C.A.D.E.T Tutorial

How to Use the CADET

E&L Instruments®
An Interplex Electronics Company
1486 Highland Avenue • Unit 2
Cheshire, CT 06410
(800) 572-1028 • FAX (203) 272-4330
www.elinstruments.com

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GETTING STARTED

If you have never used the CADET trainer then the following theory and HANDS-ON exercises will help you get started right. This will be a systematic overview of the features and operation of the CADET. Refer back to this information as you perform the experiments if you forget how a certain section of the trainer operates. Both general information and information dealing specifically with using the CADET trainer in digital experiments will be found on the next few pages. Time spent here...will be time well spent!

So here goes!

BREADBOARD SOCKETS

As you look at the trainer there is a large white area in the center full of holes called "tie points" or "connect points". This is the breadboarding area and it is not connected to any circuitry underneath the surface of the trainer EXCEPT the top two strips. They are internally connected to the power supply. We will talk more about these two strips later.

This breadboarding area is where you will place your components. Describing this area is more difficult than understanding it. There are actually three separate breadboards or sockets in the center of the trainer/ Let's look at just one of them. Pick any one of the three and notice there is a sort of valley or divider running vertically up the center of it. To the left and right of this divider are many rows of five holes or tie points. Inside the plastic there is a metal strip electrically connecting all five of the points in each row together. No row of tie points is connected to any other row however. Each row is independent. If you connect several different devices such as resistors, capacitors, etc. to several of the tie point in the same row, these devices are electrically connected together. When placing integrated circuits or chips on the breadboard socket the pins of the chip should straddle the valley running up the center of else pins on opposite sides of the chip will be shorted together.

On the far left and right sides of each breadboard or socket you will notice two vertical columns of tie points in groups of five. The far left column of points, from the top down to the center mounting screw, are all connected together by metal embedded in the plastic. From the center mounting screw, down to the bottom of the socket, all tie points are likewise connected together. The other column on the left side is arranged the same way. On the far right side of each breadboard socket there are two columns of tie points arranged the same as the left side. Notice that none of the columns are connected to each other. Often these tie points are connected with wires to the power strips at the top of the trainer and are used as convenient places to provide power to each circuit or chip.

BREADBOARD SOCKETS-HANDS ON

Set the VOM or DMM to the Rx1 range. Connect wires to the probes. (It will be very helpful to have meter leads which have alligator clips or some other type of end which will hold on to wires). Try checking the resistance between any two tie points in a row of five. DO NOT ATTEMPT TO MEASURE THE RESISTANCE OF THE TIE POINTS IN THE TWO NARROW BREADBOARD STRIPS LOCATED AT THE TOP OF THE TRAINER. THESE ARE CONNECTED TO POWER. YOU MAY DAMAGE YOUR METER BY CONNECTING IT TO A VOLTAGE WHILE IT IS SET TO MEASURE RESISTANCE. You should find zero ohms of resistance between any two tie points in a row. Measure the resistance across the divider running up the center of the breadboard. You should find infinite resistance. Do the same in the vertical columns on the left and right side of each breadboard or socket. You should find continuity between all tie points in any one column as long as both leads are either above the center mounting screw or below it.

IT IS VERY IMPORTANT TO UNDERSTAND EXACTLY HOW THE TIE POINTS ON THE BREADBOARDS ARE ARRANGED! It is not possible to successfully construct circuits unless you know which tie points are electrically connected together and which are not.

Experiment with the tie points on the main breadboards until you have a good understanding of how they are arranged.

BREADBOARD SOCKETS-SUMMARY

Horizontal rows of five are the same point electrically. Vertically columns of fifty, above and below the center mounting screw, are the same point electrically.

POWER SUPPLY

At the very top of the breadboard area are two horizontal connector strips of breadboarding material. To their right are lines printed on the surface of the trainer indicating that they are connected to the power supply. The top row of 50 tie points go t0 the +5V part of the supply. The second row is connected to the +1.3V-15V part of the supply. Both of these rows are on the top horizontal breadboard strip. Now look at the next strip down. The top row of tie points on this strip are connected to the -1.3-15V supply and the bottom row are connected to ground. Each of the circuits used in these experiments require power to operate and this is where you'll get it from.

