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WIEN

DISSERTATION

Cool Science

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“The Setesh guard’s nose drips.”
TEAL’C

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¹ 1 Cicero Word Generator

² This chapter describes the installation and initial setup of Cicero Word Generator^[1]
³ on a PC running Windows 10 with analog and digital cards from National Instruments
⁴ (NI). The code is freely available on Github^[2]. This chapter contains only differences,
⁵ problems, and possible solutions encountered when Cicero was installed for the PC
⁶ ‘Fritz Fantom’ which will be used for the QuaK experiment. It is therefore advised
⁷ to use the technical and user manual^[3] in conjunction. The titles in this chapter and
⁸ font style with Courier and Boldface was mirrored to fit the manual.

⁹ 1.1 Installation of National Instruments drivers

¹⁰ Before setting up the Cicero Word Generator, it is necessary to install the newest
¹¹ .NET Framework^[4] from Microsoft. For the first installation of NI drivers, NI-DAQmx
¹² (version 9.3), NI-VISA (newest version), and NI-4888.2 (newest version) should be
¹³ downloaded from the National Instruments website^[5]. When installing the NI drivers
¹⁴ it is possible to get an ‘Runtime Error!’. In this case it is necessary to set the Regional
¹⁵ format settings of Windows 10 to ‘English (United States)’^[6].

¹⁶ 1.2 Installation of National Instruments Cards

¹⁷ After installation of the necessary drivers, the physical cards can be inserted into the
¹⁸ PCIe slots on the motherboard. On ‘Fritz Fantom’ the digital card (NI PCIe-6537B)
¹⁹ was installed in PCIe bus 3 while the analog cards (NI PCIe-6738) were installed in
²⁰ PCIe bus 4 and 5.

²¹ 1.3 Configuring Atticus

²² After installation of the NI cards, Atticus should be launched for the first time and
²³ closed without changing any settings. After this, the NI-DAQmx drivers should be

updated to the newest version. If version 9.3 was not used when launching Atticus in this step, it could result in an error. After this, “Configuring Atticus” on the user manual can be followed. The **Server Name** was set to ‘Fritz_Phantom’. **Dev1** to **Dev3** were set in the same ascending order as the physical installation on the motherboard.

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1.3.1 Configure hardware timing / synchronization

For synchronization, a **Shared Sample Clock** was used with **Dev1** being the master card. The settings are summarized in table 1.1 and table 1.2. For **Dev3** ‘SampleClockExternalSource’ should be set to ‘/Dev3/RTSI7’. The ‘SampleClockRate’ is set to 350 kHz since this is the fastest rate with all 32 analog channels active. It is possible to raise this to 1 MHz by only using 8 channels (1 channel per bank).

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Table 1.1: Settings for **Dev1**.

Setting	Value
MasterTimebaseSource	
MySampleClockSource	DerivedFromMaster
SampleClockRate	350000
UsingVariablenamebase	False
SoftTriggerLast	True
StartTriggerType	SoftwareTrigger

Table 1.2: Settings for **Dev2**.

Setting	Value
MasterTimebaseSource	
MySampleClockSource	External
SampleClockExternalSource	/Dev2/RTSI7
SampleClockRate	350000
UsingVariablenamebase	False
SoftTriggerLast	False
StartTriggerType	SoftwareTrigger

1.4 Configuration and Basic Usage of Cicero

² After setting up the Atticus server, Cicero can be configured. In step 3.c. it is necessary
³ to write the full IP address and not ‘localhost’. Once step 6 is finished, Cicero should
⁴ run without any problems.

1.5 Saving of Settings and Sequences

⁶ The ‘SettingsData’ of the Server Atticus are saved in C:\Users\confetti\Documents
⁷ \Cicero_Atticus\Cicero\SettingsData while the ‘SequenceData’ of Cicero are saved in
⁸ C:\Users\confetti\Documents\Cicero_Atticus\Cicero\SequenceData.

