60 Hz X-Tal CONVERTER
for vintage TWG Hammond organs.

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60 Hz Converter

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1 Forewords – Purpose of this project.

The 50/60Hz converter is mostly destined to European market where the AC Mains network is different from the US market.
Hammond TWG organs produced for 230V/50Hz operation are not concerned by this project since they fully comply with European norms.

However, there are many US made 117V/60Hz organs that are also sold in Europe. As it, those 117V/60 Hz need a 50Hz to 60Hz conversion so that TWG can spin at the right speed in order to get the correct tuning. Organs with asynchronous RUN motors (self-starting) are not concerned by the 60 Hz Converter described hereafter.

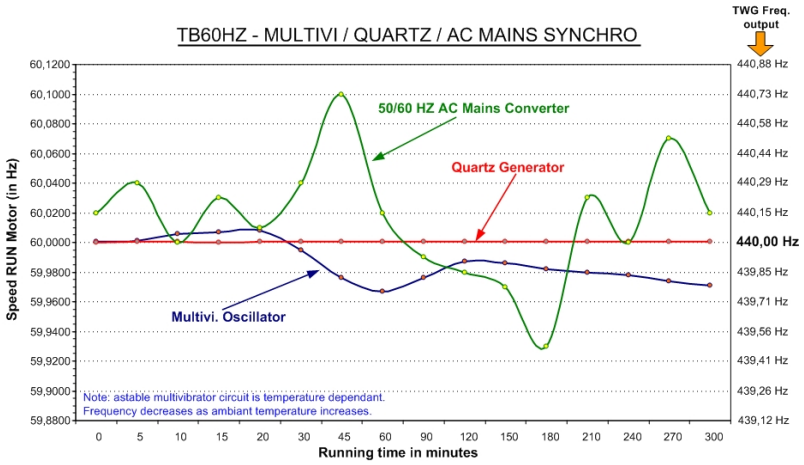
The voltage adaptation from 230V to 117V is much easier to cope with a basic step-down transformer providing the correct AC Mains voltage.
The purpose of this article is mainly focused on the frequency conversion that is much more complex than the voltage adaptation.

2 Types of 50Hz to 60Hz converters .

Nowadays, several types of converters are available on the market and can be summarized as follows:

- Industrial products such as SWC-60 (Keyboard Partner-GE), SC-60D (TrekII-USA) as a few examples do provide a proper solution. Such converters are quite easy to install in the organ and all X-Tal driven, hence the frequency of the RUN motor is extremely stable. Such units are somewhat expensive.

- Local converters hand-made by smaller service centers. Those converters do merit some attention as concerning the stability of the tuning frequency.



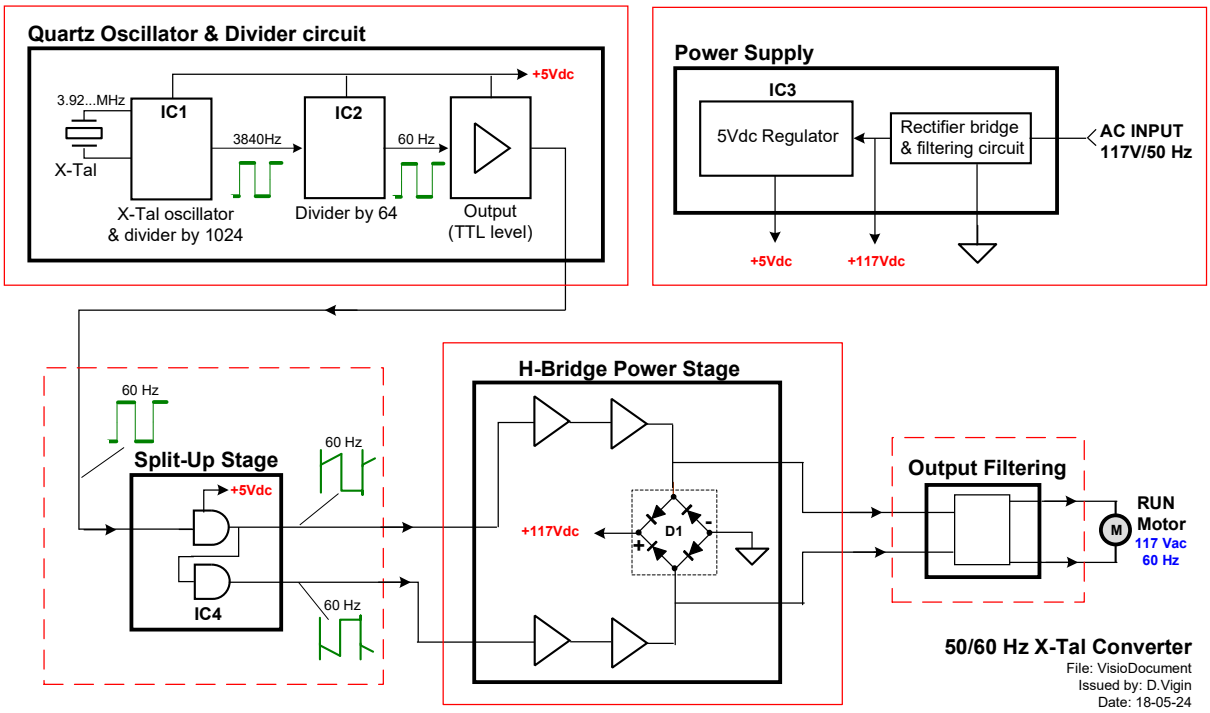
On the graph here-above, one can see the various fluctuations of the A-440Hz in function of the driven frequency. The X-Tal (quartz) solution provides the perfect stability while the two others may become ‘out of tune’.

