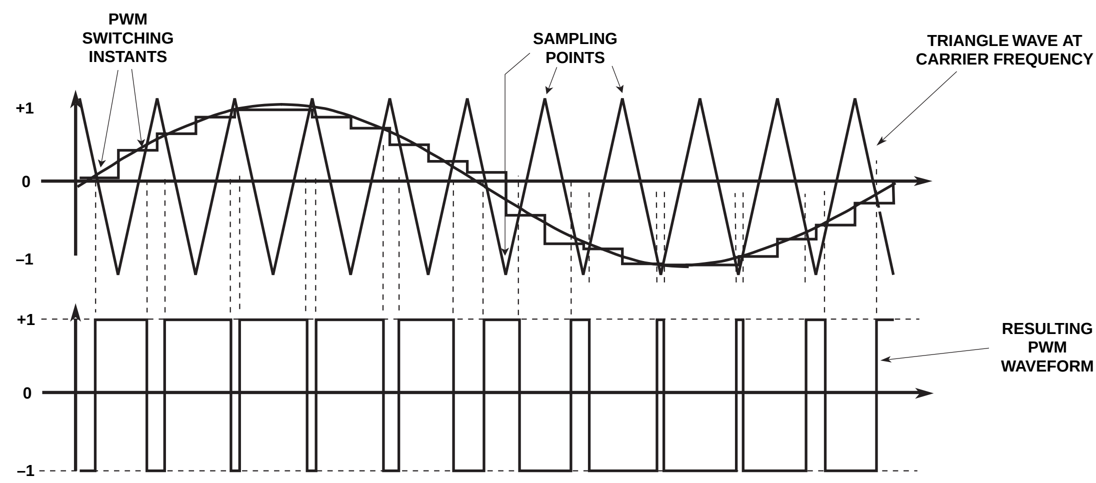

Fig.2: Asynchronous PWM generation with 'double-edged' regular sampling as used on the Mitel PWM family

FUNCTIONAL DESCRIPTION

Microprocessor Interface

The block diagram in Fig.3 shows the internal architecture of the SA828. The device is controlled via an 8-bit industry standard microprocessor interface. Decode logic has been integrated on-chip so that no 'glue-logic' is required between the microprocessor and the SA828. The device also features a novel 'bus identifier' which automatically adjusts the interface to accept Motorola or Intel machine cycle formats with no user intervention. This is referred to as a MOTEL* interface. Microprocessors from the 80XX and 68XXX families can be used directly with the device as can microcontrollers such as the 8051 and 6805. (Refer also to AN4677.)

Full chip select and read/write strobing inputs are provided and in addition a reset line allows the user to return the device to a known condition at any time.

The whole device, with the exception of the microprocessor interface, is timed via the clock input. The clock will normally be generated from a crystal of up to 12.5MHz to ensure good temperature characteristics.

It should be noted that the microprocessor interface is entirely independent of the clock generator circuit such that the microprocessor can load all parameters asynchronously.

Internally, the device has a series of registers which may be written to directly from the interface. These are used to tailor all aspects of the PWM output pulses, including carrier frequency, pulse deletion, pulse delay and rotational speed. This gives cost advantages both in terms of component savings and in allowing the same circuit to control a number of different motor drives simply by changing the microprocessor software.

Carrier Frequency

The carrier frequency, i.e. the frequency of the carrier waveform, is derived directly from the master clock input according to the contents of the Initialisation Register. Carrier frequencies up to 24kHz are available to allow the use of the entire spectrum of power switches from MOSFETs and IGBTs (at ultrasonic carrier frequencies) down to bipolars at low carrier frequencies. If a different set of carrier frequencies is required, the crystal frequency may be changed.