1.6 Sequence length limit

¹⁰ The duration of a sequence is limited to $2^{32}/(16 * 32 * 350 \text{ kHz}) = 23.967 \text{ s}$ coming
¹¹ from a 32-bit application, 16 bit per channel, 32 channels in a NI PCIe-6738 card, and
¹² 350 kHz clock rate.

2 Electron beam setup

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2.1 Charatarization of a working CRT

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HAMEG HM507 oscilloscopes [7] were used for testing purposes. These contain a D14-363GY/123[8] CRT hereinafter abbreviated as ‘D14’, ‘tube’, or ‘CRT’. Although the HM507 has only a bandwidth of 0 MHz to 50 MHz, which is not sufficient for the hyperfine splitting frequency of 461.7 MHz of ^{39}K , it was used nevertheless because of its simple construction and availability. A schematic view of the device is shown in fig. 2.1 with the back pin arrangement in fig. 2.2.

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The voltages and currents of the necessary pins to drive the CRT were measured using a 2.5 kV probe with an attenuation ratio of and are summarized in table 2.1. It was not possible to measure pin g3 directly. Therefore a HVPS (section 2.2) was used to set a voltage and the beam diameter was observed. The best focus was achieved with the voltage mentioned in the table. The voltage offset of x-, and y-plates was not possible to measure directly, since it varies with time to draw the necessary image on the phosphor screen. The given values in table 2.1 are the mean of the minimum and maximum measured voltage. The deflection coefficient is summarized in table 2.2.

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13current?

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2 Electron beam setup

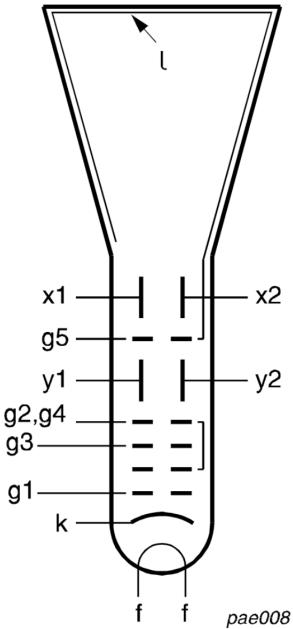


Figure 2.1: Electrode configuration (from [8])

how to cite figure

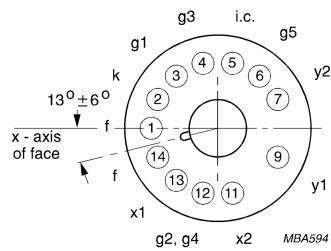


Figure 2.2: Pin arrangement, bottom view (from [8])

how to cite figure

2 Electron beam setup

Table 2.1: D14-363GY/123 CRT pin measurements

current empty or '-' symbol

number	pin	voltage/V	current/ μ A
1	f	-1.99×10^3	86.6×10^3
2	k	-2.00	-7.6
3	g1	-2.03	0
4	g3	-1.813×10^3	
5	i.c.	71.7	0.1
6	g5	64.0	7.2
7	y2	78	
9	y1	78	
11	x2	96	-
12	g2, g4	71.0	0
13	x1	96	-
14	f	-1.97×10^3	-86.2×10^3

Table 2.2: D14-363GY/123 deflection coefficient (from [8])

how to cite source

horizontal	M_x	19 V/cm
vertical	M_y	11.5 V/cm

¹ 2.2 High Voltage Power Supply HVPS

² To produce high dc voltages to drive the CRT, four HCP 14-6500 power supplies^[9]
³ were used. They were named ‘HVPS 1’ to ‘HVPS 4’ and can provide up to ± 6.5 kV and
⁴ 2 mA. To connect the output to the CRT pins, BNC cables were refitted with a save
⁵ high voltage (SHV) connector on one side while on the other end the BNC connector
⁶ was kept (fig. 2.3). A 6 kV probe was used to obtain the breakdown voltage, which is
⁷ around 3 kV caused by the coaxial cable which was not built do sustain high voltages.

find name of bi
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find exact value