3 Overall Description.

Several reasons turn me in developing a 60Hz converter that is:

- X-Tal driven in order to get the best frequency stability
- easy to build by qualified technician
- built with standard electronic components
- reliable and easy to install in the organ
- affordable price

4 Block Diagram



A shown on the block diagram, this 60Hz converter is composed of several sections:

Power Supply circuit provides 117Vdc to the power stage as well 5Vdc to the X-Tal oscillator and associated dividers. .

Quartz Oscillator is followed by the first frequency divider by 1024 and a second divider by 64. The oscillator generates a frequency of 3.932160 MHz. This frequency is divided by 1024 in IC1 and becomes 3840 Hz that is, in turn, divided in IC2 again by 64 to reach a output frequency of an accurate 60 Hz signal.
A basic output circuit does provide the TTL output level.

Split-Up Stage circuit having the role is to feed the H-Bridge stage with two 60Hz signals in opposite phase at TTL level.

H-Bridge power stage that provides two amplified signals of about 117Vac based on the H-Bridge principle.

Output Filtering circuit needed to assure the proper shape of output signals connected directly to the synchronous RUN motor.

5 Circuit Diagram.

Refer to the detailed schematic diagram shown on the next page.

5.1. X-Tal time base: the clock signal of 3.932460 MHz is generated by IC1 (CD4060). Refer to the data sheets to get more details and to understand more clearly how this crystal oscillator is connected and operating.

The output of this oscillator (clock) is routed internally through a chain of dividers.
At pin Q10 (divider by 1024), the available frequency signal becomes so 3840 Hz.
This 3840 Hz signal is connected directly to the Clock input of IC2 (CD4024).
The frequency available at pin Q6 of IC2 after division by 64 is now 60 Hz.
That was the target.

Finally a buffer circuit composed of one transistor T9 mounted in common emitter delivers a 60 Hz signal at TTL level (~ 5Vpp).
The trimcap C10 of 3-30pf located near the X-Tal can be adjusted in order to get an accurate frequency of 60,00 Hz.

5.2. Split-Up Stage : the purpose of this IC is to feed the Half H-Bridge Power stage with two input signals in opposite phase.
Only two basic NAND gates are needed for this operation.
The output of the first NAND gate is connected to the input of the second NAND gate.

The output signal is also inverted and two 60 Hz signals in opposite phase become now available.
Resistors network R14 ~ R17 do adapt the levels for Half H-Bridge circuit.

5.3. Half H-Bridge Power Stage: in this circuit, both driving circuits are identical but they are operating alternatively in ON-OFF function (like a Flip-Flop).
Refer to 'Block' and 'Timing' diagrams.

All transistors are mounted in Darlington configuration.
Circuits T1 ~T4 and T5 ~T8 operate as ON/FF switches (reproduced by S1 and S2 on 'Timing' diagram).
Output signal from channel A is feeding the circuit T1 ~ T4 and T5 ~T8 for channel B.