Power Frequency Range Selection

The power frequency range (the frequency range of the power output waveform) can be selected via the Initialisation Register and is also a direct function of the carrier frequency. As a result, a 'sliding scale' is effected giving power frequency ranges from 0 - 1.95Hz up to 0 - 4000Hz, depending upon the choice of carrier frequency. Hence an unprecedented range of frequencies can be selected. In fact there are forty-two combinations of carrier frequency and power frequency range. The power frequency range also serves to limit the maximum frequency supplied to the motor to provide a safe operating range.

Rotational Frequency Control

The actual frequency at which the PWM waveform is produced is governed by a 12-bit binary word, written directly to the SA828 by the micro. In addition, a sign bit is provided which changes the phase sequence from R-Y-B for forward rotation to R-B-Y for reverse rotation. Hence an effective 13 bits of speed control is achieved. This, in combination with the power frequency range control mentioned above gives speed control from ±500µHz to ±4000Hz without reconfiguring hardware, giving over 300 000 selectable speeds.

Zero frequency may always be selected irrespective of the carrier frequency and power frequency range to provide a DC injection brake facility. This is of particular use in machine tools where the work may be brought to a rapid standstill.

**MOTEL is a registered trademark of Intel Corp. and Motorola Corp.*

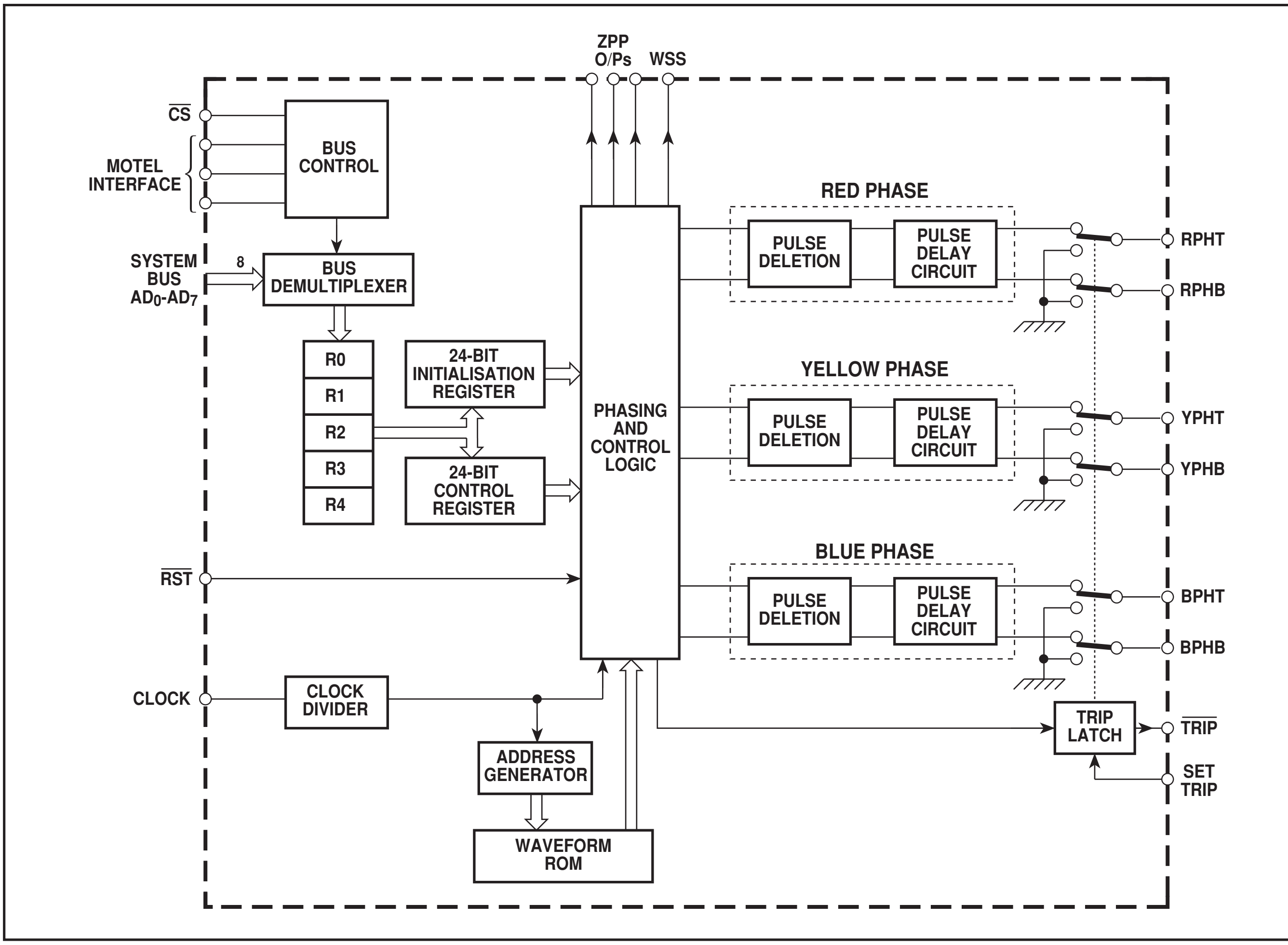

Fig.3: Block diagram of the SA828

Power Waveform

