Some New Magic Sinewave Development Chips

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A new class of **math functions** called **Magic Sinewaves** now lets you efficiently produce power sinewaves that can have **any** chosen number of low harmonics forced very near **zero**. And do so using the fewest possible switching events for the highest possible energy efficiency. Two new intros appear **here** and **here**, along with a development proposal **here**, a tutorial **here**, visualizations **here** , jitter and distortion analysis **here**, lots of calculators **here**, early evaluation chips **here** and seminars and workshops **here**.

With this and possible future **GuruGrams**, I will be introducing newer and improved **Magic Sinewave** development devices when and as they become available. Early planned introductions include this **Delta 28** with enhanced input and sync capabilities, **Delta 44**, **Delta 60**, possible analog input devices, and matching **Best Efficiency** versions. Other devices and sourcecode can be created for you on a **Custom Programming** basis.

Eval samples are normally based on a DIP packaged **PIC 16F628A** or **16F648A**, and working with the **Oshensoft** simulator and **Pocket Programmer II**. Both stock and custom sourcecode is licensable at low cost.

MS28D-05X Delta-28 with improved inputs and sync

Our first improved chip upgrades the existing **MS28D-4X** for additional input flexibility. As before, this is a delta friendly **28** pulse per cycle **Magic Sinewave** generator whose low harmonics **2-22** are all **-65** or more decibels below the fundamental **before** filtering. Also as before, a **PIC 16F628A** gets used. The key improvement is that you now have **seven** amplitude input lines whose **128** possible codes may be used in several different auto-switching modes.

In the **parallel** mode input amplitudes **0-100** are input on seven binary lines. In the **up-down** mode, three msb input lines are held **high**, and the other four will respond to **slew up**, **slew down**, **pulse up**, and **pulse down** pushbuttons or inputs. Up to **eleven** additional special functions can also be added.

The pinouts have changed somewhat from the **earlier design**. Here is the new schematic for the **MS28D-05X**…
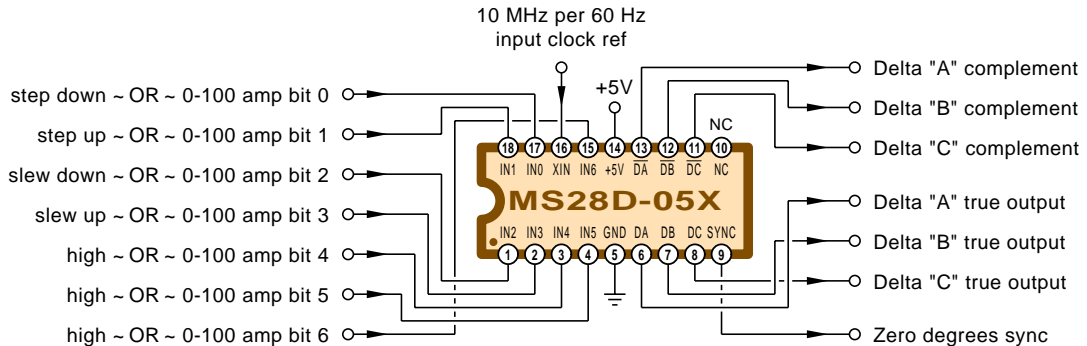
The 18 pin **DIP** chip is powered from a conventional +5 volt dc source and draws less than ten milliamperes. An external clock input reference of approximately **six Hertz per Megahertz** is required to set your output speed or frequency. A **ten MegaHertz** reference input thus becomes a **sixty Hertz** output frequency.

The exact number of clock cycles per output cycle is presently set to **12*4*3472 = 166656**. Thus a **10.000** MHz clock currently produces a **60.00384** Hertz output.

Your clock normally will come from an externally provided digital or analog reference, a voltage-to-frequency converter, or a frequency setting phase lock loop. The **Linear Technology LTC1799**, **LTC6903**, or **LTC6904** also look very interesting as clock sources.