At the top of the trainer above the power connector strips are two voltage adjustments. One labeled +V and the other-V. The voltage of the +1.3-15V tie points is adjusted within this range by the +V adjustment. The voltage of the -1.3-15V tie points is adjusted within this range by the -V adjustment. Most of the digital experiments will use +5V and ground so you may not use these adjustments too often. Be careful to use the correct voltage for each experiment.

At the top center of the trainer is a center tapped 12.6VAC voltage source. Note that this is AC, not DC. This source has been included primarily for analog experiments normally done in other courses.

POWER SUPPLY-HANDS ON

Lets' use our VOM or DMM to check these voltages. Turn the CADET's power switch on. Set your meter to be able to read at least 5V DC. Insert a wire in the bottom row of the power connector strips, the one which is connected to ground. Connect the ground lead of your VOM to this wire. Now insert a wire in the top row of the power connector strips, the one which is connected to +5V. Connect the red or positive lead of your VOM to this wire. Your meter should indicate approximately 5V. If the needle of the VOM tries to go backwards you have the leads of your meter reversed. Now using a Phillips screwdriver carefully turn the +V and then the -V adjustment screws at the top of the trainer.

THESE ADJUSTMENTS POTENTIOMETERS ARE PLASTIC. BE CAREFUL NOT TO DISTORT THE SCREWDRIVER SLOTS BY APPLY TOO MUCH FORCE WHEN YOU REACH THE END OF THE ROTATION.

Notice that the voltage indicated on the VOM does NOT change. The +5V power supply is not adjustable.

Now adjust your VOM to be able to read up to 15 VDC. Remove the wire from the +5V row and insert it into the +1.3=15V row which is next down from the top. Again, using the Phillips screwdriver turn the +V adjustment screw. The lowest voltage indicated should be a little over 1V. The highest voltage may be as high as 20V.

Turn off the trainer. If your meter has a polarity reversing switch use that now. If not, reverse the positive and ground leads of your meter. Move the wire which is in the +1.3-15V tie point to the -1.3-15V tie point. Turn the trianer on again. Turn the -V adjustment screw. Your meter should again indicate between a little over 1V and 20V. If your meter needle tried to go backwards reverse the meter leads.

Power can be obtained directly from the red, blue, yellow, and black binding posts on the top of the trainer in addition to the power connector blocks if desired. The colored part can be tightened down onto a wire placed in the hole in the post or a banana plug may be inserted into the top of the post.

Finally, check the voltage of the 12.6 VAC connection a the very top of the trainer. Remember, this is AC, not DC, set your meter accordingly. Between the center lead and either of the outside leads you'll find 6.3 VAC and between the tow outside leads there will be 12.6 VAC.

POWER SUPPLY-SUMMARY

Two continuously variable DC power supplies are available which provide voltages in the range of +1.3-15V and -1.3-15V giving a full 30 V range. In addition a fixed +5V supply is always available. AC voltages of 6.3 and 12.6 are provided.

LOGIC INDICATORS

Let's look now at the logic indicators on the right side of the trainer. A small connector block allows these LED's to be connected to the rest of the circuit being constructed. There are eight red LED's at the top of this section and eight green LED's at the bottom. The red LED's indicate a high or "1" logic level. The green LED's indicate a low or "0" logic level. The indicators work in pairs shown by the numbering from one to eight. Each pair has two tie points on the small connector block to the left. It doesn't matter which of the two tie points you use.

The +5/+V switch in the upper left corner of this section determines the voltage to be connected to the logic indicators and should be the same as the circuitry to which the indicators are connected. The switch in the bottom left corner of this section determines the threshold voltages for the indicators. When the +5/+V switch is in the +5 position the TTL/CMOS switch should be in the TTL position. This is the TTL/+5V mode. When the +5/+V switch is in the +V position the TTL/CMOS switch should be in the CMOS position. This is the CMOS/+V mode.

When in the TTL/+5V mode, if the voltage connected to a pair of LED's is 2.2 volts or higher the red indicator will light. If the voltage is .8 volts or less the green indicator will light. If the voltage is between 2.2 and .8 volts or there is no voltage then neither will light. When in the CMOS/+V mode, if the voltage connected to a pair of LED's is 70% of the selected voltage or higher, then the red indicator will light. If the voltage is 30% or less than the selected voltage, then the green indicator will light. If the voltage is between 30% and 70%, or if there is no voltage, then neither LED will light.

