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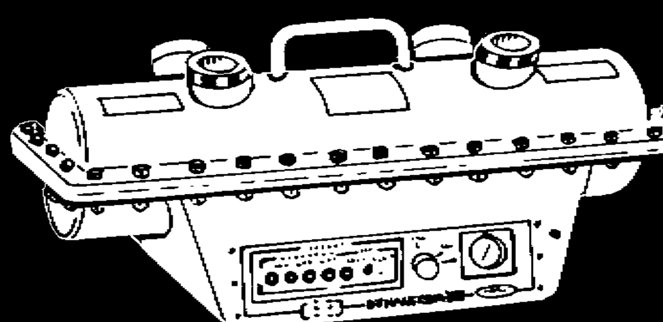
Application notes for the Dynalyzer™ II and III and Voltage Dividers

By: Dr. Jonathan S. Shapiro President, Greenwich Instrument Co. Inc.



4th Edition

Important Notice:
All material contained herein is believed to be correct. However we cannot be responsible for misinterpretation or misuse of this material. Consult x-ray equipment manufacturer should this information be in conflict with established test procedures.

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I have written these application notes in response to the many telephone questions I received during the course of the last sixteen years that GiCi has been calibrating and repairing Dynalyzers and Voltage Dividers. As many of you are aware, I was the original project manager and design engineer for the Dynalyzer system, when it was designed at Machlett Laboratories in Stamford, CT. I hold three US patents in my name, or jointly with other Machlett engineers. During my eleven year stay at Machlett, I was involved in the design and upgrade of the Y1-A Dynalyzer, the Dynalyzer II and the Dynalyzer III. I was also in charge of engineering at Raytheon Medical Systems, Raytheon Medical Imaging, and Raytheon Nuclear Diagnostics. There was a fine team of engineers on these programs, and to them I am grateful.

When Machlett was being sold to Varian, I formed Greenwich Instrument Co. Inc. to provide continued support for the Dynalyzers. I have more experience with this test equipment than any one, or any company in this business. GiCi has an *unbroken* sixteen year commitment to the support of the Dynalyzer. Dr. Shapiro has thirty years with this project.

To this end, we have designed many mechanical upgrades to the Dynalyzer high voltage unit, assisted in the development of the OEC interface modification, and continue to work on enhancements. Being a small company, GiCi has routinely provided calibration and repair service within 3 days of receipt, or approval of repairs.

We provide these application notes at no charge to our valued customers, in the hope that it makes your job just a little bit easier.

Jonathan S. Shapiro, Ph.D.
President

Introduction:

Under certain circumstances, erroneous time milliampere values may be obtained from the Dynalyzer Display. This is primarily due to the way the initial conditions of the trigger circuit are set in the Percent Mode. By using the Preset trigger level, maximum trigger accuracy will result. Comparison with the Dynalyzer II will be made. High frequency generators may also pose special problems.

Trigger Circuit Description:

The Dynalyzer III has two trigger circuit modes.

➯ First there is a PRESET mode. This is quite simple. The trigger circuit will start when there is the first crossing of the trigger source with its level. When using KV trigger, the user would, for example, dial in a fixed KV value that might be 75% of the expected KV value. If the exposure was 125 KVP and 300 mA then the KV trigger value chose would be 94 KVP.

0.75 x 125 KVP = 93.75 KVP or 94 KV selected.

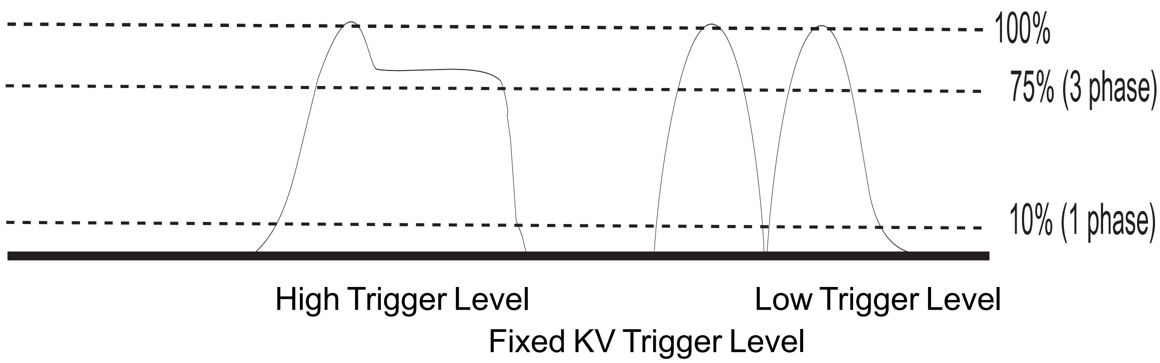


Figure 1.

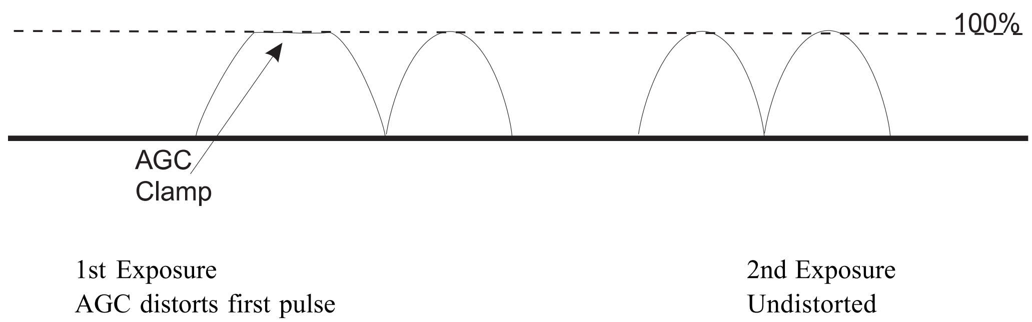
When the exposure ends, and the microprocessor has determined that there is not another pulse in the sequence, as happens in a single phase generator, the exposure time from the first to the last crossing of this threshold is saved, and so is the corresponding MAS data. The milliamps, or *average anode current* is calculated from

mA = MAS/ TIME.

If the KV value is changed, the trigger level is unaffected. If the KV is lowered below the preset trigger level, the system may not trigger at all. If milliampere triggering were used, then a milliampere value would be entered.