Here is what the pins do…

pin 1 - IN2 In parallel mode, inputs **0-100** amplitude bit **2**. In up-down mode, **slews down** if high at a **360/SLEWR** rate, sticking at **0**.

pin 2 - IN3 In parallel mode, inputs **0-100** amplitude bit **3**. In up-down mode, **slews up** if held high at a **360/SLEWR** rate, sticking at **100**.

pin 3 - IN4 In parallel mode, inputs **0-100** amplitude bit **4**. Forces up-down mode if held high along with **IN5** and **IN6**.

pin 4 - IN5 In parallel mode, inputs **0-100** amplitude bit **5**. Forces up-down mode if held high along with **IN4** and **IN6**. Note: **MCLR** is done internally.

pin 5 - GND   System **ground** pin.

pin 6 - DA   Terminal **"A" delta output**. Normally routed to a half bridge driver. Phase A is **clockwise** from this output. Phase C is **counterclockwise**.

pin 7 - DB   Terminal **"B" delta output**. Normally routed to a half bridge driver. Phase B is **clockwise** from this output. Phase A is **counterclockwise**.

pin 8 - DC   Terminal **"C" delta output**. Normally routed to a half bridge driver. Phase C is **clockwise** from this output. Phase B is **counterclockwise**

pin 9 - SYNC   Outputs a square wave whose **leading edge** occurs at the Phase A **positive going** zero crossing. High for 0-180, low for 180-360.

Sync pulses are output at all amplitudes. This includes amplitude zero.

Use as an optional output frequency reference and scope sync for testing. Also very useful for phasing or **synchronous inverter** locking. Phase may be adjusted by briefly raising or lowering the input frequency.

pin 10 - NC   **Reserved** by PIC for low voltage programming.

pin 11 - $\overline{DC}$ **Complement** of **DC** output may be needed by certain half bridge drivers. May be resistively summed with **DB** for analog phase **B** output.

pin 12 - $\overline{DB}$ **Complement** of **DB** output may be needed by certain half bridge drivers. May be resistively summed with **DA** for analog phase **A** output.

pin 13 - $\overline{DA}$ **Complement** of **DA** output may be needed by certain half bridge drivers. May be resistively summed with **DC** for analog phase **C** output.

pin 14 - +5V   **+5 VDC supply**. Typical current is under 10 milliamperes and depends on frequency and port loading. Bypassed using at least two 0.05 microfarad capacitors as close as practical.

pin 15 - **IN6**	In parallel mode, inputs **0-100** amplitude bit **6**. Forces up-down mode if held high along with **IN4** and **IN5**.
pin 16 - **XIN**	Reference frequency **clock input**. Scale factor is **Six Hertz per MegaHertz**. Or **10 MHZ** in for a **60 Hertz** output.
pin 17 - **IN0**	In parallel mode, inputs **0-100** amplitude bit **0**. In up-down mode, **single steps down** when high, sticking at **0**. Handshake ends when line goes low or on any other input **change**.
pin 18 - **IN1**	In parallel mode, inputs **0-100** amplitude bit **1**. In up-down mode, **single steps up** when high, sticking at **100**. Handshake ends when line goes low or on any other input **change**.

Input Instruction Set

Here is how the 128 possible parallel input instructions are currently used…

X000 0000 - Amplitude 0 zeros outputs and maintains sync.
X000 0001 - Amplitude 1 (defaults to amplitude 4).
X000 0010 - Amplitude 2 (defaults to amplitude 4).
X000 0011 - Amplitude 3 (defaults to amplitude 4).

X000 0100 - Changes to Amplitude 4.
X000 0101 - Changes to Amplitude 5.
   . . . .
X110 0100 - Changes to Amplitude 100.

X110 0101 - No action. Reserved for future use.
   . . . .
X110 1111 - No action. Reserved for future use.

X111 0000 - No action.
X111 0001 - Single step up.
X111 0010 - Single step down.
X111 0011 - No action multikey lockout.