LOGIC INDICATORS-HANDS ON

Place the top switch in this section in the +5V volt position and the bottom switch in the TTL position and the bottom switch in the TTL position. Connect a wire from the +5V supply to the #1 LED pair. The red LED will light. Now connect the wire to the ground point in the supply and the green LED will light.

To demonstrate the voltages necessary for a logic 1 and a logic 0 try this. Select the +5V/TTL mode in the Logic Indicators section, that is, both switches in that section are up. Locate the two potentiometers at the bottom of the trainer. Connect a wire from the #8 LED pair to the center (#2) tie point of the 1K pot. Connect the left (#1) terminal of the pot to ground. Connect the right (#3) terminal of the pot to +5V. If you rotate the pot fully counterclockwise the green LED will light. If you rotate the pot fully clockwise the red LED will light. There is an area between these two extremes in which neither LED will light.

Adjust your VOM to be able to read 5V DC or more. Connect the ground lead of your VOM to the ground of the power supply. Connect the positive lead of your VOM to the center (#2) tie point of the 1K pot (where your already have your LED connected). Now, turn the pot fully counterclockwise. The green LED is lit. Turn the pot slowly clockwise, until the green LED goes out. Move slightly back and forth with the pot until you find the exact spot where the green LED lights. Look at the reading on your VOM. It should be close to .8V. Continue to rotate the pot clockwise until the red LED lights. Again go back and forth until you find the exact spot where the red LED illuminates. Check your VOM. It should indicate approximately 2.2.

If desired, this same type of experiment could be done in the +V/CMOS mode also. Check the voltage adjustment when you begin the experiment and remember that the green LED will light at approximately 30% of that value and the red LED will light at approximately 70% of that value.

LOGIC INDICATORS-SUMMARY

Each LED pair indicates the presence of a logic with the red LED. A logic is shown with the green LED. And undefined values between logic 1 and 0, as well as no voltage at all, are indicated by neither LED lighting.

SPEAKER

Next we find an 8 ohm speaker. Each of the two speakers leads has four tie points on the connector block.

SPEAKER-HANDS ON

When you reach the section about the Function Generator you will have an opportunity to test the speaker.

BNC CONNECTOR

At the bottom right corner of the trainer is a BNC connector. This connector will allow you to use the CADET with oscilloscopes or other test equipment without using clip leads. Attach a wire from one of the eight tie points for the BNC connector to whatever place on the breadboard you wish to connect your test instrument to. You will be able to have your test equipment attached without a tangle of leads in your breadboard area.

SWITCHES

Two single-pole double-throw slide switches have been provided on the lower side of the CADET toward the right. The lines printed on the trainer indicate these switches have three leads. When the switch is in the "up" position the middle and top leads are connected. When in the "down" position the middle and bottom leads are connected. The top and bottom leads of each switch have two tie point on the connector block and the middle lead has four tie points.

SWITCHES-HANDS ON

Insert a wire into the right (#3) tie point of the right (#10) SPDT switch on the bottom of the trainer. Insert another wire into the center (#2) tie point of the same switch. Note that according to the lines printed on the surface of the trainer the center pin of the switch is connected to the center tie point. The top pin of the switch is connected to the right tie point. Set your VOM or DMM on its lowest resistance range (Rx1). Connect the leads of your meter to the two wires. (Remember to zero the ohms adjust).

Move the switch into the up position and the meter will show zero ohms indicating you have continuity between the center and top pins of the switch. Move the switch to the down position and the meter will show infinite resistance indicating no connection between the center and bottom pins of the switch.

Now, leaving the meter leads connected to their wires move the wire in the right (#3) tie point over to the left (#1) tie point of switch #10. Move the switch into the down position and the meter will show zero ohms indicating continuity between the center and the bottom pins of the switch. Move the switch to th up position and the meter will show infinite resistance indicating no connection between the center and top pins of the switch.

Switch #9 is the same as switch #10 except that the tie point numbers for the bottom and top pin connections are reversed.

SWITCHES-SUMMARY

The operation of the SPDT switches can be summarized by the following statements. When the switch is in the "up" position it connects the center and top pins of that switch. When in the "down" position it connects the center and bottom pins of that switch.