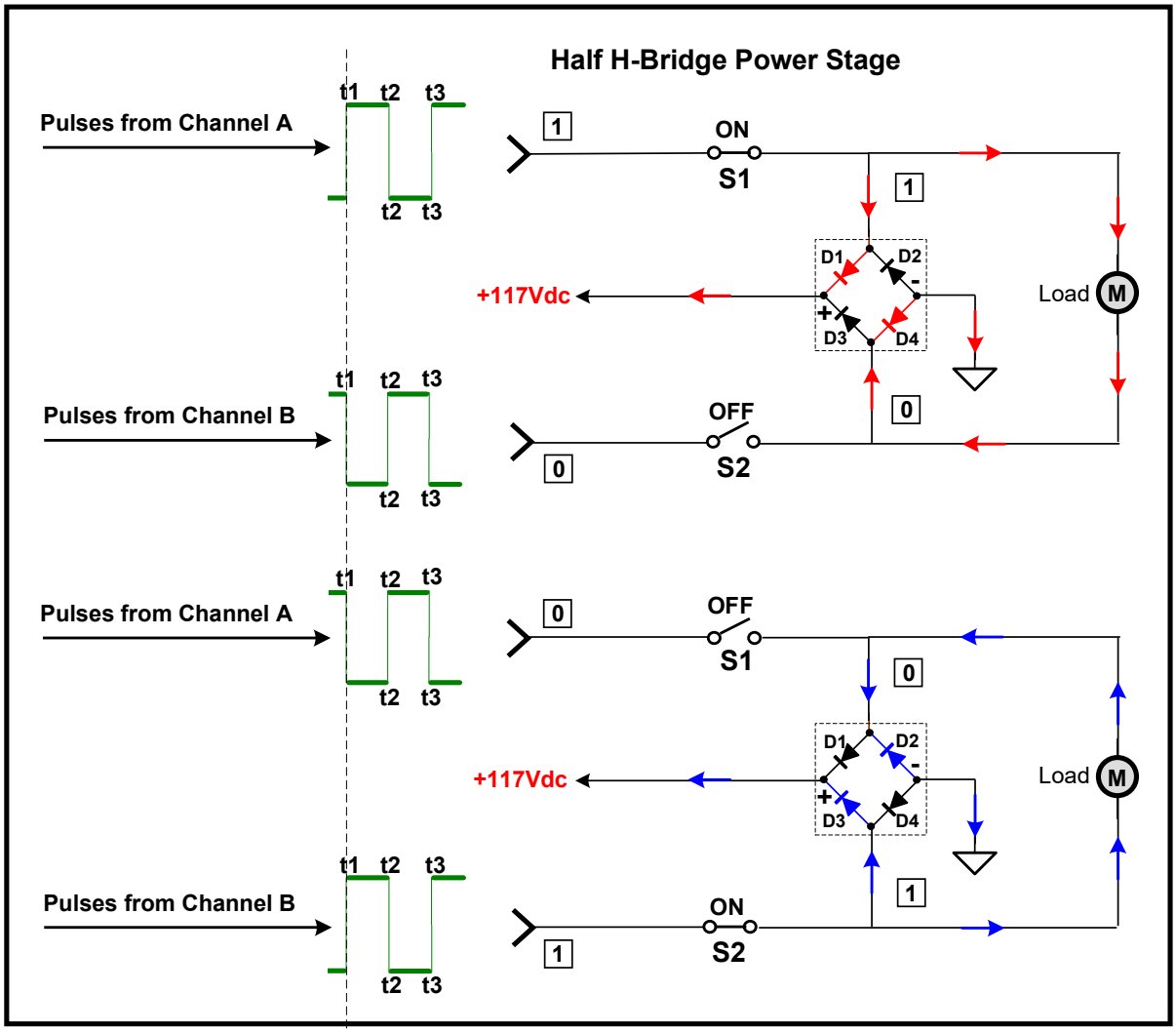
The incoming signal from channel A has a positive pulse during t1 to t2 period and the state of S1 is ON. Inversely, during the same period of time t1 to t2, the circuit T5 ~T8 remains blocked (S2 on OFF position) since incoming level stays at zero level.

The outputs of each driving circuit are connected to a bridge composed of four diodes D1 ~ D4, similarly to Graetz bridge but working differently.