The desired waveshape is held in an on-chip ROM of size 384 x 8. Only the first 90° of the waveform is stored - the remainder of the waveform being created by reflecting the ROM contents about to 90°, 180° and 270° points of symmetry. This helps to minimise the area of the chip and hence minimise the cost of the device.

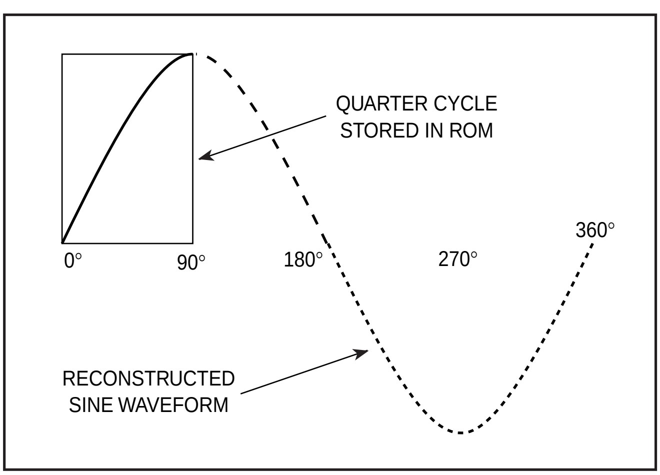

Fig.4: Reconstruction of full cycle from ROM

Two specific wave shapes are available in the on-chip ROM:

1. Pure sine wave. Used in applications where waveform purity is of particular importance or where only a single phase is required, e.g. switched mode power supplies and uninterruptible power supplies. The part number is SA8X82.

2. Sinewave with third harmonic superimposed at one sixth the amplitude of the fundamental. (Used in motor drives) the part number is SA8X81.

Due to inverter operation it can be shown that the maximum achievable output from a PWM system such as this is only 86.6% of the output voltage swing. This clearly does not make for an efficient system and inevitably leads to motor derating.

In order to make full use of the input voltage swing it would be necessary to increase the output voltage to 1/0.866 = 1.154 of its normal value - i.e. an increase of 15.4%.

This is achieved by adding an attenuated third harmonic components as shown in Fig.5.

Fig.5a shows the two individual frequency components and Fig.5b shows the composite signal when they are summed. The phase output voltage remains unchanged but line voltage is now increased by 16.7% due to the cancellation of cophasal (odd triplen) harmonics in a three phase system (as shown by the dotted line of Fig.5b.)

This increase in performance is obtained with no increase in harmonic components at the output due to the harmonic cancellation effect.