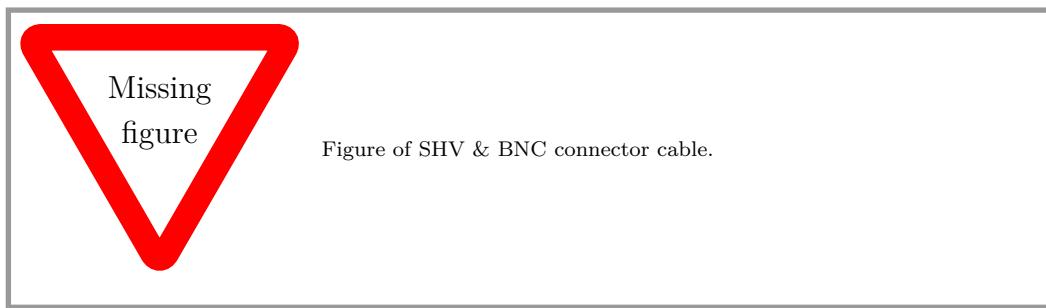


Figure 2.3: Coaxial cable with SHV and BNC connector.

⁸ 2.2.1 Ripple measurement

⁹ Each power supply was measured for its ripple with a set voltage of 2 kV. A 2.5 kV
¹⁰ probe (attenuation ratio)was connected to an oscilloscope set to ac coupling with a
¹¹ timescale of 1 ms. To get the electronic noise of the oscilloscope itself, the probe was
¹² shorted and the noise measured. A picture of a measurement is shown in fig. 2.4 with
¹³ the values summarized in table 2.3.

100:1 or 1:100

Table 2.3: HVPS ripple

device	ripple/mV
short	116
HVPS 1	136
HVPS 2	138
HVPS 3	194
HVPS 4	204

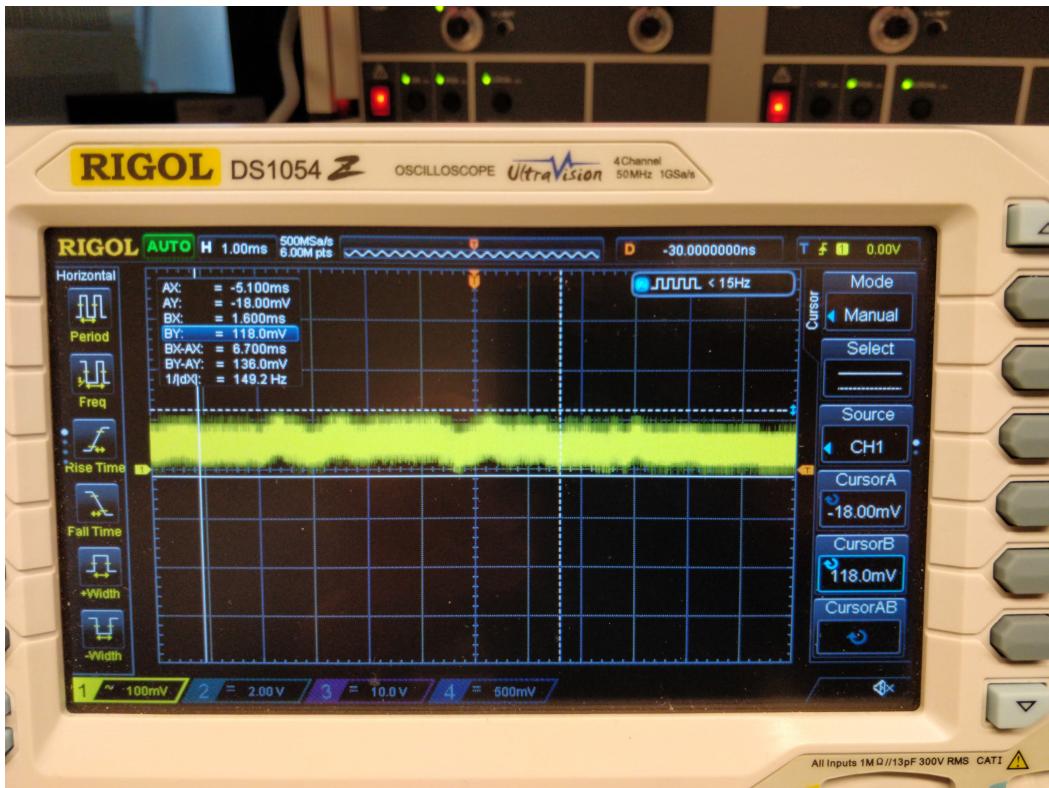


Figure 2.4: Measurement of HVPS ripple.