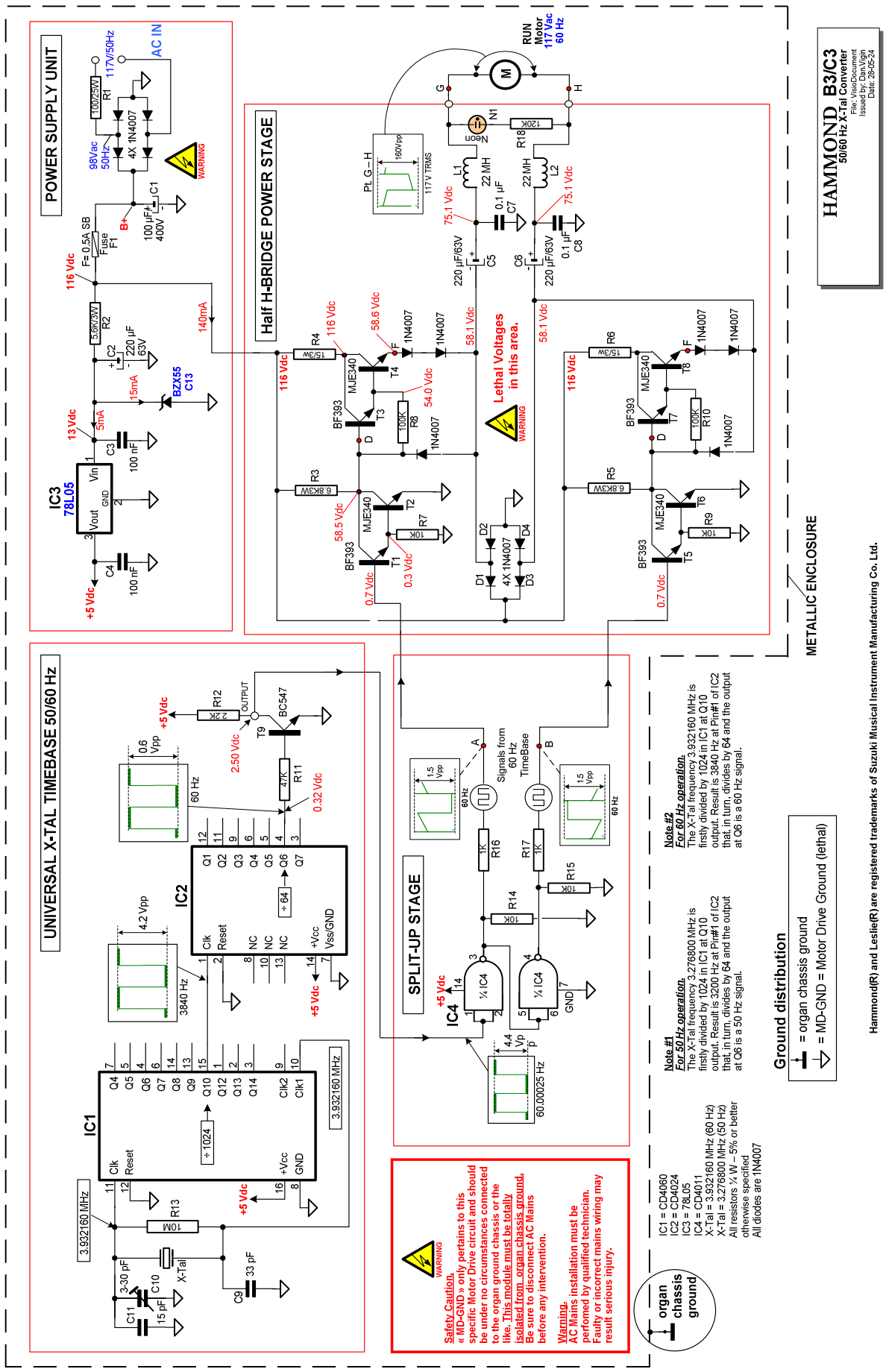
When on positive state (Red colored), diode D1 becomes conductive and the 117Vdc voltage is applied to one terminal of the load, RUN motor in our case.
The other terminal of the load returns to ground via diode D4.
When on negative state, it is just the reverse situation (Blue colored).

It is not the purpose in this article to describe in more details the functioning of an H-Bridge concept. A lot of technical information on the subject can be easily found on the internet websites.

7 Timing Diagram



5.4. Output filtering: the role of this basic filtering circuit is to smooth to a certain extend the sharps edges of square signals in order to minimize so transient spikes.
Choke coils L1 and L2 are optional and do not improve too much the shape of the outgoing signal driving the RUN motor.
One Neon bulb lamp N1 is connected in parallel of the output just to monitor the presence of 117Vac/60Hz voltage of the RUN motor. Not essential but '*nice to have it*'.