POTENTIOMETERS

Two pots can be found at the bottom center of the CADET. The one on the left is a 10 k ohm pot and the one on the right is 1 k ohm. The center adjustable lead on each had four tie points and the two fixed leads have two tie points each.

POTENTIOMETERS-HANDS ON

Connect a wire into the left (#1) tie point of the 1K pot at the bottom of the trainer. Connect another wire into the middle (#2) tie point at the same pot. Notice that according to the lines printed on the surface of the trainer the #1 tie point is connected to the left side of the resistance which makes up the pot. The #3 tie point is connected to the right side of the resistance which makes up the pot. The center (#2) lead is adjustable.

Set your VOM so that 1,000 ohms will register toward the left side of the ohms scale. (The Rx10 range will probably be appropriate.) Zero it with the ohms adjust control. Connect the leads of the meter to the two points.

If you rotate the pot fully counterclockwise (towards the left) the meter will show approximately 0 ohms. This indicates the center adjustable contact of the pot is very close to the left lead and the current is flowing through very little resistance.

Turn the pot fully clockwise (toward the right) and the meter will indicate approximately 1,000 ohms. This indicates that the center adjustable lead is near the far right side of the resistance element inside the pot and the current must flow through the entire 1K resistance path.

Rotate the pot to the 12 o'clock position (the halfway position). The meter will indicate half of the full 1,000 ohms. That is 500 ohms. (Remember, the needle does not actually move half way up the scale because a resistance scale is non-linear)

The 10K pot is set up the same except that it has 10,000 ohms of resistance.

POTENTIOMETERS-SUMMARY

As your rotate a pot in either direction, resistance between the center lead and the one which your are moving towards will decrease. Resistance between the center lead the one which your are moving away from will increase.

LOGIC SWITCHES

On the lower part of the trainer toward the left side are eight sliding type logic switches. Each has two tie points on the connector block above the switches. When a logic switch is in its down position it is placing its tie point on the connector block at logic 0 or ground. When in the up position it places its tie point at logic 1. Just exactly what voltage logic 1 is depends on several factors. In the upper left corner of this area is a switch labeled +V and +5. If this is in the +5 position then a high or 1 for the logic switches at this time is +5 volts. If the voltage selection switch is in the +V position then a high or 1 will be determined by the setting of the +V adjustment on the top of the trainer. Be careful to use the correct voltage for each experiment.

LOGIC SWITCHES-HANDS ON

Turn on the CADET. Place the voltage selection switch in the Logic Switches section in the up or +5 position. Set your meter to read at least 5 VDC. Connect the ground lead of the meter to the ground of the power supply. Connect the positive lead of the meter to the tie point for logic switch #8. Put the logic switch in the down position. Your meter should indicate 0 VDC. Move the switch to the up position. The meter should now indicate approximately 5 VDC. Move the switch back to the down position.

Look at the Logic Indicators section and move the top switch to the +5 V position and the bottom switch to the TTL position if they are not already in those positions. You are now in the +5V/TTL mode.

While leaving the meter attached to one of the tie points for logic switch #8, attach a wire from the other tie point for that same switch to logic indicator #8. The green or low logic indicator should light. Move the logic switch to the up position and the red or high LED should light. Take note of the fact that logic 1 at this time is +5 VDC. Move the logic switch back to the down position.

Adjust your meter to be able to read at least 20VDC. Temporarily connect the positive lead of your meter to the +V power supply and adjust the supply to 15 volts. Now move the positive lead of your meter back to the tie point for logic switch #8. Turn off the trainer. Move the voltage selection switch in the Logic Switches area to the +V position. Move the voltage selector switch in the Logic Indicators section to the +V position also. Move the bottom switch in the logic Indicators section to the CMOS position. You are now in +V/CMOS mode.

Turn the CADET back on. Notice the numbers 1 and 0 printed on the surface of the CADET on the left side of the logic switches. A 1 is shown as being the up position on the switch and the 0 is the down position. If logic switch #8 is in the down or 0 position then the green or low indicator will light as expected. Place logic switch #8 in the up or 1 position and the red indicator lights. Look at your meter now. Notice that it is reading the same 15 VDC that you set the +V power supply to. While in the +V/CMOS mode the value for a logic 1 has changed from +5 VDC to the value of the +V power supply. Actually, any voltage from 70% of the +V supply up to 100% of that voltage will be accepted as a logic 1 by the logic indicators.