2.3 CRT wiring

A schematic of the supplied power is shown in fig. 2.5. A small ac or dc voltage is necessary to drive the heater filament f. This part of the setup is explained in section 2.4.

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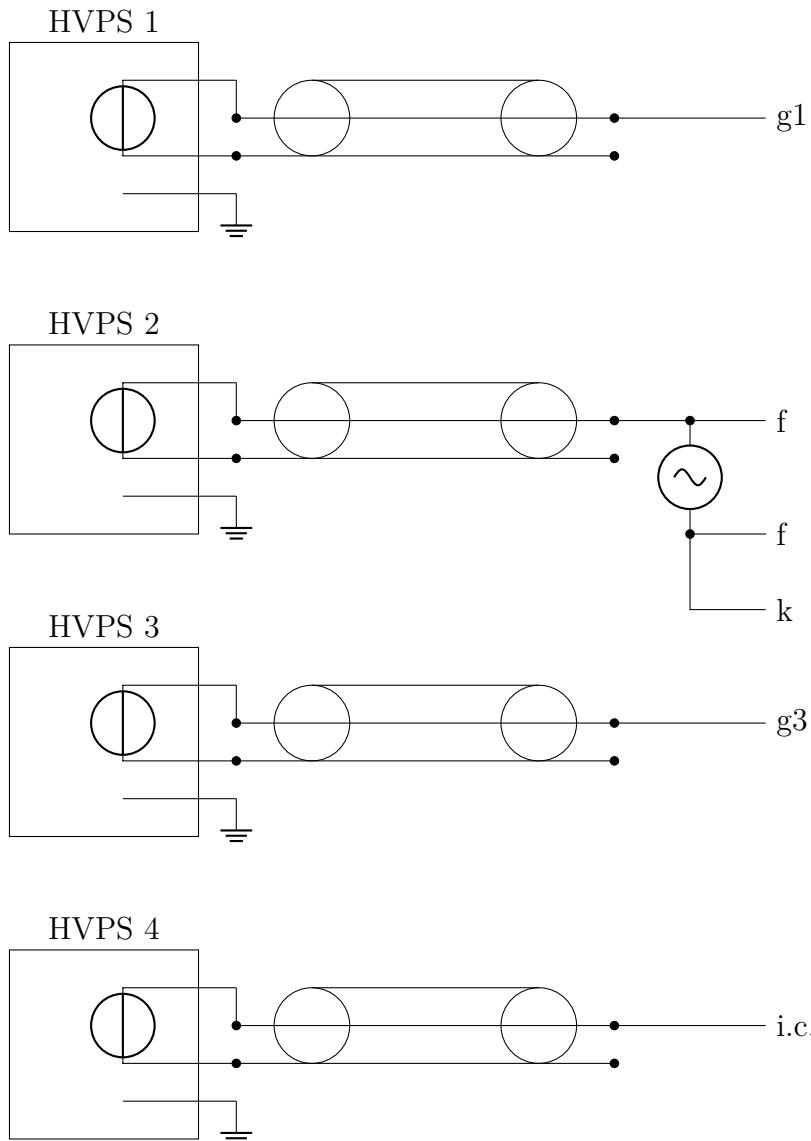


Figure 2.5: Schematics of supplying CRT pins with power.