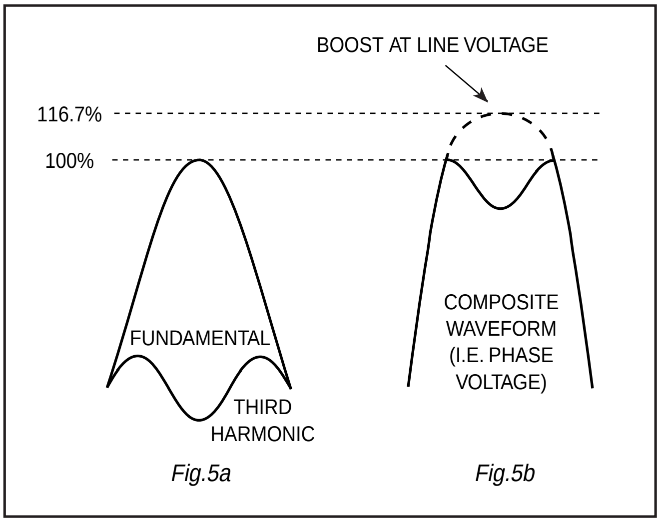

Fig.5: Construction of composite phase voltage

AMPLITUDE CONTROL

In the majority of drive applications, two particular kinds of amplitude response are required, as shown below in Fig.6.

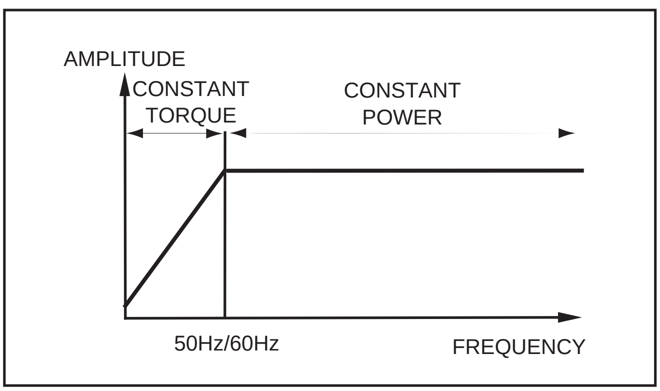

Fig.6a: Amplitude response for motor control

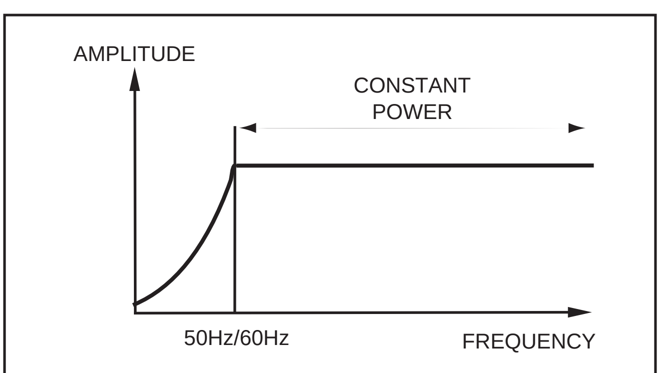

Fig.6b: Amplitude response for fan control

If the device is to be used with a motor load, a curve such as that shown in Fig.6a will be required. Alternatively, if a fan is used a square-law curve as Fig.6b may be used for reduced energy consumption at low speeds.

Successive 8-bit amplitude words can be written to the SA828 from the controlling microprocessor in order to reproduce these curves, or for that matter, any complex amplitude function. Usually, these curves will be retained in a small look-up table within the microprocessor memory and the amplitude will be changed whenever the power frequency is altered.

If the device is to be used as part of a switched mode power supply, uninterruptible power supply or any other waveform generator application, a constant amplitude word will be set to full scale at all times.

Pulse Deletion/Pulse Delay

Fig.7 shows the typical inverter network used in three phase PWM systems.