LOGIC SWITCHES-SUMMARY

The logic switches will put out a logic 0 or 0 volts when in the down position. They will put out a logic 1 when in the up position. When in the +5/TTL mode, a logic 1 is 5V. When in the +V/CMOS mode a logic 1 is the value set by the +V adjustment.

BNC CONNECTOR

At the lower left corner of the trainer is another BNC connector identical to the one at the lower right corner of the CADET. See the description of the first BNC connector for more information.

DEBOUNCED PUSHBUTTONS

You will find two pushbuttons on the left side of the trainer. These are called "debounced" pushbuttons because they consist of the physical mechanical switch with additional circuitry to eliminate the multiple switch closures normally found when operating mechanical switches. That is, most switch contacts actually bounce very briefly when closed. Even though this period of time is brief, digital circuitry is fast enough to falsely interpret this as several closures rather than just one. Thus, the need to electronically "debounce" these switches.

Each switch has eight tie points of two different types. Four of the points are marked by the letters "NC" meaning "normally closed". These points are connected to ground when that pushbutton is in its normal position and become open when you press the button. Four of these points are marked by the letters "NO" meaning "normally open". These points are open when the switch is in its normal position and are connected to ground when you press the button. The small switch diagram printed on the trainer helps illustrate this.

DEBOUNCED PUSHBUTTONS-HANDS ON

Connect a wire from the "normally closed" (NC) tie points for the top debounced pushbutton (PB1) to logic indicator #1. Connect another wire from the "normally open" (NO) tie points for the same debounced pushbutton (PB1) to logic indicator #2. Green LED #1 should be lit at this time. This is because it is connected to ground as is shown by the diagram of PB1 on the trainer. Press PB1, green LED #1 should go out and green LED #2 should light. When you press the

pushbutton it disconnects the NC contacts from ground and connects to NO contacts to ground. Release the pushbutton. #1 is again lit and #2 is off.
PB2 works in exactly the same manner as PB1.
Notice that you never get a high or logic 1 from these pushbuttons.
These debounced pushbuttons perform this same function whether in +5/TTL or +V/CMOS mode.

DEBOUNCED PUSHBUTTONS-SUMMARY

These two pushbuttons provide a way for a point to be normally connected to ground then momentarily disconnected from ground, or, to be normally open momentarily connected to ground.

FUNCTION GENERATOR

Also on the left side of the trainer is the function generator where you will get the clock pulses needed for some of the experiments. You will normally only need the TTL output for digital experiments. However, for the sake of completeness let's look at what this generator can do.

There is a switch with sine, triangular, and square wave symbols above its three positions. This selects one of the those three waveforms.

The speed of frequency of the selected waveform is adjusted by three other controls. One is the frequency slide adjustment on the left which varies between 0.1 at the bottom and 1.0 at the top. Another is the decade range selection switch at the top right side of this selection. It has positions labeled 1, 10, and 100. The last is at the top left part of this section. It is a two position switch labeled "kHz" and "Hz". The frequency of your waveform is the number of Hertz and kilohertz (as indicated by the switch at the top left) found by multiplying the frequency slide adjustment by the decade range selection switch. For example, if the top left switch is in the "kHz" position, the sliding frequency adjustment is at the bottom (0.1), and the decade range selector is in the middle (x10) position, you have 0.1 x 10 or 1 kHz. The lowest frequency available is 0.1 Hz and the highest is 100 kHz.

The "amplitude" of the waveform is adjusted by sliding control label "AMP". It can range from 0V to +10V or -10V (20V peak-to-peak). All of these adjustments apply to all of the waveforms.

You will be using square waves for digital work and it is possible to create them without the TTL output. However, there are advantages to using the TTL output. The square waves coming from this output have much faster rise and fall times than the square waves normally created. In fact, the TTL square waves have rise and fall times that are 20 times faster than the regular square waves (25 nanoseconds vs. 0.5 micorseconds). If the rise and fall times of square waves are not fast enough then the sides of the waveforms have a sloping tendency. The faster the rise and fall times the more vertical the sides of the waveforms are and thus the square waves are more "square".

