3 AVO VCM163

Since the circuits in the VCM163 differ from the other models mentioned here I have put these calculations in their own chapters. We will also see that some of the calculations show that we can't compare measurements between the VCM163 and the other models as the values used for some components gives raise to different measurements.

3.1 Calibration resistor plus Continuity and Insulation tests

This chapter will discuss the following parts, referring to schematic drawings in chapter 6:

- Calibration resistors (R20 – R21)
- Calibration circuit (RV3, R19 & C6)

For the AVO VCM163 the circuit is somewhat different compared to the earlier models in that it does not have one calibration resistor (although made up from two matched resistors) but it has two calibration resistors! The two 2.2MΩ resistors work as both a voltage divider for the insulation and continuity tests and also as the current limiter setting the current flowing in the circuit for the calibration! Otherwise the circuit works identically which means that the SET ~ region is still at 90% of FSD. This then means that a current of 45µA needs to flow through the meter for the needle to reach the SET ~ centre position. Since the calibration position can be adjusted with RV3 the two 2.2MΩ resistors only need a 1% tolerance, but the more close they are to this value and the more identical they are the easier it will be to perform the calibration. These two resistors are also made up from the well known black body Welwyn resistors that are known to drift high over the years, so you'll need to check these two resistors before you start calibration procedures. Calibration is adjusted with RV3, which is in series with R19 at 4.7KΩ, so the needle reaches the SET ~ region on the meter. In the calibration circuit, which is used for all of the CHECK(C), CHECK(H), C/H Ins and GAS test positions the voltage is smoothed by C6, 60µF/250VDC, to make this voltage a DC voltage and not just a half wave rectified voltages as in the TEST position.

As I mentioned above the current flowing in this circuit as well as the voltage drop across the calibration resistors are used for both the Continuity and Insulation tests, so it needs to be correct not just for the calibration setting. The voltage drop across the calibration resistor voltage divider is also use to put the unused electrodes in multi electrode valves at 50V DC.

There is not really much to calculate here, but if you want to check your circuit it is good to know that the voltage across both of the calibration resistors should be close to 99.2V DC when in the calibration position. This voltage comes from the following calculations:

Voltage drop across meter at SET ~ position:

0.9 * 50µA * 2.400Ω = 0.108V = 108mV

Current through 2.2MΩ resistor R20 in parallel with meter:

0.108V / 2.2MΩ= 0.049µA

Total current through meter and 2.2MΩ resistor R20:

45µ+ 0.049µA = 45.049µA

Voltage drop across 2.2MΩ resistor R21:

2.2MΩ = 45.049µA = 99.108V

Total voltage drop across meter and R21:

99.108V + 0.108V = 99.216V ≈ 99.2V

3.2 VCM163 Anode Current measurements

This chapter will discuss the following parts, referring to schematic drawings in chapter 6:

- Current Sensing resistors (R11 - R14)

The Anode Current measurement in the VCM163 has been improved over the method used in the Mk III, Mk IV and CT160/A; resulting in a substantially lower internal resistance in the Anode circuit. This means that valves with a low Ra can be measured more accurately in the VCM163. This has been done by lowering the measurements resistor used for each Ia range; now they range from 2.4Ω on the 100mA range, up to 82.8Ω on the 3mA range. The meter is now directly connected across the shunt resistors, R11 - R14, and indicates the Anode current, without the need to use any extra series resistors. The calculations for the Anode Current measurements are now very simple. The meter needs 50µA to reach FSD and has a total internal resistance of 2400Ω. This resistance is made up from a moving coil resistance of 1,560Ω and a network consisting of one resistor, in series with a second resistor, which is in parallel with an NTC thermistor, a Mullard VA1039, resulting in an extra resistance of 840Ω. These extra components have been installed in the meter to compensate for temperature changes in the resistance of the copper wire in the moving coil. A similar arrangement of resistors and NTC thermistor was introduced in the AVO TT537 transistor tester. The design with the NTC thermistor was also used in the AVO EA113 and Avometer models 15,16 & 20.

Meter voltage drop is: 50µA x 2,400Ω = 120mV

<u>Ia range: 100mA, 30mA, 10mA, 3mA:</u>

Ia 100mA: (50µA x 2,400Ω) / 2.4Ω + 50µA = 50.05mA
Ia 30mA: (50µA x 2,400Ω) / 8.02Ω + 50µA = 15.01mA
Ia 10mA: (50µA x 2,400Ω) / 24.3Ω + 50µA = 4.99mA
Ia 3mA: (50µA x 2,400Ω) / 82.8Ω + 50µA = 1.5mA

As before we need to double these values as we are working with half wave rectified AC RMS voltages, we then get 100mA, 30mA, 10mA and 3mA.