POWER SUPPLY UNIT
AC IN
117V/50Hz
98Vac 50Hz
4X 1N4007
WARNING
R1 100/25W
C1 100 µF/ 400V
B+
Fuse F1 F= 0.5A SB
116 Vdc
R2 5.6K/3W
C2 220 µF 63V
140mA
15mA
5mA
BZX55 C13
13 Vdc
IC3 78L05
Vin
Vout
GND
C3 100 nF
C4 100 nF
+5 Vdc
Half H-BRIDGE POWER STAGE
RUN Motor 117 Vac 60 Hz
Neon
N1
R18 120K
L1 22 MH
L2 22 MH
C7 0.1 µF
C8 0.1 µF/63V
C5 220 µF/63V
C6 220 µF/63V
75.1 Vdc
Pt. G – H
117V TRMS
160Vpp
Lethal Voltages in this area.
R4 15/3W
R5 6.8K3W
R6 15/3W
R3 6.8K3W
R7 10K
R8 100K
R9 10K
R10 100K
T1 BF393
T2 MJE340
T3 BF393
T4 MJE340
T5 BF393
T6 MJE340
T7 BF393
T8 MJE340
D1 4X 1N4007
D2
D3
D4
1N4007
58.5 Vdc
58.6 Vdc
58.1 Vdc
54.0 Vdc
0.7 Vdc
0.3 Vdc
0.32 Vdc
2.50 Vdc
HAMMOND B3/C3
50/60 Hz X-Tal Converter
First Version Document
Issued by: Dan.Vigin
Date: 28-05-24
METALLIC ENCLOSURE
UNIVERSAL X-TAL TIMEBASE 50/60 Hz
IC1
IC2
IC3
IC4
Clk
Reset
÷ 1024
÷ 64
+Vcc
GND
Vss/GND
NC
3.932160 MHz
3840 Hz
60 Hz
4.2 Vpp
0.6 Vpp
R12 2.2K
OUTPUT
T9 BC547
R11 47K
R13 10M
C9 33 pF
C10 X-Tal
C11 3-30 pF
15 pF
SPLIT-UP STAGE
Signals from 60 Hz TimeBase
R14 10K
R15 10K
R16 1K
R17 1K
¼ IC4
1.5 Vpp
4.4 Vp-p
60.00025 Hz
Safety Caution.
« MD-GND » only pertains to this specific Motor Drive circuit and should be under no circumstances connected to the organ ground chassis or the like. This module must be totally isolated from organ chassis ground. Be sure to disconnect AC Mains before any intervention.
Warning.
AC Mains installation must be performed by qualified technician. Faulty or incorrect mains wiring may result serious injury.
organ chassis ground
IC1 = CD4060
IC2 = CD4024
IC3 = 78L05
IC4 = CD4011
X-Tal = 3.932160 MHz (60 Hz)
X-Tal = 3.276800 MHz (50 Hz)
All resistors ¼ W – 5% or better otherwise specified
All diodes are 1N4007
Note #1
For 50 Hz operation.
The X-Tal frequency 3.276800 MHz is firstly divided by 1024 in IC1 at Q10 output. Result is 3200 Hz at Pin#1 of IC2 that, in turn, divides by 64 and the output at Q6 is a 50 Hz signal.
Note #2
For 60 Hz operation.
The X-Tal frequency 3.932160 MHz is firstly divided by 1024 in IC1 at Q10 output. Result is 3840 Hz at Pin#1 of IC2 that, in turn, divides by 64 and the output at Q6 is a 60 Hz signal.
Ground distribution
= organ chassis ground
= MD-GND = Motor Drive Ground (lethal)
Hammond(R) and Leslie(R) are registered trademarks of Suzuki Musical Instrument Manufacturing Co. Ltd.

9 SAFETY ASPECT

On the schematic diagram, we can see that ground terminals are in direct contact with 117V AC voltage. It is indicated on the schematic diagram by MD-GND (**M**otor **D**rive-**G**round).