With external trigger, only preset level triggering is used. An error will be displayed if percent trigger is selected. External trigger is used in the Dynalyzer calibration procedure. It also allows the user to set up some custom measurement procedure. Dial in a trigger level corresponding to the trigger source. For a 5V TTL signal, set the dial for “30” = 3.0 volts.

➪ PERCENT triggering is a carry-over from the Dynalyzer II. The concept behind the percent mode was quite simple. Initially, the Dynalyzer is reset. The trigger level is quite low. Any percentage of zero is zero. There is a low default value of trigger level in the percent mode. An offset is added to prevent the system from triggering on noise. When the first exposure is made in a Dynalyzer II, an automatic gain control amplifier adjusts itself to pass the KV waveform through at a fixed amplitude. The trigger waveform is normalized to 10 volts peak. The trigger level is therefore 0 to 10 volts, with 10 volts being 100%. The first exposure primed the system, and the data was discarded. This is because the AGC amplifier gain distorted the waveform on the first exposure. If there is leading edge overshoot, the AGC amplifier will lock onto the *highest* value.

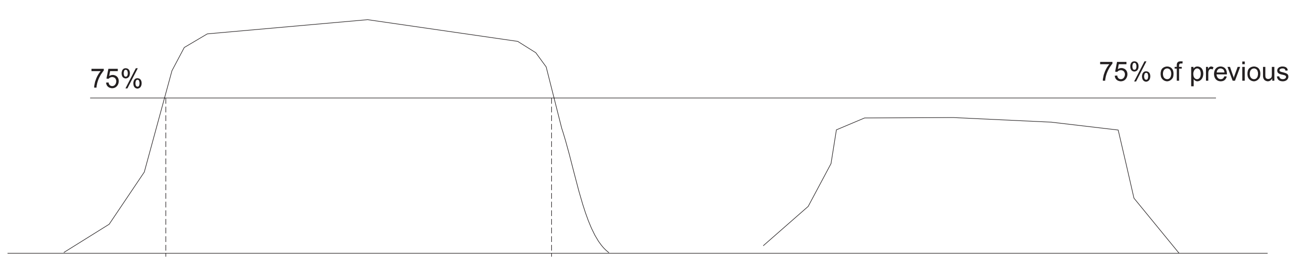


AGC Amplifier of Dynalyzer II % trigger

Figure 2.

In a Dynalyzer II, if there is a sequence of exposures, each at a *higher* voltage or current than the previous one, the trigger level would rise, but in proportion to the *preceding* exposure. This system would at least insure that the Dynalyzer II would trigger. The actual trigger level in this sequence would be lower than expected.

If the exposure sequence was decreasing in KV or mA values, then the trigger level would stay fixed (except for leakage effects), at the highest value. The trigger circuit would not know that the KV values were dropping. Thus the reference level would be constant and the waveform would be getting smaller.



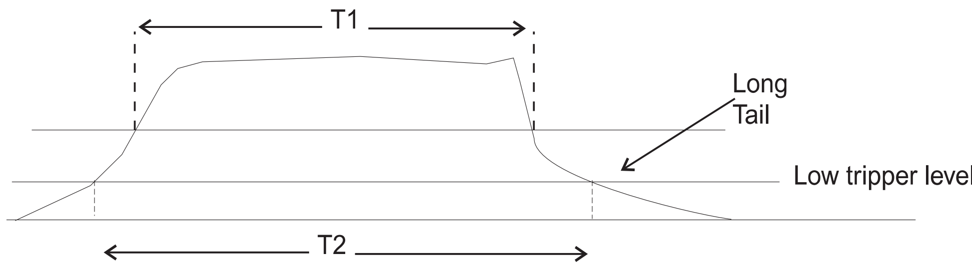
How to miss an exposure when KV decreases
Dynalyzer III % Trigger Mode

Figure 3.

It is easy to miss the exposure if the trigger level was high, and the next exposure in the sequence was low. The AGC amplifier would not reset itself, as it only follows increasing signal levels.

The Dynalyzer III is smarter. With a microprocessor, it is possible to calculate a new *percentage* trigger level from exposure to exposure. The waveform is not processed. The trigger level is supplied by a DAC. The front panel trigger level control indirectly generates the trigger level. Its voltage is read by the analog circuit board and the CPU computes the DAC controls. The first exposure is still in error, as the trigger level is suppressed to an artificially low value, with 100% equivalent to 20 KV, and the range of 25% to 2% is 5 KV. After the first exposure, the trigger level is set to the calculated level. If there is a sequence of exposures, the trigger level will always be a percentage of the preceding exposure. If the steps between exposures are small enough, the system will always trigger.

A low trigger level will usually have a longer exposure time. If the cable lengths are long, and the mA values low, there will be significant discharge time of the cable capacitance.



Effect of cable discharge at low trigger levels
Figure 4.

The Dynalyzer instructions recommend using 75% trigger level for 3 phase equipment and 10-20% for single phase equipment. Our experience shows that when using mA trigger, try to keep the trigger level as high as possible in three phase applications. The higher the trigger level, the closer to the correct mA will be indicated. Experiment... you will find the best correlation of the mA value, especially in three phase or constant potential type equipment. The mA waveform rises and falls faster than the KV waveform. At 20% of the voltage, the mA may be at 80% of final value because x-ray tubes are generally emission limited.

High Frequency Generators

Certain high frequency generators have a slowly rising leading KV waveform to allow the internal stabilization circuitry to operate. Under certain load conditions, the ripple on the leading edge is large enough to cause a Dynalyzer III display to appear to lock up. This is because each trigger pulse causes an interrupt to the CPU, and the display cannot handle too many interrupts. GiCi has developed a modification for these displays. We would be happy to install it on request when your equipment is sent in for calibration.

Introduction

The Dynalyzer x-ray calibration system is a highly accurate tool for the measurement of x-ray generator voltages and currents. To use this instrument efficiently, it is necessary to understand some of the physics behind the measurements. This application note will outline the procedure that will produce the maximum accuracy, and then will describe the physical reasoning behind it.

Optimal Test Protocol and Rationale

The procedure outlined below will enable a technician to calibrate properly an x-ray generator, when combined with the protocol of the equipment manufacturer. This procedure must be modified for specific types of generators.

1) Equipment Installation:

Install the Dynalyzer between the x-ray tube and the x-ray generator according to Figure 5. Connect the Dynalyzer terminal exactly as shown. Connect both the anode and cathode cables.