The square wave from the TTL output is continuously available regardless of the position of the waveform selection switch and is in phase with the regular square waves. We will normally use the TTL output in our experiments.

FUNCTION GENERATOR-HANDS ON

Connect a wire from ground to one of the speaker terminals. Connect the other speaker terminal to the connector block for the Function Generator on the left side of the trainer. Use any one of the six right tie points which are for the three waveforms but do not use the left two tie point for the TTL output at this time. Slide the waveform selection switch to the square wave position. Slide the frequency adjustment to its lowest position (0.1). Place the kHz/Hxz switch in the Hz position. Slide the decade range switch (1/10/100) to the 1 position. Move the amplitude adjustment (AMP) to its highest position

Ready?

Turn on your trainer. Now listen quietly for at least 10 seconds. You should hear a "click" approximately every 5 seconds. Multiply 0.1 (your frequency adjustment) by 1 (your decade selection) and you will get .1 (your frequency). In other words you have a frequency of 1/10 Hz. Using the formula T=1/f (time period equals the reciprocal of the frequency) you'll find you are hearing a complete square wave every 10 seconds. One click is when the wave rises and the other when it falls. One click every 5 seconds. (If you have an oscilloscope you may want to watch the waveform as well).

Now slowly slide the frequency adjustment up. The clicks are increasing in speed. The frequency is getting faster. When the frequency adjustment is at the top you have two clicks per second, which is one complete square wave per second or 1 Hz.

Move the waveform selection switch to the triangular wave position, then to the sine wave position. You can't hear anything but the waves are there. If you have an oscilloscope you can see them. Move the waveform selection switch back to the square wave position.

Slide the frequency adjustment to its lowest position. Now move the decade range switch (1/10/100) to 10. You are now at 1 Hz again. Slide the frequency adjustment upwards slowly, all the way to the top. (if it is too loud slide the amplitude (AMP) adjustment down a little). If you again multiply the frequency adjustment by the range selection you will find you are now at approximately 10 Hz or 20 alternations (clicks) per second.

Check the triangular and sine waves. Again you cannot hear them but the waves are indeed there. Go back to the square wave position.

Now move the frequency adjustment back down to its lowest position and move the decade range switch to the 100 position. you are again at 10 Hz (o.1 x 100). Slide the frequency adjustment forward, all the way to the top. This is 100 Hz.

Try the triangular and sine waves. If the amplitude (AMP) is all the way up you can hear the triangular wave more faintly than the square wave. The sine wave is audible if you put your ear near it (or are in a quiet place). Return to the square wave.

Slide the frequency adjustment back to its lowest position. Move the decade switch to 1. Move the kHz/Hz witch to the kHz position. You are now again at approximately 100 Hz. (0.1 x 1,000). Move the frequency adjustment to its highest position. You are now hearing a 1 kHz tone.

Check the triangular and sine wave. They are now easy to hear. Notice that the sine wave is very "soft" or mellow", the triangular wave is a little "sharper", and the square wave has the most "cut" to it. Go back to the square wave.

Using the frequency adjustment and the decade range switch continue in this same manner to check increasingly higher frequencies. You will have some frequencies too high for you to hear. You can still see them on an oscilloscope though.

There is one other experiment to try. Set the generator to a sine wave which is easily heard (e.g. 1 kHz). Now remove the wire going to the generator connector block (from one of the six right tie points) and place the wire in the TTL tie point (one of the two left points) on the same connector block. Its not that same "mellow" sine wave is it? You are hearing a square wave. The TTL tie point puts out square waves regardless of the position of the waveform switch. Try adjusting the amplitude of position of the waveform switch. Try adjusting the amplitude of the wave (its probably quite loud and may be wearing on your nerves by now). You can't turn it down can you? This is another important difference. The amplitude of the TTL waveforms is NOT adjustable. Try changing its frequency. That IS adjustable.

Turn off your trainer.

Always use solid wire for breadboard connections. When stripping the wire ends, be careful not to strip more than about three-eighths of an inch of insulation from the wire. Too much bare wire may result in unintentional connections near the wire end.

After you have built up a few circuits, you will have a good collection of prestripped jumper wires. Save them. By reusing these wires, you can save even more time and effort in assembling future circuits.