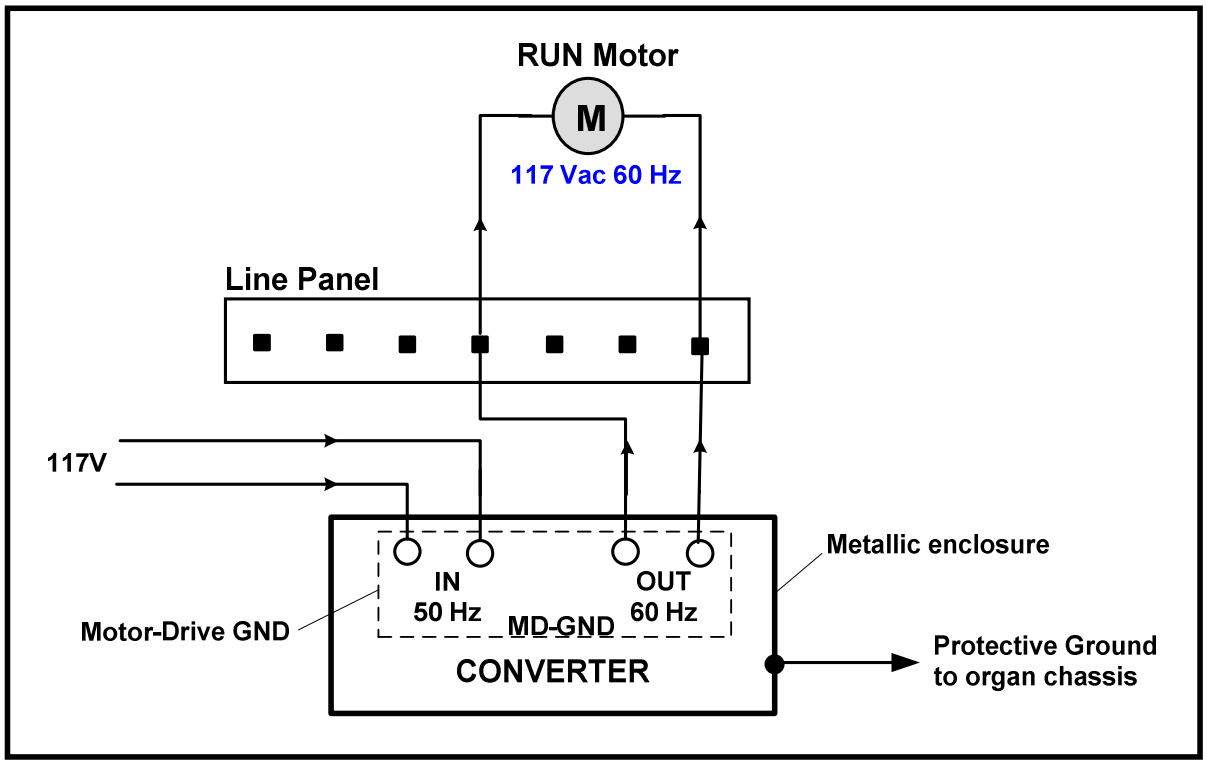
This ground connection is represented by the ⏚ symbol

Needless to remember that the whole PCB is lethal.
It is highly recommended to insert an isolation transformer during tests on the workbench. This will prevent from injuries and will avoid serious problems on test-equipment as well.

The Converter PCB is installed in a ventilated metal enclosure that must be absolutely galvanic isolated from the organ chassis The MD-GND of PCB must be totally separated from the metal enclosure. However, the metal enclosure must be connected to the chassis ground of the organ for two reasons: Protective Earth and EMI reduction .

Most of converter units on the market are also based on the same concept.

10 INSTALLATION & WIRING.



The converter should be installed on the left side of the organ (rear side view) preferably nearby the line panel aside the RUN motor.
OUT leads (117V/60Hz) are connected to terminals #4 and #7 of the Line Panel.
IN leads (117 V/50Hz) are coming either from the Line Panel or directly from the power transformer.

IMPORTANT: the metal enclosure must be connected to the organ chassis.

11 TWG Rotation for 50 Hz and 60 Hz organs.

It's interesting to understand the sequence during starting of TWG spinning when using different type of organs and converters.

Basically, there are two types of TWG Hammond organs:

- **115V/60Hz**, originally made for countries with voltage of 115Vac and frequency of 60Hz.
On these organs, the Power Transformer, START and RUN motors are designed to only operate on 115V/60Hz AC Mains networks.
The START motor will spin at 1260 RPM (+ 5% than normal RUN speed).
When switching ON the RUN button and releasing the START button, the rotation speed of TWG will decrease in a few seconds from 1260 RPM to **1200 RPM**, the RUN motor is so synchronized (locked) and TWG spins at its correct speed.

- **230V/50Hz**, specially designed to operate in countries with 230V/50Hz AC Mains networks. TWG's of those organs are working differently.
The START motor will spin at 1580 RPM (+ 5% than normal RUN speed).
When switching ON the RUN button and releasing the START button, the rotation speed of TWG will decrease in a few seconds to **1500 RPM**, the RUN motor is so synchronized (locked) and TWG spins at its correct speed.

Important Notice: if we want to use a 60Hz organ on 50Hz networks, the speed of the START motor will only reach 1167 RPM instead of 1260 RPM. This speed is too low to allow synchronization of RUN motor. Even if the RUN motor could be locked at 1200 RPM, the overall tuning of the organ will become A352 Hz (20% lower) instead of A440 Hz.
We know that a synchronous motor is not self-starting and has to be driven very near its correct rotation before being synchronized.