1.1) Do not add more than 5 feet of cable between the Dynalyzer and x-ray tube. Extra cable length will increase the series resistance in the filament circuit. Extra filament circuit resistance will decrease the filament current in generators using constant voltage power supplies. The extra cable capacitance stores energy. In single and three phase generators the capacitance would mostly affect timing accuracy at low anode mA, where cable discharge time is significant. High frequency generators may not function properly with a Dynalyzer or voltage divider (bleeder, KV “Drop Box,” etc.) in series with the transformer. Some of these generators are resonantly tuned to their cables and tubes, and introduction of the Dynalyzer will cause problems. Check with the manufacturer for specific recommendations.

1.2) Do not place the Dynalyzer under the x-ray tube. The x-rays will ionize the SF6 gas, and at higher voltages cause measurement errors. It will, over time, darken the mA light pipe and reduce mA output.

2) Initial Adjustments:

Following the machine specific instructions, adjust the anode current for each tube station during tube installation, or during preventive maintenance, first measure the KV and mA for each station.

2.1) If the all the KV’s are correct or slightly high, and all the mA’s are slightly low, then readjust the filament master resistor (there should be a separate adjustment for small and large filament) if the generator is so equipped. Decide if the small error is caused by the introduction of the extra cable and contact resistance of the measurement equipment. If this is the case, then the calibration of all stations may proceed at this point.

2.2) If there is no master filament adjustment, as may be the case in a solid state design, then adjust the mA of each station and check that the KV is correct. If the mA errors are both high and low, then complete calibration of the generator is required.

2.3) As a check, measure and record anode + cathode, anode only and cathode only. This applies whether a Dynalyzer or bleeder is used. In a single phase generator the sum of anode peak and cathode peak will equal anode + cathode. This is because the positive and negative peaks are in phase. A three phase generator may be built as a “6 pulse” or a “12 pulse” unit. Checking the anode only and cathode only will produce interesting results. In a 6 pulse, anode (only) and cathode (only) will be one half the peak KV. In a 12 pulse, the anode (only) and cathode (only) will be 30 degrees out of phase, and the anode (only) and cathode (only) will be 1.15 x 1/2 the sum or 57.7% of the A+C. See figure 6A for the anode and cathode waveforms. Figure 6B illustrates the 12 pulse ripple that is approximately 4% of the total voltage, p-p..

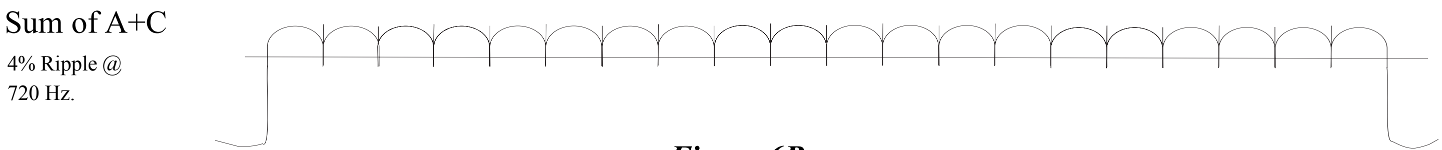


Figure 6B

In a 6 pulse generator, the secondary coils for the positive and negative voltages, with respect to ground, are symmetrical, and are usually both Wye connected. This symmetry results in the anode and cathode waveforms to ground being in phase. In a 12 pulse generator, there are essentially two transformers. One has a delta primary and one has a wye primary, the two secondaries may be wye and have a full wave rectifier output producing 87.5 KVP to ground. There is a 30 degree phase shift between the anode and cathode ripple waveform resulting in the need for vector addition of the voltages, not algebraic addition of A (only) and C (only). Therefore it is necessary to have the voltage divider in both the anode and cathode during the initial set up of a three phase 12 pulse generator.

3) Final Adjustments

Once the generator is set up, the KVP will be a function of the KV compensation circuitry and the expected mA.

The divider or Dynalyzer may be removed from the cathode circuit, and the x-ray transformer cable from the cathode is directly attached from tube to transformer. Then the mA may be verified. If the mA has changed and the generator has a “ master” filament adjustment or a “cable compensation adjustment,” then adjust it get the correct mA value on that filament, and verify that the other mA stations have been brought back into adjustment. During this procedure, it is not necessary to verify or reset the KVP, however if the anode (only) data was previously recorded, it could be monitored.

Conclusion

From the above discussion, the important points to remember when calibrating a x-ray generator are:

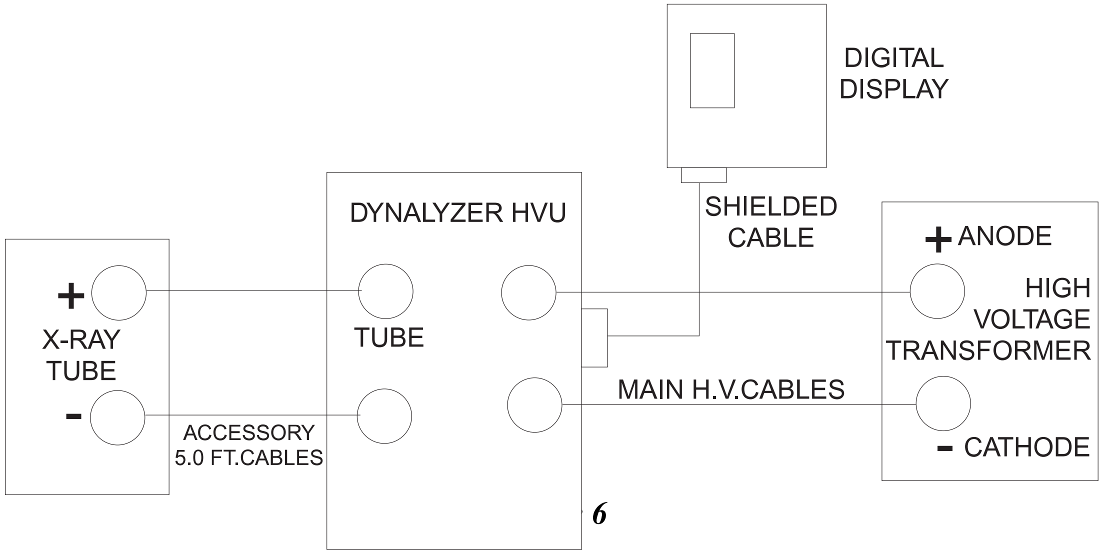
1) Introduction of extra resistance in the cathode circuit will often reduce filament current, causing a reduction in mA and increase in KVP.