3.3 VCM163 D/R measurement ranges

This chapter will discuss the following parts, referring to schematic drawings in chapter 6:

- D/R measurements (R4 - R10, R3, C5)
- Measurement voltage for D/R measurements (R15 - R17)
- Why is it not identical to other VCM's?

I feel that some comments on the VCM163 D/R measurements are necessary, as those substantially differ from the other valve testers, when it comes to the maximum values on some ranges.

The three resistors R15 - R17 are used to limit the current that can flow in the D/R circuit on the lower current ranges, so that the valve under test will not be overloaded.

The calculations for the VCM163 on the D/R ranges are as follows:

D/R range:	180mA, 120mA, 60mA, 30mA, 15mA, 5mA, 1mA
D/R 180mA:	50µA x (2,400Ω + 3.4MΩ) / 700Ω + 50µA = 243.1mA (243.0mA)
D/R 120mA:	50µA x (2,400Ω + 2.27MΩ) / 700Ω + 50µA = 162.4mA (162.3mA)
D/R 60mA:	50µA x (2,400Ω + 1.3MΩ) / 700Ω + 50µA = 93.1mA (81.2mA)
D/R 30mA:	50µA x (2,400Ω + 680kΩ) / 700Ω + 50µA = 48.8mA (40.7mA)
D/R 15mA:	50µA x (2,400Ω + 281kΩ) / 700Ω + 50µA = 20.3mA (20.4mA)
D/R 5mA:	50µA x (2,400Ω + 91kΩ) / 700Ω + 50µA = 6.7mA (6.8mA)
D/R 1mA:	50µA x (2,400Ω + 16kΩ) / 700Ω + 50µA = 1.4mA (1.4mA)

After correction for the 135% (0.74) factor we get:

D/R 180mA:	243.1mA x 0.74	= 179.9mA (179.8mA)
D/R 120mA:	162.3mA x 0.74	= 120.1mA (120.1mA)
D/R 60mA:	93.1mA x 0.74	= 68.9mA (60.1mA)
D/R 30mA:	48.8mA x 0.74	= 36.1mA (30.1mA)
D/R 15mA:	20.3mA x 0.74	= 15.0mA (15.1mA)
D/R 5mA:	6.7mA x 0.74	= 5.0mA (5.0mA)
D/R 1mA:	1.4mA x 0.74	= 1.0mA (1.0mA)

When compared to the values for the AVO Mk IV (in parenthesis above), we immediately see that we have substantially higher values on the 60mA and 30mA ranges, even before the scale factor has been used. The centre of the GREEN scale now corresponds to 69mA and 36mA. But AVO did not change the values for the rectifiers in the Valve Data Manual for the VCM163, nor did they make a special column for the VCM163 in the Valve Data Manual for D/R measurements. What does all this mean for real life measurements? If you first test a valve in an Mk IV and it shows 100% value according to the manufacturer's information, the needle lies exactly centre of the GREEN scale; if you then test the same valve in a VCM163 you will obtain a lower reading on the green scale for the 60mA and 30mA ranges! This will then mean that you might have thought the valve to be weaker, if you had only tested it on the VCM163.

I have searched for any information why AVO did it like this, but I have not found any written information anywhere. I have however found that if you examine the values which AVO used for the series resistors for these two ranges, 1.3MΩ & 680kΩ, and you look them up in the E24 resistor tables and simply move two steps down to 1.1MΩ & 560kΩ you will get D/R readings that are closer to the ones used in the Mk IV.

D/R range:	60mA, 30mA – VCM163
D/R 60mA:	50µA x (2,400Ω + 1.1MΩ) / 700Ω + 50µA = 78.8mA
D/R 30mA:	50µA x (2,400Ω + 560kΩ) / 700Ω + 50µA = 40.2mA

If you want even better values you can simply add 22kΩ + 12kΩ to the 1.1MΩ and 3.3kΩ + 2.7kΩ + 330Ω to the 560kΩ resistor to get more or less the same values as for the Mk IV.

D/R range: 60mA, 30mA – VCM163

D/R 60mA:	50µA x (2,400Ω + 1.134MΩ) / 700Ω + 50µA = 81.2mA
D/R 30mA:	50µA x (2,400Ω + 566.33kΩ) / 700Ω + 50µA = 40.7mA

I have no way of knowing if this is how AVO wanted the measurements to work, but it is at least possible to compare the values for the D/R measurements between an VCM163 and the other VCMs, by using these new resistor values. There might have been some other reason for AVO to choose to change these ranges like they did; maybe a lot of new diodes/rectifiers were introduced on the market which made it necessary to make these changes, or there may have been some other reason. It might also be one of the many typos that the AVO manuals are full of, however the resistance values for the 60mA and 30mA ranges are present in at least three VCM163's that I know of. AVO might have written an errata where these values have been changed, but I have not found any errata in all of the AVO documentation that I have searched through.