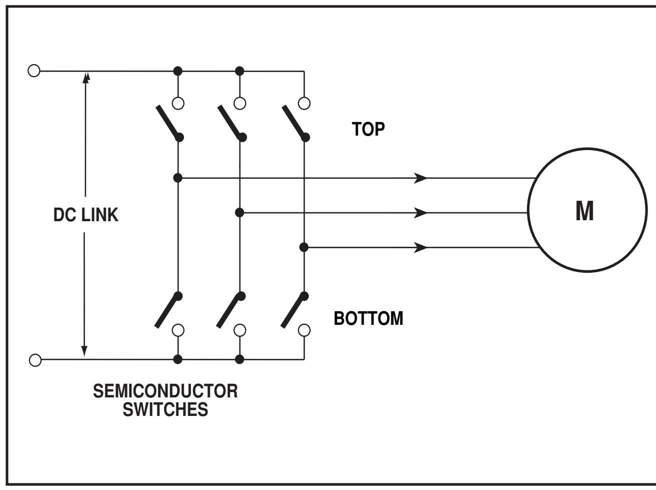

Fig.7: Three phase power bridge

It is essential when firing the switches in a network such as that in Fig.7 to ensure that both switches in any one vertical arm are off before either switch is turned on. If this rule were not obeyed there would be a risk of *shoot through* i.e. a dead short across the DC link when both switches are on simultaneously. Such a scenario would inevitably arise if the sense of both switches in an arm was changed simultaneously due to the finite and unequal turn-on and turn-off times associated with semiconductor devices.

To circumvent this problem, the SA828 allows for a pulse delay or 'underlap' time when neither switch is enabled. When sufficient time has elapsed to ensure that both switches are fully off, another change of state is allowed. The net result of this is a quasi-complementary pulse train to the top and bottom switches rather than being strictly complementary. Fig.8 shows the effect on a 'pure' PWM pulse train delay. The delay period can be predetermined by writing one byte to the SA828. The delay time is also a function of the carrier frequency in order to provide a very wide range of values for all types of power switches. The range of delay times exceeds 400:1 with a given clock frequency.

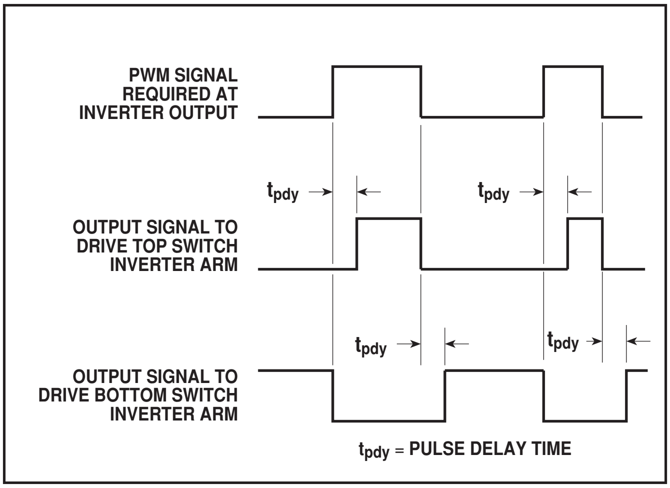

Fig.8: Effect of pulse delay on PWM pulse train

The power dissipation of the power switches is largely dependent upon the number of switching events which the power devices have to endure in a given time. In order to minimise these losses, the SA828 deletes all pulses in the train of less than a predetermined period. In this case no change of state will occur and the switching loss is reduced. This time is generally selected to correspond with the period of time taken for the power switch to turn on and immediately off again. Fig.9 shows the effect of pulse deletion diagrammatically.

The pulse deletion time is selected by writing one byte to the IC in the same way as pulse delay.

Other Features

The SA828 features six PWM outputs corresponding to the top and bottom switches of three phases. In addition, the device includes a low-going signal to indicate the zero-crossing point (i.e. 0° point) of all three phases. These may be used to provide closed-loop speed control.

Another useful feature incorporated into this device is an emergency trip. The SET TRIP pin, when taken high, acts to disable all the PWM outputs without software intervention, effecting an immediate shutdown of the power electronics. A $\overline{\text{TRIP}}$ acknowledge signal is provided for monitoring purposes.