2) Anode and cathode peak voltages do not always add algebraically, but especially in 12 pulse three phase, must be added vectorially.

3) A final check of the anode current can be made without a bleeder or Dynalyzer in the cathode circuit to reset the filament master or other appropriate mA adjustment.

4) When testing a high frequency generator with a Dynalyzer or bleeder, be certain that it does not upset the tuning of the high voltage transformer.

5) Keep the Dynalyzer out of the x-ray beam.



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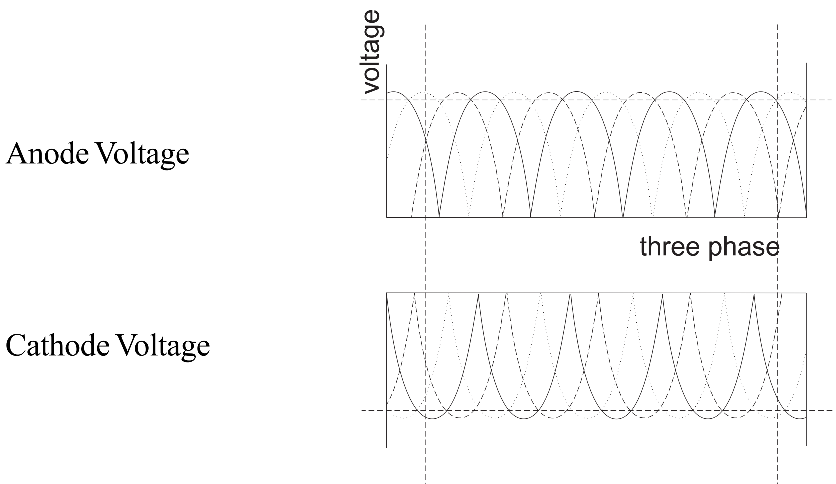

Three Phase 12 Pulse Anode and Cathode Waveform
Notice that the peaks are not in phase.

Figure 6a

There are several major sources of error in milliampere readings with Dynalyzer systems. The most common errors are caused by these factors:

1) Open ground wire in interconnect cable.

2) Connection of Dynalyzer II tank to Dynalyzer III display.

3) Failure to adjust the mA zero in the high voltage unit.

4) MAS limit exceeded in Dynalyzer III Display.

5) Reversing the polarity of the cables in the HVU.

6) Intermittent operation in Dynalyzer II displays.

7) Broken high voltage units.

This application note will address these problems, and offer the user some self help ideas in fixing their system.

1) Open Ground Wires:

The interconnect cable uses pin C as the master ground wire in Dynalyzer II systems. Stress in the cable often pulls out this connection. Check your cable with an ohmmeter. In addition pin G of the cable is the mA return ground wire in a Dynalyzer III.

2) Using a Dynalyzer II HVU with a Dynalyzer III display, and Visa Versa:

With one simple modification to the Bendix connector output on the Dynalyzer II HVU, it is easy to use the Dynalyzer II HVU with a III display. The III display is looking for a mA ground. An artificial ground is provided in the Dynalyzer III display, but there is some offset voltage associated with this circuit that can cause possibly a +/- 5 milliampere error. Open the front of the HVU and solder an insulated wire from pin G of the circular display output connector to pin C, the ground. This will provide a solid, loop free ground return. Ground wire C can have ground fault currents, especially if one connects the display and HVU to separate power outlets. By doing this, there is a real risk of blowing out some ground foil in the HVU! If you are not sure of the condition of your HVU, check continuity of grounds from the BNC's to the ground pin of the power receptacle. If it is open, the HVU needs repair.

When using a Dynalyzer II display with a Dynalyzer III HVU in the Fluoro mode, be sure to divide the indicated mA value on the display by 20. The scale factor of the HVU in the fluoro mode is 20 MV/mA. In the rad mode it is 1 MV/mA.

The Dynalyzer III display decodes a signal from the Dynalyzer III HVU and automatically displays the correct value.

3) Zero Adjustment of mA:

It is essential to check the Zero output of the mA circuit. It will drift with changes in temperature. The RAD and Fluoro mA both drift, and both have screwdriver adjustments. Check the BNC output with your DVM when starting a calibration. If your HVU is cold, check it again after it warms up. Best to connect the HVU to display or oscilloscope when adjusting.

4) MAS Limit Exceeded:

The Dynalyzer III Display first measures MAS and then divides by the exposure time. The maximum MAS in the RAD current mode is 2621 MAS. In the FLUORO mode the maximum is 131 MAS. Any exposures exceeding the MAS limit will cause the error light to come on and error 908 to be displayed. The exposure time and mA values will be in error beyond this limit. Do not exceed 50 mA on Fluoro ranges.

5) Reversing in and out on mA:

The mA circuit will provide outputs up to 2 amps (pulsed) input. It will not respond to negative inputs greater than 5-10 milliamps. Be sure to connect the anode transformer input to the transformer, and the anode tube connection properly. Do not use the anode circuit in the cathode. All three terminals in the anode circuit are shorted together, and connection in the cathode circuit will short circuit the filament.

6) Intermittent Dynalyzer II operation:

There are several types of intermittent operation in Dynalyzer II's. Some have been intermittent since their manufacture, where with certain mA values, the system begins to compute mA, and then all zero's appear. MAS can usually be displayed. This cannot be fixed, but the system is generally usable.

There is a second type of failure. This is caused by age and corrosion on the leads of the chips. Most corrosion occurs on the MOSTEK chips, which have not been manufactured for over 10 years. GiCi has a rebuild program for intermittent Dynalyzer II's that is approximately 80% effective. Call us for details.

7) Broken high voltage units:

The Dynalyzer HVU is a fragile instrument. Depending on how hard it was dropped, or how hard a tube arced, damage may occur. GiCi can make your HVU as good as new. Call us.

Do not operate a HVU with continuous mA value greater than 250 mA, or damage to resistors inside the current transmitter will result. It may be operated with pulses up to 2 amps peak. (Generally speaking, a Dynalyzer can handle any exposure an x-ray tube can!)