Another simple way of calculating the value for the resistors in the D/R circuit is by using the value for the 180mA circuit and then dividing it in steps of 1.5, 2, 2, 2, 3, 5 for each range and subtracting the meter resistance, you then get the following values which are close to the values needed to get the correct deflection of the meter needle, which confirms our calculations above:

D/R 180mA:	3,400,000Ω + 2,400Ω	= 3,402,400Ω	≈ 3.4MΩ
D/R 120mA:	3,402,000Ω / 1.5 – 2,400Ω	= 2,265,867Ω	≈ 2.27MΩ
D/R 60mA:	2,265,867Ω / 2 – 2,400Ω	= 1,130,533Ω	≈ 1.13MΩ
D/R 30mA:	1,130,533Ω / 2 – 2,400Ω	= 562,867Ω	≈ 563kΩ
D/R 15mA:	562867Ω / 2 – 2,400Ω	= 279,033Ω	≈ 279kΩ
D/R 5mA:	279,033Ω / 3 -2,400Ω	= 90,611Ω	≈ 91kΩ
D/R 1mA:	90,611Ω / 5 – 2,400Ω	= 15,722Ω	≈ 16kΩ

In the Mk III, Mk IV, CT160 / CT160A the measurement resistor for the D/R measurements is the same as the measurement resistor for the Ia ranges, i.e. R36, 200Ω. But for the D/R measurements, a load resistor of 500Ω is added to the circuit; whilst it does not form part of the measurement circuit, it loads the valve under test properly, in order to obtain the correct readings. In the VCM163, the circuit has been somewhat changed, as now we have only one resistor acting as both measurement and load resistor of 700Ω for the D/R measurements. Since we have the same total resistance in the D/R measurement circuit, you would therefore expect that the D/R ranges should give the same readings on the meter, but for some reason the 60mA and the 30mA ranges don't, on the VCM163.

For the Mk III, Mk IV, CT160 / CT160A, AVO chose not to have any scale calibrated in mA for the D/R measurements, which would show the actual value of the current flowing through the diode/rectifier being tested; instead they chose to use a broader scale of relative "goodness". Why did they choose to do it like this? My guess is that they could use smaller transformers and lower power ratings on the resistors in the circuit, all of these parts reducing the cost of the tester and making the circuit simpler.

3.4 VCM163 mA/V measurement

This chapter will discuss the following parts, referring to schematic drawings in chapter 6:

- Oscillator
- Amplifier
- Voltage divider for mA/V ranges (R28 – R30, RV1, R31)

The VCM163 is the first, and only, AVO VCM with two meters, where one meter is dedicated for mA/V measurements. The advantage of this design is that it enables you to measure the mutual conductance simultaneously with anode current; because the value of mutual conductance depends on the anode current. The mA/V measurement is performed by adding a small, high frequency signal on the grid voltage from an oscillator, which is then amplified, and displayed on the mA/V meter. In the VCM163 manual AVO say that they use a signal with amplitude of approximately 35mV RMS on the 0 - 6mA/V range and that this signal is inversely proportional to the selected mA/V range. This may be another of AVO's typos; since this signal actually measured 53mV in (admittedly only) one VCM163; so the figures would appear to have been transposed. The oscillator consists of a Wien Bridge oscillator, with a frequency of approximately 15 kHz. The oscillator is compensated for temperature drift both in frequency and output amplitude. The amplifier is used to measure the resulting high frequency signal appearing across a 10Ω sensing resistor in the anode current circuit. The amplifier is a standard amplifier design driving the 50µA, 1,500Ω meter, which indicates the gm directly, using three ranges. In this respect, the two meter movements are basically the same; except that the gm meter does not incorporate any temperature compensation. The amplifier has a feedback path, which makes it possible to drive meters with other specifications than the 50µA meter specified. This can be accomplished by changing the 200Ω feedback resistor, R14, in the amplifier, lowering its resistance means that the amplifier will drive a higher current through the meter, making it possible to use 100µA meters with an internal resistance close to the original meter resistance of 1500Ω.

> Note: The design with a Wien Bridge oscillator and an Amplifier to measure this signal was also used in the AVO TT537 transistor tester, where AVO also went on to describe the arrangement of this circuit, why it is designed as it is and how it is calibrated. I have included some of the pages from the AVO TT537 manual at the end of this document. The AVO TT537 was introduced in 1966.

The amplifier frequency response has been measured by Euan MacKenzie, and the 3dB points were found to be 7.5kHz to 500kHz, so it is not a tuned amplifier.