Since there are a lot of 60Hz organs imported to Europe, the question is 'how to make those organs operating on 50Hz networks? '

Several solutions can be envisaged.

1. External Inverters.

One possibility is to install an external inverter 230V/50Hz to 117V/60Hz. Such units do exist. However several issues have to be taken into serious consideration:

- frequency of this inverter must be very stable and accurate.
- delivered power has to be rather important specially if Leslie cabinets are also connected.
- signal should be as close as possible of sine-wave because it has to be connected to the main transformer that is only designed for sine-wave voltages.

Theoretically this system should work but almost never adopted by users.

2. 50Hz to 60Hz converters (sine-wave).

Converters such as SWC60 mk3 of KeyBoard Partner is one of the best approach while being somewhat expensive but easy to install and reliable.
In this converter, the 50Hz frequency climbs progressively until locked at 60Hz.
So, TWG will increase the spinning speed from 1167 RPM to 1200 RPM. That's exactly what model SWC60 mk3 is doing within +/- 5 seconds during the initial phase until the RUN motor is locked. The shape of the driving signal is close to sine-wave.

3. 50Hz to 60Hz converters (square-wave).

From numerous experiences conducted on 50Hz to 60Hz sine-wave converters, except for getting a progressive speed as on SWC60's units, most of the time, converters only delivering a fixed 60Hz sine-wave. Even so, the smoothness of the 60 Hz is not able to synchronize TWG since the starting speed remains too slow.
This is my conclusion based on numerous trials.

Another way to bypass this situation is to drive the RUN motor with 60Hz square-wave signals instead of sine-wave signals.

While being too slow when the START motor is spinning, when switching ON the RUN button, the sharp edges of square-wave do provide sufficient energy to catch the RUN motor to its synchronization state.

Some may argue that feeding a synchronous motor driven by square-wave voltages will create undesirable effects on rotation by comparison with the smoothness of a sine-wave signal.

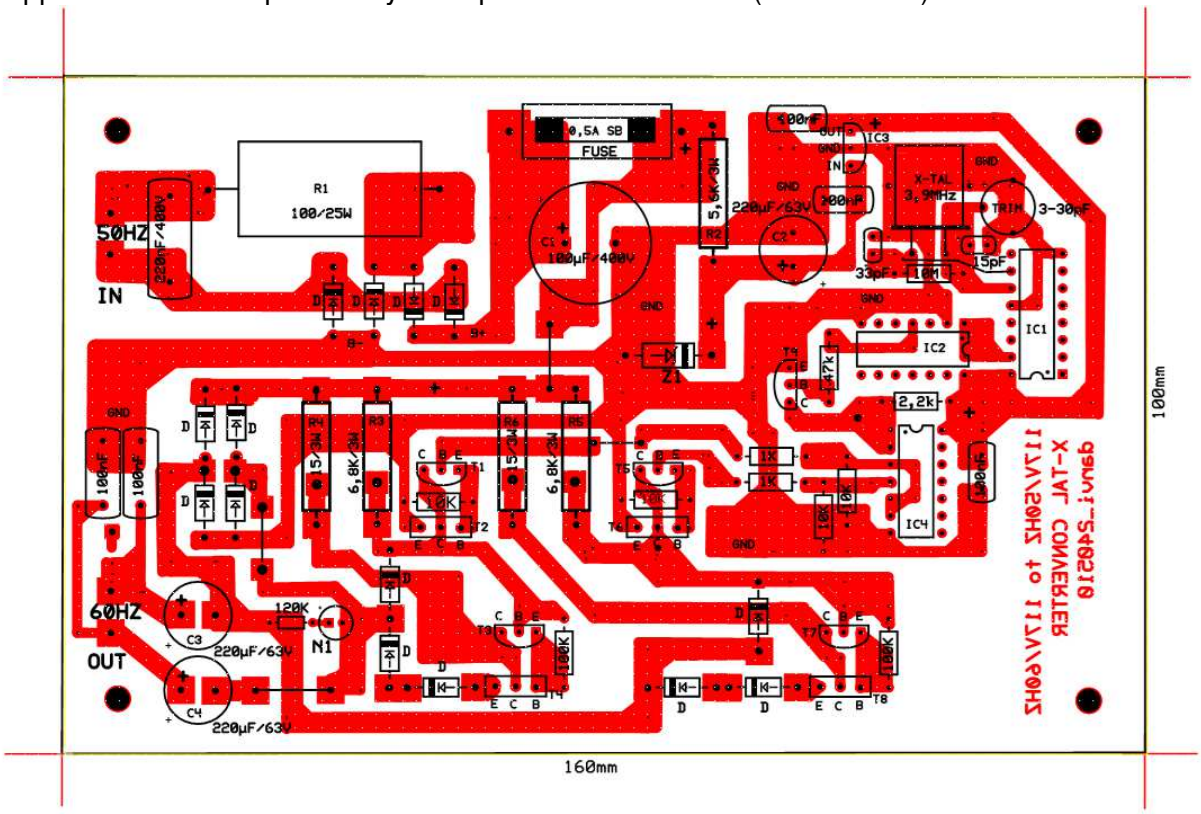
Indeed, this point is relevant and deep investigations were conducted on this matter.
Despite measurements and listening tests the spinning speed is not at all affected by square-wave signals.
No undesirable behaviours or shortcomings could be detected.
This can be also explained by the inertia of the flywheel system associated to TWG itself.