8) Influence of x-ray radiation on Dynalyzer

Extensive exposure of the HVU to x-rays will degrade the glass light pipe optic in the mA sensor. The light pipe will darken with radiation. This will make the mA appear to be low. We have seen units with 75% decrease in throughput from x-ray beams because of their exposure. Radiation can also ionize the SF_6 insulation and cause the Dynalyzer to read high at higher KV values!

JSS 12/28/91, Rev 3/22/92

We receive many Dynalyzer systems with a complaint of "**No mA**". Most of these units work; occasionally we find real problems. In order for you to complete your work, please check the following items:

1. Is the HVU plugged in? Is pilot light on?

2. What is the mA zero offset when the system is connected? Is it within +\- 10 millivolts. Can it be zeroed? Zero it with a DVM, while it is connected to the digital display. If the display is a Dynalyzer III, use AUTO trigger and adjust the Rad and Fluoro zero's so that the mA reading goes to about 0.1 mA, as zero is probably below zero. This procedure will compensate for zero drift within the digital display.

3. Is the Tube anode high voltage connector connected to the anode of the x-ray tube, and the Transformer anode HV connector going back to the transformer? If they are reversed, the system will not work. Never connect the anode of the HVU to the cathode circuit, or you will damage the x-ray generator and or tube!

4. Check that the high voltage cable ground shield is good. Often, it will snap at the termination. If both anode and cathode cables are bad a very dangerous condition can result. Be sure the cables are firmly plugged in, with the proper orientation. Is there filament current. If the cables do not make contact in the cathode circuit, you will not see a waveform in the FIL BNC. Only "CT" Dynalyzer measure DC filament current.

5. Measure the DC resistance between the Dynalyzer anode Tube and Transformer HV receptacle common pins. (Of course the generator is not connected at this time.) There should be 200 ohms +/- 5%. If you want to verify mA accuracy quickly, connect the + terminal of a 1.5 volt battery to the anode Transf common pin, and the - terminal of the battery to the anode Tube common pin. Connect DVM to mA output BNC. You should get .0075 volts (7.5 mV). In Fluoro range you should read 150 mV.

6. Check your BNC cables. Check HVU-display interconnect for shorts and opens. pin A=cath, B=anode, C=ground, D=mA, E=fil, F=mA range, G= mA ground.

7. Shake the HVU tank, and listen for tiny screws or rattles. This is serious and requires disassembly for repair.

8. Is the mA power oscillator working? There should be 10-15 v-pp at TP-1 of mA oscillator board (on right side of HVU behind front panel. Wiggle connector & filter cap.

9. When all else fails....send us your equipment for checkup, calibration, and repair if necessary!

10/30/95 js

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Application Note Number 5 — A *better* way to zero “mA” on your Dynalyzer

There is the suggested method of adjusting mA zero on the Dynalyzer II and III high voltage unit. This is to connect a digital volt meter to the BNC output of the HVU, and adjust the one or two mA zero potentiometers for rad and fluoro (Dynalyzer III only) through the hole in the lower front panel of the HVU. The method described below allows the zero drift of the digital display and high voltage unit, as well as residual system noise to be zeroed out all at one time. The method works easily with the Dynalyzer III digital display. Dynalyzer II requires some additional, but easy work.

With your Dynalyzer III digital display set for Auto trigger mode, connect the digital display to the high voltage unit. Try to plug them both into the same power outlet if possible.

1. Select RAD on the RAD/FLUORO switch.
2. Adjust the RAD zero potentiometer clockwise until the digital display begin to show a non-zero small number. Then turn CCW until the display reads 0.15 mA.
3. Select FLUORO on the RAD/FLUORO switch.
4. Adjust the FLUORO zero potentiometer CW until there is a reading greater than zero. Then turn CCW until the display reads 0.15 mA.

Note: The display may read 450 at some time, then zero. This is not a “defect”, but an anomaly of the Dynalyzer III when data values are at or below zero.

To perform these tests with a Dynalyzer II display, you need an external trigger. This may be as simple as a 1.5 volt battery and momentary switch connected to the rear external trigger input (+ to BNC signal lead). Press the momentary switch to generate an approximately 0.5 second measurement window while adjusting. Of course a TTL pulse generator would also work. Signal level up to +10 volts may be applied to this input.
September 5, 1995

Application Note Number 6 — OEC Interface Compatibility for Dynalyzer III

Since April of 1992, Varian, then RMS-Fischer and now Radcal are shipping Dynalyzer III units that are not 100% compatible with the OEC C-arm autocalibration system.

There was a change in the firmware on the display CPU board changing U14 EPROM from Rev 11 to Rev 12. This was necessary to get the new impact printer unit to function properly. Unfortunately this sends out an extra CR (carriage return) byte, and this fouls up the OEC software. So GiCi can get the interface to work, but not the printer, by changing the EPROM back to Rev 11.

This information has only recently been confirmed by some field tests. The solutions are as follows:
If you order a new digital display through GiCi, and specify OEC interface mod, we will cut a hole in the rear panel for the D-15F connector, add the ribbon cable, modify the analog board and reprogram U14 Rev 12 to Rev 11!

If GiCi modified your unit, let us know and we will supply an EPROM to you at no cost, but if it has a printer, it will not work correctly. You can always swap the chips; they are socketed. Just be sure to orient them correctly.

GiCi can make all necessary modifications for Dynalyzer II and III displays for OEC use. Call.

October, 1996

Introduction: Voltage dividers provide an unambiguous means of measuring the high voltage applied to an x-ray tube. Most voltage dividers have an accuracy better than 1%, if calibration is in date. They can be used improperly, which will negate the inherent accuracy of the instrument. In its most basic form, a high meg... ohm, high voltage resistor is connected in series with a resistor of much lower value. The divider is then connected to the inputs of the oscilloscope, or to the 10 x scope probe, depending on the manufacturers instructions. For example, the GE high voltage "bleeder" has a 100 meg...... ohm resistor array connected in series with approximately 101,000 ohm viewing resistor. When a 10 x, 10 meg.. ohm oscilloscope probe is connected to the output terminals, the oscilloscope will present the waveforms at a scale factor of 1 volt = 10 KV. The scale factor at the binding posts of the bleeder tank is 10 volt= 10 KV. The Machlett HV-1 divider can be connected in several ways, direct or through a probe, leading to large errors if not set up properly.

How not to get into trouble: It is very important to connect a voltage divider to an oscilloscope properly. Failure to do so can cause large errors. The GE divider and the Machlett HV-1 each have their own "traps".