X111 0100 - Slew down.
X111 0101 - No action multikey lockout.
X111 0110 - No action multikey lockout.
X111 0111 - No action multikey lockout.

X111 1000 - Slew up.
X111 1001 - No action multikey lockout.
X111 1010 - No action multikey lockout.
X111 1011 - No action multikey lockout.

X111 1100 - No action multikey lockout.
X111 1101 - No action multikey lockout.
X111 1110 - No action multikey lockout.
X111 1011 - No action multikey lockout.

The eleven codes **X110 0101** through **X110 1111** are reserved for future expansion. Some of the exciting possibilities here include…

- soft or slow starts
- advancing or retarding output phase
- increasing or decreasing slew rate
- speed steps for a blender
- intensity presets for stage lighting
- direct analog input modes
- flame flicker or random effects
- power factor correction or ups
- mood lighting ultra slow dimming
- custom system control features
- parallel input change slewing

An additional ten codes are presently used to lock out more than one up-down key pressed at once. These could also be diverted to new uses.

Some Fine Print

There are presently up to **six** amplitude updates possible per cycle, spaced at **30** degree intervals. For minimum load transients, all updates synchronously change at times of zero current in all three phases. Initial recommended slew rate is **120** updates per second, going from zero to full scale in **0.83** seconds or slower.

A caution…

Avoid any large amplitude changes on real world loads!

Best transient performance is usually gotten by using single count amplitude steps or their slewed groups.

Slewing of parallel input amplitude changes can be added as a **Custom Option**. More than six updates per cycle appear difficult but possible.

The **leading edge** of the sync pulse is at phase zero. Sync is maintained with zero amplitude command **X000 0000**. There is presently up to a **sixty degree** latency on any input command change. This can possibly be shortened with fancier code. Sync is especially useful for synchronous inverter applications.

And a second caution…

> **Do NOT use zero amplitude as a safety lockout or or emergency shutdown!**
>
> **Instead, deselect the output drivers, remove the PIC supply voltage and force a Power on Reset.**

The zero amplitude selection can have up to a sixty degree latency. In addition, should something go very wrong, the **UPDATE** subroutine may not even be accessible at all.

At present, **MSD28-5X** amplitudes **01**, **02**, and **03** default to amplitude **04**. They are tricky to program because of certain ultra small delay values. Note that these three amplitudes are all well below **0.1** percent power and thus are largely inconsequential. Missing low amplitudes can be added as a **Custom Option**.

Typical Waveforms

The outputs of the **MS28D-05X** are similar to the **earlier design**. We'll repeat and update some key info here for convenience…

Here is how the **MS28D-05X** normally gets connected to a three phase motor…
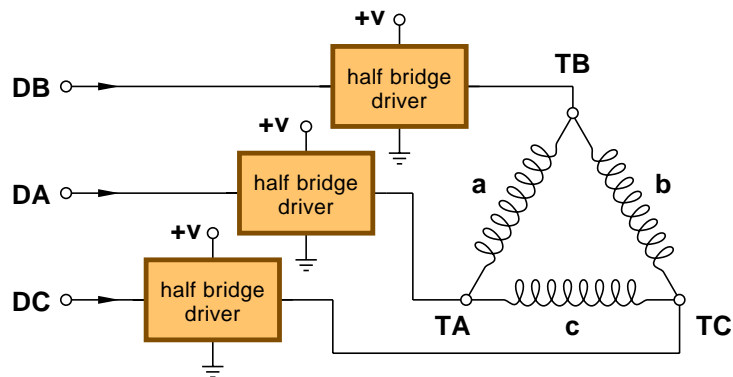
This assumes **non-inverting** half bridge drivers. Otherwise, the corresponding $\overline{DA}$, $\overline{DB}$, and $\overline{DC}$ lines are used. The half bridge supply voltage determines the **peak** of the output sinewave voltage for Amplitude 100. Minus on-state conduction drops.

