

Getting Started With TIMS

ACHIEVEMENTS: a familiarity with the TIMS modelling philosophy; development of modelling and experimental skills for use in future experiments. Introduction to the ADDER, AUDIO OSCILLATOR and PHASE SHIFTER modules

PREREQUISITES: a desire to use TIMS to enhance one's knowledge of, and insights into, the phenomena of telecommunications theory and practice.

Introduction

This experiment assumes no prior knowledge of telecommunications. It illustrates how TIMS is used to model a mathematical equation. You will learn some experimental techniques. It will serve to introduce you to the TIMS system, and prepare you for the more serious experiments to follow.

In this experiment you will model a simple trigonometrical equation. That is, you will demonstrate in hardware something with which you are already familiar analytically.

An Equation To Model

You will see that what you are to do experimentally is to demonstrate that two AC signals of the *same* frequency, *equal* amplitude and *opposite* phase, when added, will sum to zero.

This process is used frequently in communication electronics as a means of removing, or at least minimizing, unwanted components in a system. You will meet it in later experiments.

The equation which you are going to model is:

$$y(t) = V_1 \sin(2\pi f_1 t) + V_2 \sin(2\pi f_2 t + \alpha) \quad \dots\dots 1$$

$$= v_1(t) + v_2(t) \quad \dots\dots 2$$

Here $y(t)$ is described as the sum of two sine waves. Every schoolboy knows that, *if*:

each is of the same frequency: $f_1 = f_2$ 3
 each is of the same amplitude: $v_1 = v_2$ 4

and they are 180° out of phase: $\alpha = 180^\circ$ 5
 then: $y(t) = 0$ 6

A block diagram to represent it is suggested in Figure 1.

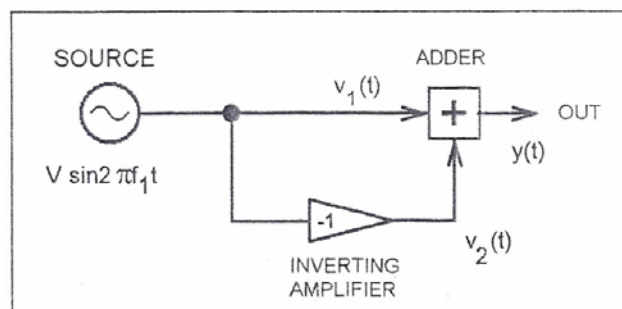


Figure 1: block diagram model of Equation 1

Note that we ensure the two signals are of the same frequency ($f_1 = f_2$) by obtaining them from the same source. The 180 degree phase change is achieved with an inverting amplifier, of unity gain.

This diagram appears to satisfy the requirements for obtaining a null at the output. Now see how we could model it with TIMS modules.

A suitable arrangement is illustrated in block diagram form in Figure 2.

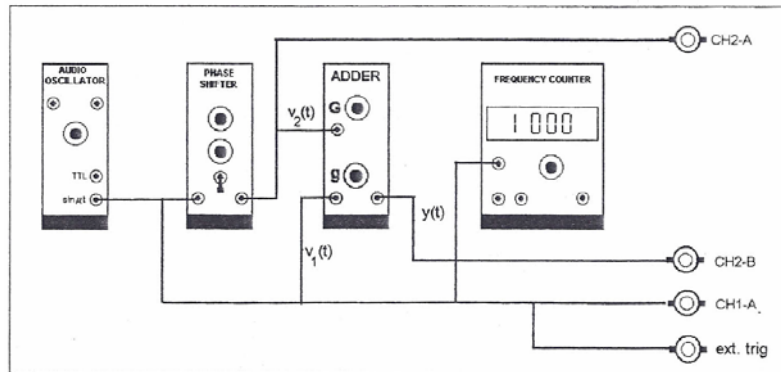


Figure 2: the TIMS model of Figure 1.

Before you build this model with TIMS modules let us consider the procedure you might follow in performing the experiment.

The annotation for the ADDER needs explanation. The symbol 'g' near one input means the signal at this input will appear at the output, amplified by a factor 'g'. Similar remarks apply to the input labelled 'G'. Both 'g' and 'G' are adjustable from the front panel of the ADDER.

Conditions for a null

For a null at the output, also referred to as a 'balance', one would be excused for thinking that if:

1) the PHASE SHIFTER is adjusted to introduce a difference of 180° between the input and the output.

and

2) the gains 'g' and 'G' are adjusted to equality

then

3) the amplitude of the output signal $y(t)$ will be zero.

In practice the above procedure will probably *not* result in zero output. Here is the first *important observation* about the practical modelling of a theoretical concept.