Since decades, I have installed such square-wave converters for RUN motors on numerous 60Hz organs (including my organs) and not a single complaint or failure was reported on that matter.
Nowadays, a lot of motors are driven by digital signals on other applications.

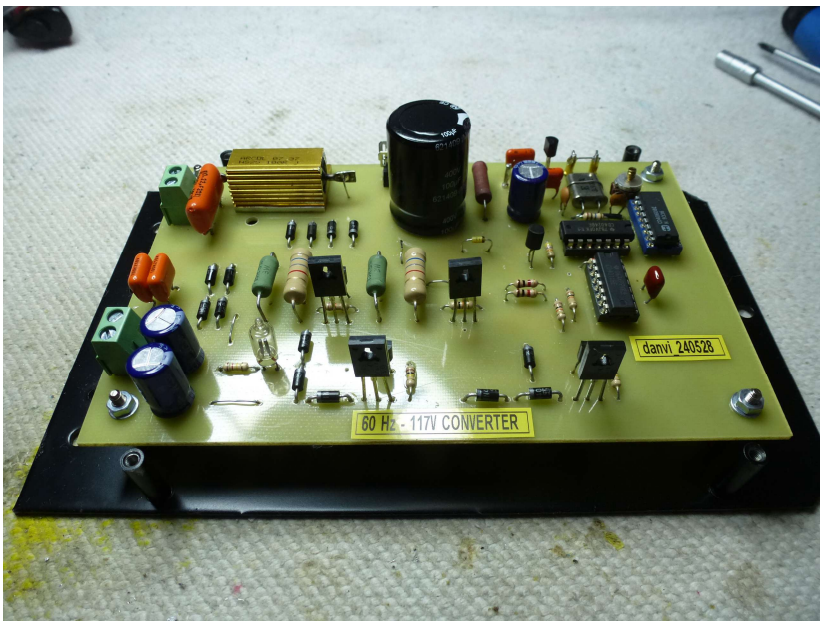
This document provides all technical information on such 60Hz converter based on square-wave principle while being locked by X-Tal Time Base assuring an excellent stability to TWG.

12 PCB realization

All components of the circuit are installed on one single layer epoxy PCB (160 x 100mm). Only standard components are used. Some power resistors (>3W) have to be raised from PCB except R1 (100Ω/25W).
Copper side and component layout is provided here-below (not real size).



As already mentioned, there are no galvanic connections between the PCB and the metal enclosure. The fixation holes on each corner do have sufficient clearance to meet the European safety regulations.



This converter has successfully undergo a life-test of 12 hours without any problem.
The metallic enclosure is ventilated due to the heat dissipation of some power resistances.

The first reason of installing this 60Hz PCB in a metallic enclosure is firstly to protect the user again electrical shocks since the entire PCB is connected directly on the AC Mains network. Another purpose of having this enclosure is to minimize EMI, if any (Electro Magnetic Interferences).

Tests have been conducted on the organ itself, no spurious interferences were revealed when playing with or without enclosure.

While being rather high, the sharp edges of the pulses driving the RUN motor are not interfering because the impedance of the output stage is quite low.
Anyhow, it's good to know that this 60 Hz converter is EMI-free.

13 Conclusions

All 60 Hz converters of that type are quite reliable.
The exceptional stability of TWG speed due to quartz oscillator is really appreciated too.

Remarks, further information, questions or the like are the most welcome.

Hammondly yours,

Dan Vigin