The delta terminal waveforms are not intuitively obvious...
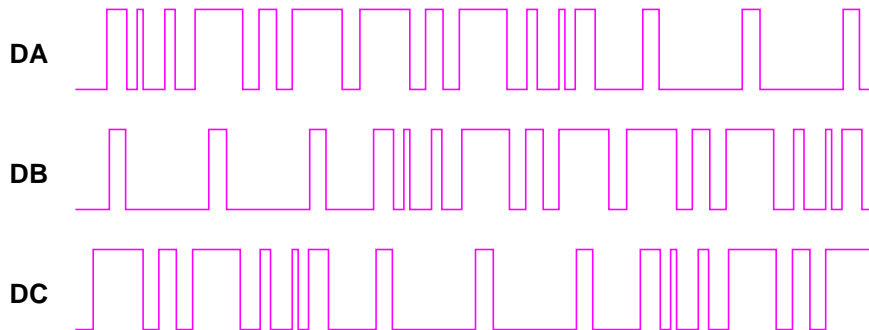
We see that the waveforms are forward and reverse symmetric. And are identical except for phase shifts of **120** and **240** degrees. These delta waveforms are derived **here**, **here**, and **here**.

Delta compatibility requires additional transitions. First, because of the **3n/4+1** harmonic rejection compared to the **4n** of best efficiency. And second because several additional transitions are needed for the above waveforms.

Any actual motor or other load phase responds to the **difference** between adjacent Delta terminals. For instance **DA** drives the left end of phase a above, while **DB** drives the right end of phase a. If **DA** is high and **DB** is low, a **clockwise** current results in phase a. If **DA** is low and **DB** is high, a **counterclockwise** current results in phase a.

Should **DA** and **DB** both be either low or high, then **zero** current results in phase a. Thus, any phase responds to the **difference** of its two drive waveshapes.

Which gives us these expected phase waveforms...
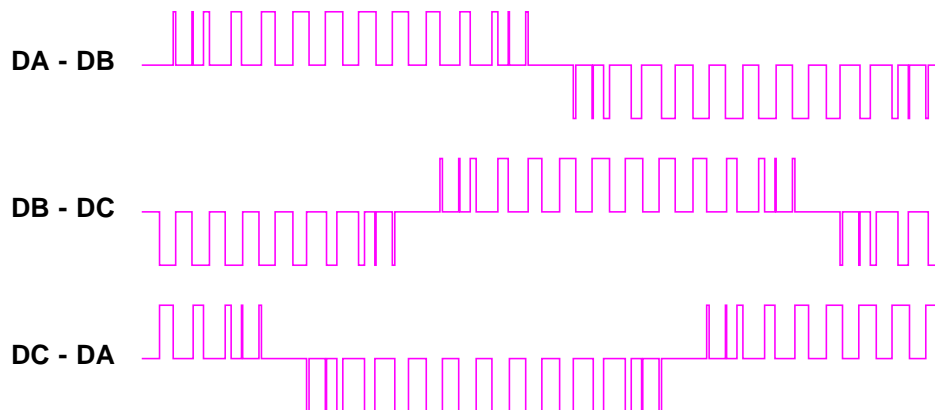
The bridge drivers will automatically take care of these subtractions for you. You also can **digitally subtract by ADDING one complement**. Which is quite handy to generate these bipolar analog test outputs…

All resistors 2.2K.
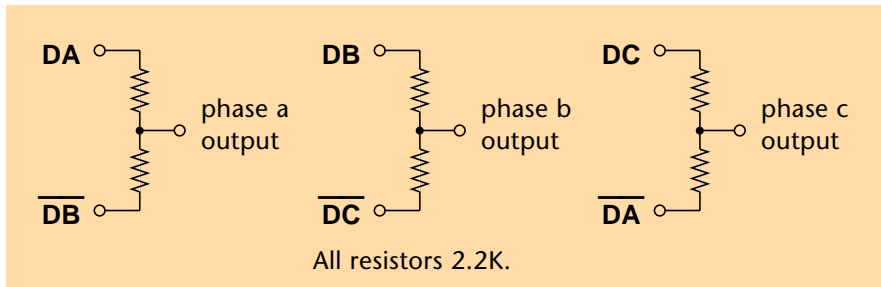
You can use similar resistive adding with opamps or filters. If not already provided, add a series 100 microfarad output coupling capacitor to block the 2.5 volt dc offset. Loading the ac output with a 1K resistor to ground will drop the output values to about a 0 DBM peak level.