In a practical system there are inevitably small impairments to be accounted for. For example, the gain through the PHASE SHIFTER is *approximately* unity, not exactly so. It would thus be pointless to set the gains 'g' and 'G' to be precisely equal. Likewise it would be a waste of time to use an expensive phase meter to set the PHASE SHIFTER to exactly 180° , since there are always small phase shifts not accounted for elsewhere in the model.

*These small impairments are unknown, but they are stable.
Once compensated for they produce no further problems.*

So we do not make precise adjustments to modules, independently of the system into which they will be incorporated, and then connect them in and expect the system to behave. All adjustments are made *to the system itself* to bring about the desired end result.

The null at the output of the simple system of Figure 2 is achieved by adjusting the uncalibrated controls of the ADDER and of the PHASE SHIFTER. Although equations (3), (4), and (5) define the necessary conditions for a null, they do not give any guidance as to how to achieve these conditions.

More insight into the null

It is instructive to express eqn. (1) in phasor form. Refer to Figure 3.

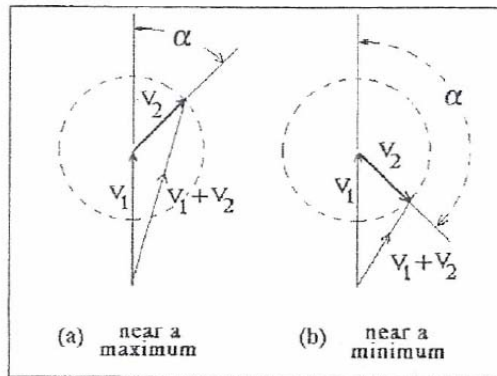


Figure 3: Equation (1) in phasor form

Figure 3 (a) and (b) shows the phasors V_1 and V_2 at two different angles α : It is clear that, to minimise the length of the resultant phasor $(V_1 + V_2)$ the angle α . In (b) needs to be increased by about 45° .

The resultant having reached a minimum, then V_2 must be increased to approach the magnitude of V_1 for an even smaller (finally zero) resultant.

We knew that already. What is clarified is the condition prior to the null being achieved. Note that, as angle α is rotated through a full 3600, the resultant $(V_1 + V_2)$ goes through one minimum and one maximum (refer to the *TIMS User Manual* to see what sort of phase range is available from the PHASE SHIFTER).

What is also clear from the phasor diagram is that, when V_1 and V_2 differ by more than about 2:1 in magnitude, the minimum will be very shallow, and the maximum broad and not pronounced I.

Thus we can conclude that, unless the magnitudes of V_1 and V_2 are already reasonably close, it may be difficult to find the null by rotating the phase control.

It would be "rise to set V_2 close to v_1 before we start nulling. This will be done in the procedures detailed below.

Note that, for balance, it is the ratio of the magnitudes V_1 and V_2 which is of importance.

So we will consider V_1 *affixed* amplitude (the reference), and make all adjustments to V_2
This assumes V_1 is not of zero amplitude!

TIMS Experiment Procedures

In each experiment the tasks 'T' you are expected to perform, and the questions 'Q' you are expected to answer, are printed in italics and in slightly larger characters than the rest of the text.

In the early experiments there will a large list of tasks, each given in considerable detail. Later, you will not need such precise instructions, and only the major steps will be itemised. You are expected to become familiar with the capabilities of your oscilloscope, and especially with synchronization techniques.

Modelling The Equation

You are now ready to model eqn. (1). The modelling is explained step-by-step as a series of small tasks.

Take these tasks seriously, now and in later experiments, and TIMS will provide you with hours of stimulating experiences in telecommunications and beyond. The tasks are identified with a 'T', are numbered sequentially, and should be performed in the order given.

*T1 both channels of the oscilloscope should be permanently connected to the matching coaxial connectors on the SCOPE SELECTOR. See the **TIMS User Manual** for details of this module.*

*T2 in this experiment you will be using three plug-in modules, namely: an AUDIO OSCILLATOR, a PHASE SHIFTER, and an ADDER. Obtain one each of these. Identify their various features as described in the **TIMS User Manual**.*

Most modules can be controlled entirely from their front panels, but some have switches mounted on their circuit boards. Set these switches before plugging the modules into the TIMS SYSTEM UNIT; they will seldom require changing during the course of an experiment.

T3 set the on-board range switch of the PHASE SHIFTER to 'LO'. Its circuitry is designed to give a wide phase shift in either the audio frequency range (LO), or the 100 kHz range (HI).

Modules can be inserted into anyone of the twelve available slots in the TIMS SYSTEM UNIT. Choose their locations to suit yourself. Typically one would try to match their relative locations as shown in the block diagram being modelled. Once plugged in, modules are in an operating condition.

T4 plug the three modules into the TIMS SYSTEM UNIT

T5 set the front panel switch of the FREQUENCY COUNTER to a GATE TIME of 1 s. This is the usual selection for measuring frequency.