A. **General Electric C1515A (46-154966GA) voltage dividers** are designed to be connected to an oscilloscope , by means of a 10X , 10 meg. ohm scope probe. It is very important that it be 10 meg. ohms. In addition, the frequency response of the divider can be greatly disturbed if you connect the probe directly to the binding posts. The GE "Bleeder" (Ref. 1) instructions states:

"...the following items are required: 1) C1515A Bleeder, 2) Two 5 ft. HV cables with standard termination at each end. 3) One dual trace oscilloscope capable of algebraic addition. Tektronix model 46 or 465 Model UC are preferred.... 4) One 30 ft. twisted pair cable, low capacitance 2-conductor, shielded. Belden No. 8422 (18 mmfd/ft) or equivalent. A 17 ft. length of cable must be used to obtain proper calibration on AMX-3. This permits locating the scope away from the area of radiation for safe viewing. **Never use the bleeder without this cable as it is part of the calibration!**"
(Ref. 1) General Electric Co., Direction 13288G, "Connection... Application"

GiCi experiments indicate that the best frequency response of the GE divider can also be obtained by connecting one 470 pf. ceramic capacitor, 500V, from anode binding post to ground, and a second like capacitor from cathode binding post to ground. This provides the equivalent capacitance of the 30 feet of cable. The scope probes can then be connected directly to the terminals, as many technicians are now doing....but without the capacitor. Failure to have the correct equivalent capacitance will result in the divider showing large overshoot in pulses or in high frequency ripple. We have been making this recommendation in our application notes for several years. (Use the capacitor or the twisted pair, but not both.)

B) Machlett-Varian HV-1 Voltage Dividers have their own little traps. There are two slide switches on the top of the connection panel. They offer setting of divider ratio (1,000:1 or 10,000:1), and offer setting of load resistance (1 meg. or 10 meg). We have often found these switches are often set in a way that appears to be in error. It is not very likely that one would use the divider in a 10,000:1 ratio and then use 10X scope probes in addition, but we have found these units set up imply this. To properly use the HV-1 divider in 99% of possible applications **set the slide switches to 10,000:1 and 1 meg ohm,** leave them there forever (1 volt = 10KV). Connect the HV-1 directly to the oscilloscope 1 meg ohm input terminals with 12 feet of RG-58U coaxial cables. Using longer or shorter cables will alter the frequency response. Try and keep oil out of the switches, or place some clear tape over the slots to prevent oil contamination.

GiCi calibrates the other possible useful mode of the HV-1, its 1,000:1 ratio into 10 meg ohm load. We do not recommend using the HV-1 as a substitute for the GE divider 1,000:1 divider because the divider resistance of the HV-1 is 700 meg ohms, which means the viewing resistor is 700 k ohm, while the GE divider is 100 meg ohm with a 100k ohm viewing resistor. In some applications, GE recommends connecting its "bleeder" directly to the AMX-3 or 9800 scanners. We do NOT recommend using the HV-1 as a substitute. Serious damage to the generator may result.

C) Nuclear Associates Voltage Dividers are relatively easy to use and trouble free. They have a 100,000:1 ratio and connect directly to the oscilloscope input terminals. (1 volt= 100 KV.) . This divider is frequency compensated, and has a 100 meg ohm internal resistance. Because of its low output viewing resistance (1 k ohm), variations in load resistance and cable capacitance of little effect on its performance.

D) GiCi 2000 (H917) Voltage Divider is a 100 meg ohm, frequency compensated voltage divider. It has two modes of operation, selected with a single switch: Either 10,000:1 when connected directly to a 1 meg ohm scope input, or 1,000:1 for connection to a 10 X scope probe, or as a frequency compensated substitute for the GE C1515A voltage divider. The divider is supplied with 15 feet of coax cable for connection to an oscilloscope. Binding post terminals are optional.

Tech Talk:

It is important to understand the construction of the voltage divider you are using in order to properly use it. Voltage dividers differ in internal resistance which vary from a low as 60 meg ohms to as much as 1000 meg ohms (1 gigohm). See table 1. Some voltage dividers are frequency compensated to a greater extent than others.

When using a voltage divider, it is important to match the resistance of the readout device such a oscilloscope direct input or probe input to the divider. The GE high voltage bleeder type C1515A is designed to be connected to a 10 megohm load. If it is connected by mistake to a 1 meg ohm load, then the user will see the output drop by 9%, because the output load resistor will shift from 100k ohm, to 100k ohm in parallel with 1 meg ohm, or 90.9 K ohm. The mismatch error with the HV-1 divider is significantly larger, because of the higher resistance of that unit. The HV-1 divider has several modes of operation which can lead to error and confusion. Because of its high resistance, small mismatches in viewing resistance can cause large errors.

The Nuclear Associates divider tank has a 100,000 :1 ratio. It has a 1000 ohm viewing resistor, so whether you are using a 1 meg scope, or for some reason a 10 meg scope probe, the output will change no more than .1% .

What makes a divider frequency compensated? In the real world of voltage dividers, the divider resistors have some stray capacitance across them, as well as stray capacitance to the walls of the container. To frequency compensate the divider, it is important to reduce the stray capacitance, as well a compensate the divider network. Elementary circuit theory for a voltage divider requires that the following equation be met, where R1 is the high voltage resistor(s), C1 its compensating capacitor(s), and R2, C2 the viewing resistor and capacitor.

$$R1 \times C1 = R2 \times C2$$

Simple 10 x scope probes have a trimmer capacitor, C2, to adjust the probe to a scope, and so do high voltage bleeders. The Dynalyzer is also highly frequency compensated, but uses additional compensation as well.