The output signal level from the oscillator is 81mV RMS and is coupled through a voltage divider made up from resistors R28, R29, R30 and RV1. Resistor R31 is used to set the calibration of the output level in combination with RV1. The voltage divider delivers a voltage level that is inversely proportional to the mA/V range. On the 0 - 6 mA/V range AVO state that the signal is approximately 35mV RMS, but measurements show that it is 53mV in one calibrated VCM163, the voltage level at 0 - 20 mA/V has been measured at 16mV and at the 0 - 60 mA/V range it has been measured at 5.3mV. These voltages are very close to the values we get when we calculate the values with the components in the circuit. To be able to carry out the calculations, we measured the resistance of the gm calibration potentiometer RV1, when set to the red calibration line on the gm meter, to be 239.7Ω.

> Note: There are actually two RV1s in the VCM163! The other one is on the oscillator board, and is only used to set the oscillator output (across the brown and red terminals on the oscillator board) to 15mV; AVO state that this setting is only correct when measured between 18 and 22ºC.

Combining this with the measured voltage at the output transformer, 81mV RMS, and the internal DC resistance of the output transformer, which was measured to be 28.1Ω; the calculations then become:

Voltage from the voltage divider in the 0 - 6mA/V range

$V_{0\text{-}6mA/V} = V_{Transformer} \times R28 / (R_{Transformer} + R28 + R29 + R30 + RV1)$

$= 81mV \times 44.4\Omega / (28.1\Omega + 44.4\Omega + 88.9\Omega + 310\Omega + 239.7\Omega) = 5.1mV$

Voltage from the voltage divider in the 0 - 20mA/V range:

$V_{0\text{-}20mA/V} = V_{Transformer}$ x (R28 + R29) / ($R_{Transformer}$ + R28 + R29 + R30 + RV1)

= 81mV x (44.4Ω + 88.9Ω) / (28.1Ω + 44.4Ω + 88.9Ω + 310Ω + 239.7Ω) = 15.2mV

Voltage from the voltage divider in the 0 - 60mA/V range

$V_{0\text{-}60mA/V} = V_{Transformer}$ x (R28 + R29 + R30) / ($R_{Transformer}$ + R28 + R29 + R30 + RV1) =

= 81mV x (44.4Ω + 88.9Ω + 310Ω) / (28.1Ω + 44.4Ω + 88.9Ω + 310Ω + 239.7Ω) = 50.5mV

Voltage from the voltage divider which is used in the Calibration of the mA/V meter amplifier; the 10Ω value below is the sensing resistor in the anode current circuit, at the amplifier input.

$V_{Cal.mA/V} = V_{Transformer}$ x ((R28 + R29) // R31 + 10Ω) / ($R_{Transformer}$ + ((R28 + R29) // R31 + 10Ω + R30 + RV1) =

= 81mV x ((44.4Ω + 88.9Ω) // 1300Ω + 10Ω) / (28.1Ω + ((44.4Ω + 88.9Ω) // 1300Ω + 10Ω) + 310Ω + 239.7Ω) = 14.96mV

We see that these values, 5.1mV, 15.2mV and 50.5mV are close to the measured values as well as they correspond well to the range factors of 3.33… and 10 (20mV/6mV = 3.33… and 60mv/6mv = 10).

3.5 VCM163 over current relay

This chapter will discuss the following parts, referring to schematic drawings in chapter 6:

- Relay coil and holding circuit (RL1, D3, R18, C7, LP1 & R34)

There are some small differences between the older VCM's and the VCM163 in this circuit, but not much. The over current relay only has one coil and it is part of the common rail for the Anode and Screen voltages as it is situated between the common cathode connection and the 0V winding connection of the Anode / Screen transformer. This then means that the relay will operate if either the Anode or the Screen circuits become overloaded or if both become overloaded at the same time or have a combined current that is enough to trip the relay. The relay has a resistance of 1.2Ω. For the highest current ranges, 180mA and 120mA, the relay is shunted with resistor R34 at 1.5Ω which results in only 56% of the current flowing through the relay. The current through the relay coil is calculated with the formula for current division through two resistances in parallel which results in the following calculation:

Relative current through relay coil then becomes:

$$R34 / (R34 + R_{relay}) = 1.5\Omega / (1.5\Omega + 1.2\Omega) \approx 56\%$$

The hold circuit for the relay consists of the diode D3, resistor R18 and capacitor C7, the power for the hold circuit is taken from the heater transformer and the relay contacts only breaks the mains voltage to the Anode / Screen / Grid volts transformer; so as long as the wall plug is connected and the power switch is on, the hold circuit will hold the relay. The relay has one extra pair of contacts that close when the relay is actuated, lighting the blue lamp, LP1, indicating "Over Current". This arrangement means that the valve still has the heater voltage connected!