APPLICATIONS

Fig.10 shows a typical application circuit for the SA828 in a motor drive system. Generally a microcontroller having on-chip ROM and RAM will give a minimum component system, whilst still having enough I/O port lines to directly interface to the keypad, display and watchdog inputs.

Clearly, it is possible to produce a working system using only two integrated circuits: a microcontroller, and an SA828. This represents a considerable saving in hardware development time compared to other alternatives.

Similar systems may be developed to provide soft start and dynamic braking using the SA828.

Note that once the various parameters have been written into the working registers within the SA828, the PWM sequence will begin and no further intervention from the microprocessor is required until, for example, the rotational speed needs to be changed. This frees the microprocessor to carry out other tasks, such as keypad scanning, display driving and watchdog functions. As a result of the small software overhead, the software development time and costs are considerably reduced.

The product range is backed up by a comprehensive range of literature, development hardware and software, including a demonstration unit containing typical software for use in a variable frequency environment. The order code is PWMDEMO. In addition, on line applications support is provided at all times to potential and existing customers.

The SA828 is available in production quantities and is currently designed into many commercial AC drives throughout the world.

RELATED PRODUCTS

A single phase version of the SA828 (known as the SA838) is also available for applications such as SMPS and UPS. It has just two PWM outputs, allowing it to be connected to a push-pull style H-bridge power stage.

In addition, Mitel Semiconductor also plans a range of PWM devices which do not require an accompanying microprocessor for low cost applications such as white goods and HVAC.