T6 connect a patch lead from the input of the FREQUENCY COUNTER to a sinusoidal output of the AUDIO OSCILLATOR. The display will indicate the oscillator frequency f_1 (you may leave the connection until the counter is required for some other measurement)

T7 set the frequency f_1 with the knob on the front panel Of the AUDIO OSCILLATOR, to approximately 1 kHz (any frequency would in fact be suitable for this experiment).

T8 patch a lead from the AUDIO OSCILLATOR output to the 'ext. trig' [or 'ext. synch'] terminal of the oscilloscope. Make sure the oscilloscope controls are switched so as to accept this external trigger signal; use the automatic sweep mode if it is available.

T9 patch a lead from the AUDIO OSCILLATOR output to CH1-A of the SCOPE SELECTOR module. This will display, throughout the experiment, a constant amplitude sine wave, and act as a monitor on the signal you are working with.

T10 set the sweep speed of the oscilloscope, and the gain of CH1, to display a few periods of the sine wave. The period of a 1kHz sine wave 1 ms – a sweep speed of 0.5 ms/cm is suitable)). Use the oscilloscope CH 1 shift control to locate the trace in the upper half of the screen.

T11 patch a lead from the AUDIO OSCILLATOR output to the input of the PHASE SHIFTER.

T12 patch a lead from the PHASE SHIFTER output to the input G of the ADDER.

T13 patch a lead from the AUDIO OSCILLATOR output to the input g of the ADDER.

T14 patch a lead from the input g of the ADDER to CH2-A of the SCOPE SELECTOR.

T15 patch a lead from the output of the ADDER to CH2-B of the SCOPE SELECTOR.

Your model should be the same as that shown in Figure 4 below. You are now ready to set up some signal levels.

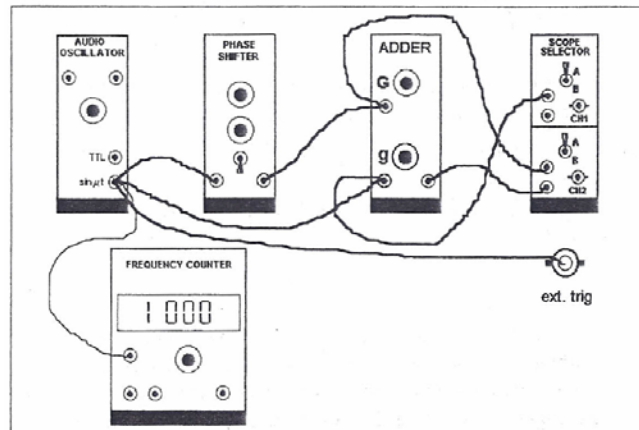


Figure 4: the TIMS model.

T16 switch the SCOPE SELECTOR to CH1-A and CH2-A.

T17 find the sine wave on CH2-A and, using the oscilloscope controls, place it in the lower half of the screen.

These two signals, of the amplitudes indicated by the oscilloscope, are connected to the two ADDER inputs. One goes via the PHASE SHIFTER, which has a gain whose nominal value is unity.

As part of the plan outlined previously it is now necessary to set the amplitudes of the two signals at the output of the ADDER to approximate equality.

Comparison of eqn. (1) with Figure 2 will show that the ADDER gain control g will adjust V_1 and G will adjust V_2 .

You should choose to set V_1 and V_2 at or near the TIMS ANALOG REFERENCE LEVEL, namely 4 volt peak-to-peak.

T18 switch the SCOPE SELECTOR from CH2-A to CH2-B. Channel 2 is now displaying the ADDER output. The ADDER gains have not yet been adjusted; so ignore any display on this channel for the moment.

T19 remove the patch cord from the g input of the ADDER. This makes V_1 zero, and so it will not influence the adjustment of V_2 .

T20 adjust the G gain control of the ADDER until the signal at the output of the ADDER, displayed on CH2-B of the oscilloscope, is about 4 volt peak-to-peak. This is V_2 . You may need to set the CH2 amplitude and shift controls of the oscilloscope for a convenient display.

T21 remove the patch cord from the G input of the ADDER. This makes V_2 zero, and so it will not influence the adjustment of V_1 .

T22 replace the patch cord from the AUDIO OSCILLATOR to the g input of the ADDER, thus restoring V_1

T23 adjust the g gain control of the ADDER until the signal at the output of the ADDER, displayed on CH2 of the oscilloscope, is about 4 volt peak-to-peak. This is V_1

T24 replace the patch cord from the AUDIO OSCILLATOR to the G input of the ADDER.

Both V_1 and V_2 are now displayed on the lower half of the screen (CH2-B). Their individual amplitudes have been made approximately equal. Their sum may lie anywhere between zero and 8 volt peak-to-peak, depending on the value of the phase angle α . It is true that 8 volt peak-to-peak would be in excess of the TIMS ANALOG REFERENCE LEVEL, but it won't overload the oscilloscope, and in any case will soon be reduced to a null.