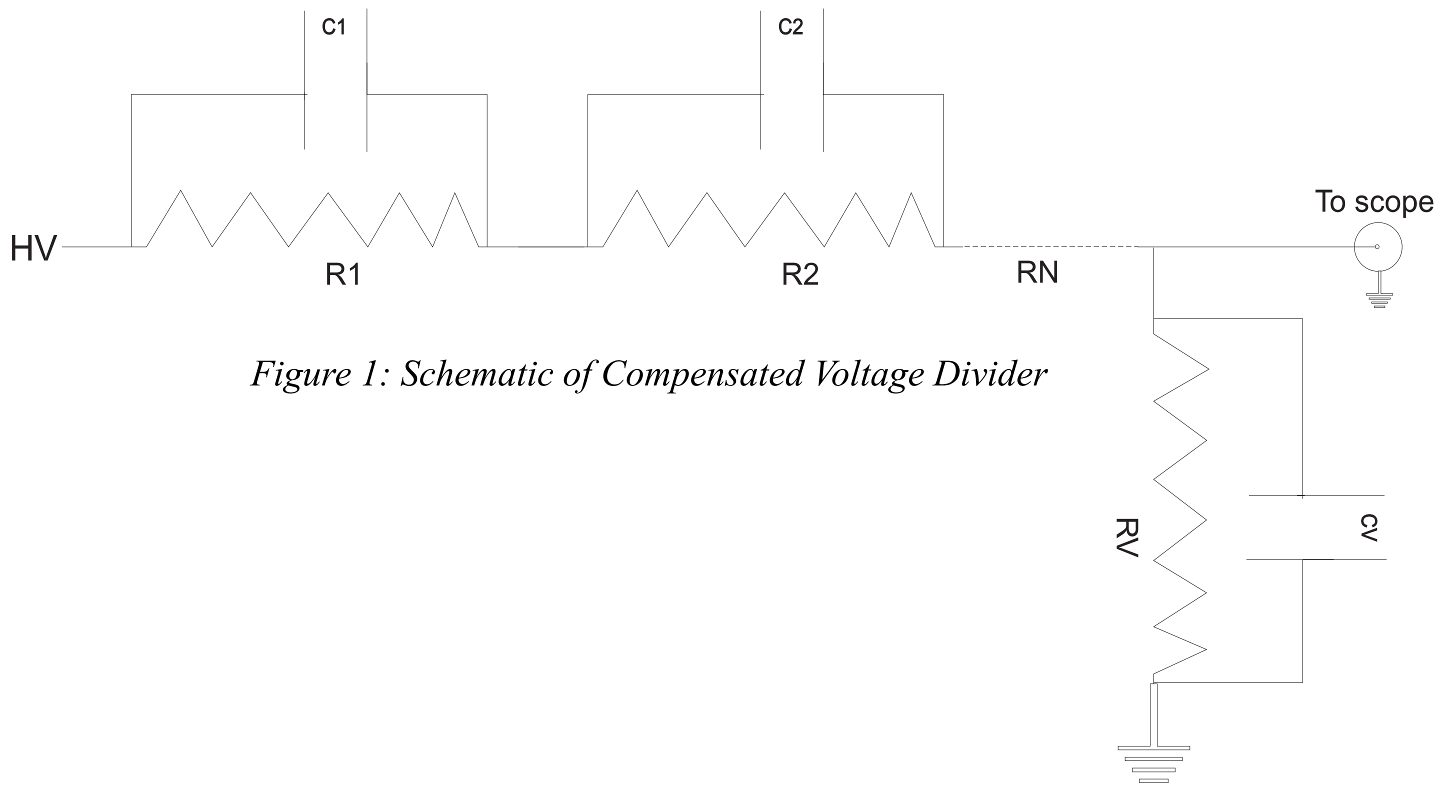

Figure 1: Schematic of Compensated Voltage Divider

TABLE 1

Model	Divider Resistance	Ratio	Load Resistance	Freq.Respons 3 db*
General Electric C1515 A	100 meg ohm	1000:1*	10 meg ohm	2.5 kHz +
Nuclear Assoc. 07-476DT	100 meg ohm	100,000:1	1 meg to 10 meg	15 kHz
Machlett HV-1	700 meg ohm	10,000:1	1 meg to 10 meg	>100 kHz
GiCi Model 2000 divider	100 meg ohm	10,000:1	1 meg to 10 meg	>100 kHz

*10,000:1 when used with 10X scope probe

** based on GiCi measurements. Note: This does not mean that the frequency response is flat for any of these dividers. 3db point is where the output of the sine wave of that frequency is down by 50%.

+There are no internal compensating capacitors, however the load capacitor and wiring is critical.

jss 4\21\96

Application Note Number 8 — Why Doesn't My Non-Invasive kVp Read the Same as a Divider?

An opinion by Dr. Jon Shapiro, President, Greenwich Instrument Co. Inc.

There are many reasons why a properly calibrated Dynalyzer or Voltage Divider will read differently from a non-invasive KVP meter. The differences are even larger in Mammo voltage ranges, where a 1 KVP difference in readings in not only a 4% error, but makes large differences in image quality.

A voltage divider is not filtration dependent. If you doubt that filtration makes any difference between invasive and non-invasive devices, put a thin piece of aluminum foil in the beam over a non-invasive device, and see how the readings change. A 10 micron change in the MO (molly) filtration will change the non-invasive readings by more than 1 KVP at 27 KVP!!

Most non-invasive KVP meters have problems if there is significant high frequency ripple. If the waveform is smooth, then this should not be a problem. If the instrument has a three phase, single phase switch, it means it has problems with waveforms and ripple. It has to add a fudge factor.

Voltage dividers can be a source of error from lack of understanding in hook up, such as impedance mismatch, or limited frequency response. Please read Application Note 6 for details.

The Dynalyzer has few limits to its accuracy, other than miscalibration, or failure. The scope outputs have a flat frequency response to 100 kHz, at which point the internal amplifiers roll off. The digital display has good frequency response to 10 kHz, beyond which there is some error in reading the high frequency ripple. Usually the ripple is a few percent, and the error is a percentage of this, so in practical uses, it is not a problem. In any case, at a frequency that the Dynalyzer would have a minor problem with, the non-invasive device detectors and amplifiers would be brain dead, in my opinion.

While a non-invasive meter is labeled KVP, it is calibrated against a calibrated divider or Dynalyzer by the manufacturer, and it is calibrated with a specific x-ray tube (beam quality) on a specific x-ray generator (waveform). Without a doubt, a brand new instrument would read differently on different generators the very day it was made.

GiCi believes that non-invasive meters have a place in the quality control market. Their best use is as a double check against the voltage dividers. While setting up the x-ray generator, use the non-invasive to make some comparison readings while the Dynalyzer, Inspec 200 or voltage divider is in the circuit. Then remove the Dynalyzer. If the KVP reading on the non-invasive changes, there is the possibility of "loading" due to the presence of the Dynalyzer. Then follow this procedure.

1) Set up generator with Dynalyzer in Anode and Cathode.