Getting Started

Evaluation chips are presently provided in **18 pin** DIP packages. You can use most any breadboarding or test system that is **20 MHz** friendly. Those new **PIC Mockup breadboards** from **Technical Works** are especially handy and well suited for this task. But even an older **Heath ET3200** logic breadboard or similar can be used.

Your regulated **+5 volt DC** power supply has to be able to provide ten mils and must be properly bypassed with at least two **0.05** microfarad capacitors as close to the **MS28D-05X** as practical.

An external CMOS compatible clock of **6 Hertz per Megahertz** must be input. A **10 MHz** clock will produce a **60 Hertz** output frequency.

Ultimately, this clock will come from the rest of your system and will provide your frequency or speed reference. Initially, though, you could use most any old hf function generator or a three-cascaded-inverter oscillator built from a **74HCT14** hex CMOS Schmidt trigger, a resistor, and a capacitor. The **Linear Technology LTC1799**, **LTC6903**, or **LTC6904** also look very interesting as clock sources.

As shown above, your **DA**, **DB**, and **DC** outputs are routed to three half bridge drivers to power your load. Should your half bridge drivers be inverting, you can use the $\overline{DA}$, $\overline{DB}$, and $\overline{DC}$ complementary outputs instead. Optical isolation may be required for wye connected loads or for loads that must remain ground balanced.

The seven command inputs can be connected to ground through 22K resistors and to the positive supply via seven DIP switch stations. The lower four input lines can also have four pushbuttons placed in parallel with their DIP switches.

This will provide the **slew up,slew down**, **pulse up**, and **pulse down** commands.

To select the **up-down** mode, make **only** the three highest input lines **positive** and then use the pushbuttons. To use the **parallel** input mode, simply input any amplitude level between **0** and **100** directly on the DIP switches.

Your **SYNC** output can be routed to an electronic counter to verify your output frequency. This line is also useful for unambiguous scope sync or to provide phase locking for on-grid synchronous inverters.

As shown above, your **DA** and **DB** lines can be summed to provide a convenient bipolar analog output for distortion and spectrum measurements. A classic analog audio spectrum analyzer and a frequency selective voltmeter is recommended for most accurate results. As is a **Direct Fourier Transform** rather than a **FFT**.

Note that a typical computer sound card will sample a **60** Hertz waveform only around **400** times or roughly once per degree. This is far too low a sample rate to give you accurate **Magic Sinewave** distortion figures. Similarly, real time spectrum analysis software often will use a **Fast Fourier Transform** or **FFT** that may add windowing artifacts and sampling restrictions to your analysis.

Regardless…

Be sure your distortion and spectrum testing is actually and accurately measuring the magic sinewave and NOT viewing its own sampling or windowing artifacts!

Accurate predictions of **Magic Sinewave** performance can be found by using these **Magic Sinewave Calculators** and this **Quantization Analysis Tutorial**.

The **SigView** shareware software might also be of some assistance here. As is detailed in **this GuruGram**.

Some Options

There are all sorts of different **Magic Sinewave** chip options available. Some other devices in the series are planned that would provide maximum efficiency **single phase operation**. Or would zero out **three phase** delta harmonics up through the **34th** or the **46th**. Or possibly higher. Additional switching transitions do have to be one-on-one traded off per phase for any extra harmonics zeroed.

Lower reference frequencies such as **6 MHz / 60 Hz** may be possible, as would **400 Hertz** aerospace apps.