Your task is to adjust the model for a null at the output, as displayed on CH2-B of the oscilloscope.

You may be inclined to fiddle, in a haphazard manner, with the few front panel controls available, and hope that before long a null will be achieved. You may be successful in a few moments, but this is highly unlikely. Such an approach is definitely not recommended if you wish to develop good experimental procedures.

Instead, you are advised to remember the plan discussed above. This should lead you straight to the wanted result with confidence, and the *satisfaction that instant and certain success* can give.

There are only *three* conditions to be met, as defined by equations (3), (4), and (5)

- the *first* of these is already assured, since the two signals are coming from a common oscillator.
- the *second* is approximately met, since the gains 'g' and 'G' have been adjusted to make V_1 and V_2 about equal.
- the *third* is unknown, since the front panel control of the PHASE SHIFTER is not calibrated.

It would thus seem a good idea to start by adjusting the phase angle α : So:

T25 whilst watching the lower trace, $y(t)$ on CH2-B, vary the front panel control of the PHASE SHIFTER. Unless the system is close to a null already, rotation in one direction will increase the amplitude, whilst in the other will reduce it. Continue in the direction which produces a decrease, until a minimum is reached. That is, when further rotation in the same direction changes the reduction to an increase. If such a minimum can not be found before the full travel of the control is reached, then reverse the front panel 180° toggle switch, and repeat the procedure. Adjust the sensitivity of the oscilloscope CH2 amplifier, as required, to maintain a convenient display of $y(t)$.

Leave the PHASE SHIFTER control in the position which gives the minimum.

T26 now select the G control on the ADDER front panel to vary V_2 , and rotate it in the direction which produces a deeper null. Increase the sensitivity of the CH2 amplifier as required to maintain a convenient display of $y(t)$.

T27 repeating the previous two tasks a few times should further improve the depth of the null. These adjustments are NOT interactive, so you should reach your final result after only a few such repetitions.

*Nulling of the two signals is complete! You
have achieved your first objective*

You will note that it is not possible to reduce the ADDER output to absolute zero. This never happens in a practical system. But it *is* possible to reduce $y(t)$ to zero!

T28 reverse the position of the PHASE SHIFTER toggle switch. Record the amplitude of $y(t)$, which is now the sum of $V_1(t)$ and $V_2(t)$.

signal-to-noise ratio

There is no contradiction in the previous paragraph. Do not confuse the ADDER output with $y(t)$. Only while $y(t)$ is of the same order of magnitude as the TIMS ANALOG REFERENCE LEVEL does it appear that this is the only output. But when $y(t)$ is reduced in amplitude, to well below the TIMS ANALOG REFERENCE LEVEL, and the sensitivity of the oscilloscope is increased, the inevitable noise becomes visible. *Here noise is defined as anything we don't want.*

The noise level will not be influenced by the phase cancellation process which operates on the 1 kHz test signal, so will remain to mask the moment when $y(t)$ vanishes. However, the nature of this noise can reveal many things.

Achievements

Compared with the models you will be examining in later experiments you have just completed a very simple exercise. Yet many experimental techniques have been employed, and it is fruitful to consider some of these now, in case they have escaped your attention.

To achieve the desired proportions of two signals V_1 and V_2 at the output of an ADDER it is necessary to measure first one signal, then the other. Thus it is necessary to remove the patch cord from one input whilst adjusting the output from the other. Turning the unwanted signal off with the front panel gain control is not a satisfactory method, since the original gain setting would then be lost.

As the amplitude of the signal yet) was reduced to a small value (relative to the remaining noise) it remained stationary on the screen. This was because the oscilloscope was triggering to a signal related in frequency (the same, in this case) and of *constant amplitude*, and was *not affected* by the nulling procedure. So the triggering circuits of the oscilloscope, once adjusted, remained adjusted.

Choice of the oscilloscope trigger signal is important. Since the oscilloscope remained synchronized, and a copy of $y(t)$ remained on display (CH1) throughout the procedure, you could distinguish between the signal you were nulling and the accompanying noise.

Remember that the nulling procedure was focussed on the signal at the oscillator (fundamental) frequency. Depending on the nature of the remaining unwanted signals (noise) at the null condition, different conclusions can be reached.

a) if the AUDIO OSCILLATOR had a significant amount of harmonic distortion, then the remaining 'noise' would be due to the presence of these harmonic components. It would be unlikely for them to be simultaneously nulled. The 'noise' would be stationary relative to the wanted signal (on CH1). The waveform of the 'noise' would provide a clue as to the order of the largest harmonic component, or harmonics.

b) if the remaining noise is entirely independent of the waveform of the signal on CH1, then one can make statements about the waveform purity of the AUDIO OSCILLATOR