¹ 2.4 Heater

- ² The heater provides an adjustable ac voltage, which is used to regulate the temperature
³ of the cathode. In the cold state, the heater filament has a an electrical resistitance
⁴ of approximately $15\ \Omega$, when the filament is hot, this value rises to $90\ \Omega$. The normal
⁵ heater voltage for the D14-363GY/123 during operation is 6.0 V to 6.6 V according to
⁶ [8]. Our ac-power supply (figure 2.6 shows its circuit diagram) consists of an isolation

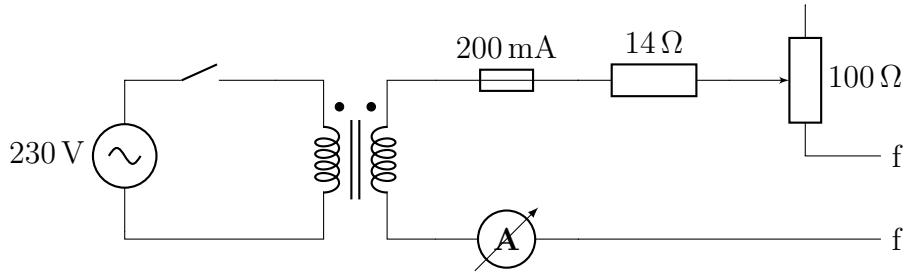


Figure 2.6: Circuit diagram of filament power supply.

check if really 14Ω or if it event exists

transformer (from grid voltage to 12 V), its primary and secondary circuits are isolated up to 4 kV [10]. The power supply has two banana plug sockets to connect to the heater filament. It is connected to the transformer in series with a 100Ω potentiometer. Using the full resistance, there is a voltage of approximately 5.7 V applied to the heater filament, by lowering the resistance this value can go up to nearly the full voltage of the transformer. The current running through the filament is measured with an integrated amperemeter [11] that measures currents up to two 2 A with mA accuracy.

At the beginning of operation it is recommendable to set the maximum resistance and slowly increase the current to the desired value once the filament is heated up. As the resistance of the cold filament is significantly lower, high onset currents could otherwise damage it.

¹ 3 CRT handling

² 3.1 Opening CRTs

³ In order to hit the ^{39}K cloud with an electron beam, it is necessary to cut open the
⁴ CRT. This section explains the different methods which were tried and which resulted
⁵ in clean and easy cuts. All slices were made in a glove box filled with nitrogen gas
⁶ (fig. 3.1) to avoid oxygen poisoning of the cathode.

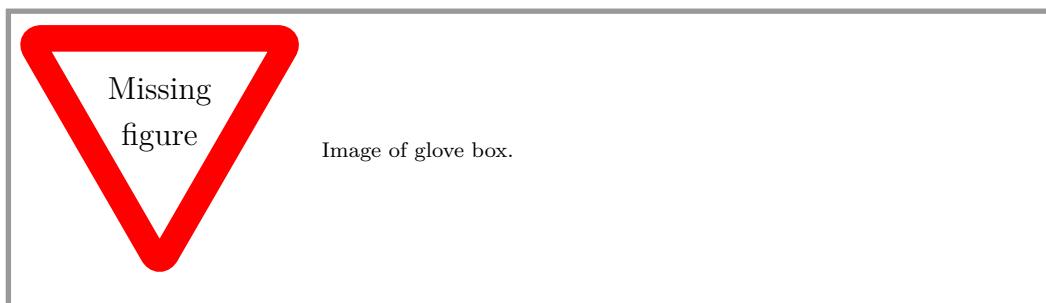


Figure 3.1: Glovebox filled with nitrogen gas to open CRTs.

⁷ 3.1.1 Rotary tool

⁸ First, a small hole was drilled in the center of the CRT pins to pressurize the CRT
⁹ with nitrogen. Then a diamond wheel attached to a rotary tool was used to cut the
¹⁰ glass. This method was tried twice, but did not work well, as the method produced a
¹¹ lot of glass dust, which adhered to the electron optics. Another obstacle is the plastic
¹² box, since it is not fully transparent and therefore made more difficult to see inside.

¹³ 3.1.2 Wire cutting

¹⁴ Higher success was achieved by cutting the glass with a heated wire. Two wires were
¹⁵ put through the glove box, each ending in a ring terminal. A small height adjustable
¹⁶ stage was built out of optical table parts (fig. 3.2) in which the CRT was put vertically

and looped by an 0.25 mm steel wire (Fe 70/Cr 25/Al 5). It is important to keep a small gap in the loop to avoid an electrical short. Therefore two notches were made in which the wire was fixed.