2) Remove Cathode from Dynalyzer and connect directly to tube. Leave the anode in.

3) Re check and readjust mA stations. Take some non-invasive vs Dynalyzer or divider comparison readings and write them down.

4) Remove Dynalyzer or divider from circuit. See if the comparison readings from step 3 have changed significantly. Note with high frequency generators, please use HV test cable of 5 feet or less. High frequency generators are affected to some extent by the extra capacitance of loading due to long cables.... some more than others! If the readings are consistent, write them down. The Inspec 100 and 200 x-ray high voltage calibration systems have been designed to minimize the loading effects due to the extra high voltage cables required with Dynalyzers or voltage dividers. These devices plug right into the generator or tube HV sockets, and the existing HV cable is connected to the Inspec. Write, call or e-mail for information.

5) Use your comparison readings to allow period QC non-invasive tests on your generator. Even if the non-invasive readings differed from the generator control settings, they are a reference, and should they change in the future, you can then take corrective action.

Application Note Number 9

Use caution when testing the GE "Light Speed"tm CT scanner

Please be very careful when testing the GE Light Speed CT scanner. It uses the anode high voltage cable to send stator power to the x-ray tube. The Dynalyzer, HV-1 Voltage Divider, and Nuclear Associates 07-476 voltage divider all have the three wires in the anode of the voltage divider shorted together. This shorting will cause damage to the stator supply of your scanner.

GE has made this change because the rotor of the x-ray tube and stator are closely coupled. This permits the very large anode to rev up to speed quickly, so as to reduce stress on the vacuum bearings.
At this point, it is possible to measure the voltage applied to the x-ray tube by using either a GE bleeder, which is not frequency compensated for pulses, or the GiCi PM2000 voltage divider which is frequency compensated. Both of these voltage dividers have all three wires of the anode separate, and routed straight through. The high voltage measurement is made from the Common lead to ground.

- We can modify your HV-1 or Nuclear Associates divider for three through wires on anode.

Calibration Notes

These notes accompany calibration reports.

Your instruments were calibrated with our computer controlled test set. All readings were referenced to the following equipment, which is in current calibration, and is traceable to NIST:

(2) Fluke 8842A 5 1/2 digit DVM's - All readings referenced to these meters ratiometrically. (6 month interval)
Fluke 5205A Precision Amplifier
Fluke 5500A/SC600 Meter-scope calibration system, to which all other meters are traced. (2 year interval)
Spellman HVD 100-1 voltage divider (0.1%), tested at NIST every two years, 0.1% accuracy.
Hewlett Packard 6634A System Power Supply
Hewlett Packard 6632A System Power Supply
Hewlett Packard 5316B Universal Counter
Hewlett Packard 8904A Multifunction Synthesizer
(2) Spellman SL300 constant potential power supplies, 100 KV @3 ma.
Power Design 1584-R HV power supply 1-20 KV DC

Overall uncertainty of our high voltage measurements is +/-0.2% . Correction factors are available.
Dynalyzer milliampere measurements are accurate to +/- 0.1% ,+/- zero offset.
ALL VOLTAGE DIVIDERS ARE TESTED TO THEIR FULL RATING OF 150 KV DC! Not all our competitors do this.

We recommend that your HV test cable be 5 foot (1.5 m) or less!

Dynalyzer Notes:

Attached are reports giving the HVU voltage divider ratio and frequency response, the current transducer (MA) response and the filament circuit calibration. Also attached is the verification of the digital display calibration for a series of calibrated, simulated exposures. Dynalyzer III MA output is 20X higher in Fluoro range. When using with Dynalyzer II display, be sure to divide display MA by 20. Dynalyzer III Display automatically handles this. Dynalyzer is tested at 100KVP nom @ 65 mA nom single phase for waveform accuracy, noise, and cross talk.

GiCi PM2000 Voltage Divider:

Both ranges are tested for high voltage accuracy and frequency response. New units are tested for high voltage accuracy, pulse response and frequency response. Unit is tested for both the 10,000:1 (1 meg load) and 1,000:1 (10 meg load).

G.E. Voltage Divider Notes:

Frequency response measurements are dependent on the input capacitance of the probe and cabling. They are made as a indicator of overall quality. These dividers shows a significant decrease in output above 360 Hz, which is normal for this type. Data taken with 470 pf of compensation, which is equivalent to capacitance provided to specified cabling of mfg. If you connect a scope probe directly to terminal, over-shoot is significantly improved by adding the 470 pf. capacitor (200 volt min). See our application note , which is also on our internet site http://www.giciman.com .

This report is valid only if the input impedance of the meter, or scope with probe is 10 meg ohm. The divider ratio is 1000:1 . When used with a 10 X scope probe, the measured voltage is divided by 10,000:1.

By itself, when terminated in 10 meg ohms, the divider has a 1000:1 ratio. Be certain that scope and 10 x probe are calibrated, too!

HV1 Divider Notes:

Frequency response measurements are dependent on the input capacitance of the probe and cabling. This report is valid only if the input impedance of the scope is 1 megohm and divider is switched to 1 meg . The divider ratio is 10000:1 if selected . Be certain that your scope is calibrated, too ! It is best to use this divider 10,000:1 into 1 meg, direct to scope. 1000:1, 10 meg calibrated also. Other combinations may not always produce expected results. This divider in 1000:1 range is not a substitute for GE bleeder in closed loop calibrations as impedances are different. We test the 10,000:1, 1 meg range only as the range switches in these units are fragile. (If other range is selected when received, it is tested).

Victoreen Nuclear Associates:

This divider has a 100,000:1 ratio and is accurate into 1 megohm or 10 megohm loads. Unit is calibrated into a 1 megohm load. There is no external adjustment in this unit. Unit is not adjustable.

MAS Meters:

Calibrated using precision power supply and counter. Before and after data supplied. Batteries replaced if less than 8.9 volts.

Oscilloscopes and DVM's:

Calibrated using Fluke 5500A calibrator and 5500-Cal software. Software modified for various models

High Voltage Cables

High voltage cables, if sent, are tested for continuity of shield and filament leads. Cables are Hi-pot tested at 75 KVDC with your voltage divider or Dynalyzer HVU. We recommend that the HV test cables be 5 foot or less to avoid decrease in filament current. Visual inspection of shield is made where possible, without disassembly.

Interconnect Cables

Digital Display Interconnect cable is tested with display if sent.

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