The slew rate and initial starting amplitude can also be preprogrammed. The number of available amplitudes could be increased or decreased. Amplitude steps could be made nonlinear for such effects as constant power increments, for any **low-medium-high** steps.

Other possibilities might include incandescent lamp brightness linearization, other load nonlinearity correction, or even random candle flame effects.

At present, the phase output sequence can be reversed by swapping the **DB** and **DC** delta lines. This can easily and cheaply be done using config jumpers, a **DPDT** manual switch or an external dual data selector. While an internal reversal feature is possible, doing so may end up resource intensive.

Present maximum frequency is beyond **120** Hertz, set by the **20** MHz spec limit of the **PIC** being used. The lower frequency limit and the frequency delta or speed spread is determined by your lowpass filtering and your ability to properly deal with the strong harmonics **23** and **25**.

Code modifications could allow external slew rate setting, A/D analog input, or a programmable soft start. Amplitude updates faster than six per cycle would appear possible but may require extensive new development.

Consulting Services and **Custom Programming** are available on these and other options. As are **training seminars**.

You can also **email** me for further assistance.

Transient Considerations

The **MS28D-05X** has been designed to be extremely "load gentle". Outputs start at zero phase of zero amplitude. In the **up-down** mode, they can theoretically increase or decrease at a **maximum speed of six one-level increments per cycle**.

Stock chips are slew rate limited to a slower **120** amplitude changes per second. Thus "off" to "full" will presently take a minimum of **0.833** seconds. Amplitudes can only synchronously change with all three delta outputs at zero. This should be ideal for motor starting or gentle long-life incandescent lamp startups.

However, as previously noted, the **parallel** mode allows fast and large amplitude changes. Transient behavior **must** be considered before allowing this to happen with real world loads…

> **You should carefully evaluate the dynamics of your intended use to make certain the available slew rates and latency times are compatible with your system stability!**

Filter Requirements

As with any pulse sinewave synthesis system, **Magic Sinewaves** output a mix of a desirable clean sinewave and considerable high frequency noise components. In particular, the **MS28D-28X** outputs strong amplitude dependent **23rd** and **25th** harmonics that may end up a significant fraction of the fundamental.

There are also some much higher frequency harmonics present, but these usually will completely disappear when you properly deal with the **23rd** and **25th**.

Typically, a motor's inductance usually does a one pole low pass filter, while its load intertia adds a second. Often, this will be more than enough filtering.

Regardless…

> **A minimum of 30 decibels of low pass filter rejection should be provided for your 23rd and higher harmonics!**

Your filtering and your intended load will determine the frequency or speed range you have available. Other **Magic Sinewave** chips can be made available that zero additional harmonics. These will trade off additional switching transitions for additional zeros rejected, easier filtering, and wider speed ranges. But all will give you the maximum possible number of harmonics zeroed for a given choice of pulses per cycle.

Single Phase Use

Note that those **DA**, **DB**, and **DC** unipolar delta drive waveforms are **not** stand alone magic sinewaves in and of themselves. In particular, any single output by itself will include **strong** triad harmonics. Especially the ninth. It is only when **pairs** of unipolar outputs are **subtracted** from each other that you get a low distortion and high efficiency bipolar magic sinewave.

Since the triad harmonics are identical in all three waveforms, any two outputs should automatically **cancel** their triads when they are subtracted.

Any **pair** of outputs can be used as a standalone single phase source. But specific use of outputs **DA** and **DB** is recommended for zero starting phase.

For More Help

The MS28D-05X chips are available at $19.63 each plus shipping. Sourcecode and one hour of consulting is separately available for $89 additional.

You can order your samples and sourcecode **here**. They should also be shortly available on **eBay**.

Licensing arrangements for your own chip production using our sourcecode or any of its derivatives or variants are available and are quite reasonably priced. You can **email me** for further details.

Additional **Magic Sinewave** services, programming, seminars, training and project development is available **here** and **here**. Further **GuruGrams** columns await your ongoing support as a **Synergetics Partner**.