The assembly was put inside the glove box which was subsequently filled with nitrogen. A current of approximately 2 A to 2.5 A was used to heat the thin wire which resulted in a breaking point inside the CRT glass. This method does not require a CRT pressurization before the cut. In order to not destroy a device by mistake, this procedure can first be tested on drinking glasses.

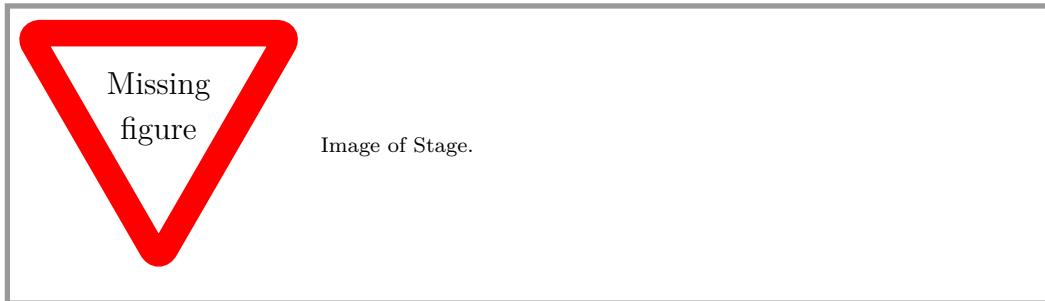


Figure 3.2: Stage to cut CRT with wire.

3.2 Oxygen poisoning

As mentioned in it is paramount to avoid contact of the cathode with oxygen. Therefore tests with a broken CRT were made to test on how well it can be isolated from air.

The first experiment consisted of filling a drinking glass put upside-down with helium and putting a lighter after a set amount of time. If the fire goes off, it means that oxygen did not get inside. This was tested successfully from 0.5 min to 10 min.

Next, plastic wrap was put on top of the glass filled with nitrogen by a rubber band. The glass was put with the open side up from 3 min to 10 min after which it was turned upside down and the foil was removed. A lighter was put inside and the flame went out again.

To improve the sensitivity, a He leak tester was used. For the first two tests, one plastic foil and one rubber band were used, for the third test three foils and two rubber bands, and for the last test an aluminum foil was hot glued on the CRT to seal it. The measurement locations are shown in fig. 3.3. As shown in table 3.1 using rubber band and clear foil results in the highest leakage while the glue seals much better (glue avg). But care needs to be taken in order ensure that the whole CRT is sealed since even a

3 CRT handling

- ¹ small leak can result in a rate around an order of magnitude above the background
² (glue max).

Table 3.1: He leak test.

location	leak rate/(10 ⁻⁵ mbar l/s)
1 plastic foil, 1 rubber band	
background	8
plastic foil	20
He gas cylinder	200
1 plastic foil, 1 rubber band	
background	7
plastic foil	20
rubber band	40
3 foils, 2 rubber bands	
background	20
plastic foil	30
rubber band	70
1 aluminum foil, hot glue	
background	6
glue avg	7
glue max	60
aluminum foil	8

3 CRT handling



(a) plastic foil



(b) rubber band



(c) glue



(d) aluminum

Figure 3.3: Measurement locations of He leakage.

¹ Todo list

²	■ namechange?	2
³	■ http://www.tobiastiecke.nl/archive/PotassiumProperties.pdf	4
⁴	■ model number	4
⁵	■ 1:100 or 100:1	4
⁶	■ current?	4
⁷	■ how to cite figure	5
⁸	■ how to cite figure	5
⁹	■ current empty or '-' symbol	6
¹⁰	■ how to cite source	6
¹¹	■ find name of big yellow probe	7
¹²	■ somewhere 2.5-4, find exact value	7
¹³	■ Figure: Figure of SHV & BNC connector cable.	7
¹⁴	■ 100:1 or 1:100	7
¹⁵	■ check if really 14Ω or if it event exists	10
¹⁶	■ Figure: Image of glove box.	11
¹⁷	■ Figure: Image of Stage.	12
¹⁸	■ where ?	12

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