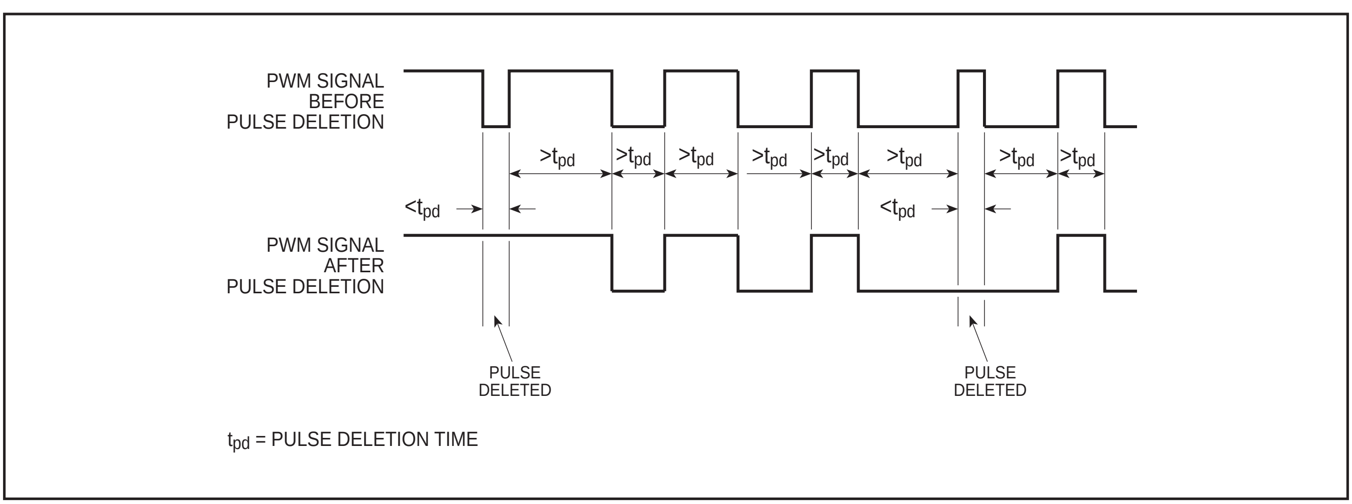

Fig.9: Effect of pulse deletion on PWM pulse train

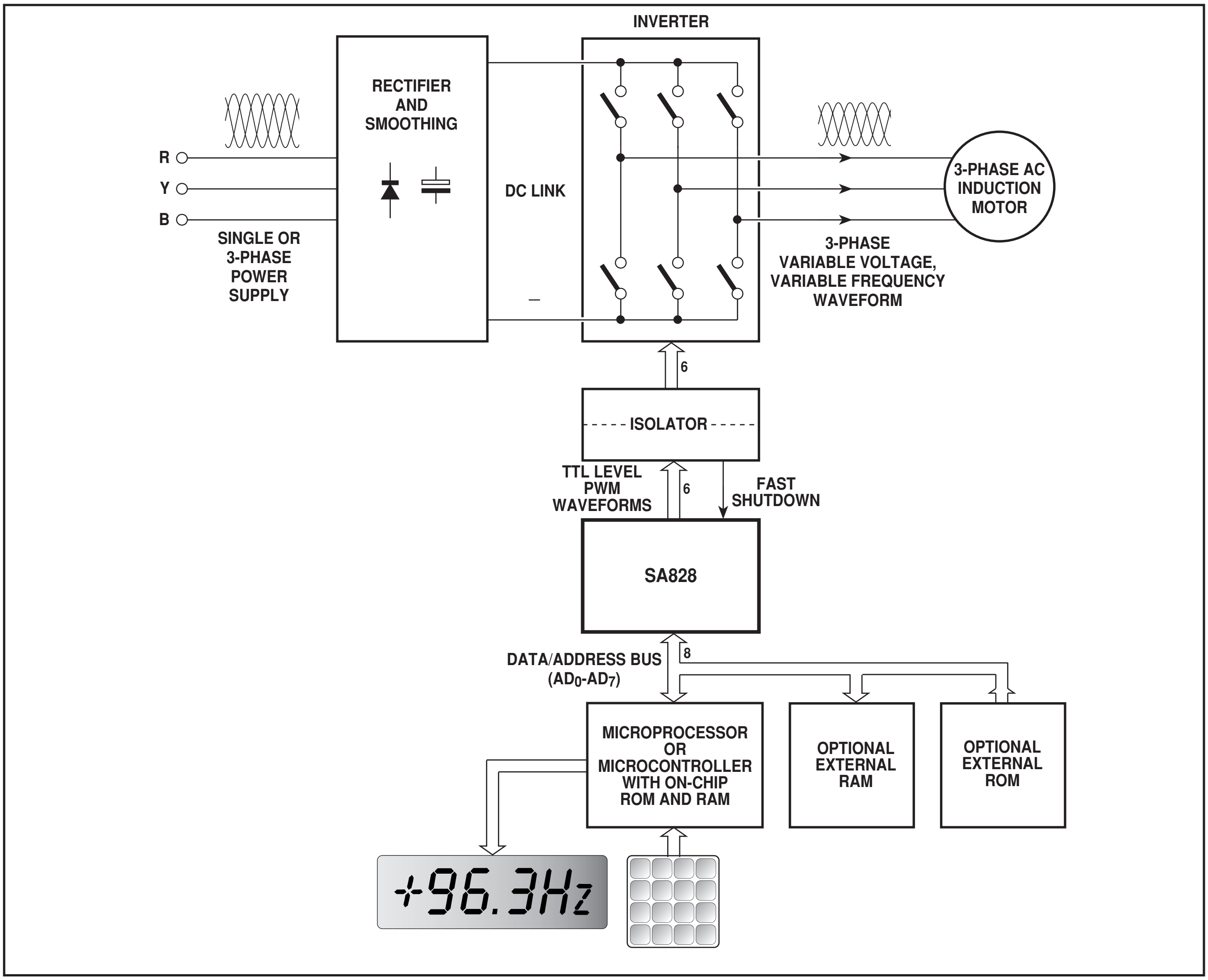

Fig.10: Typical SA828 application

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