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## **rdcRM User Manual**

### **Isolated RS-485 Ring Master**

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#### **1. Overview**

The RDC RS-485 Ring Master (rdcRM) allows a traditional Modbus network, with all its slaves, to be connected in a ring. This will create a self-healing ring where a single breakage point will not cause any slave to be unreachable by its Modbus Master (a DCS or PLC etc).

The device is designed specifically for using in industrial panel applications. It provides the following unique combination of features:

- ❑ 1 KV between all ports except between Master and Status port
- ❑ LED indicators for power, receive, fault and state indications.
- ❑ Detects segment where the ring is broken.
- ❑ Self-healing action when the ring is fixed.
- ❑ Expandable with a secondary Ring Master for redundancy in Normal mode (with one Modbus Master) or for Arbitration mode (with dual Modbus Masters)
- ❑ Monitors and provides ring diagnostics for troubleshooting in the field
- ❑ Wide power supply range (9 to 36 Vdc).
- ❑ Compact, lightweight with din-rail mount support
- ❑ Easy-to-use Windows Based Configuration GUI

Note : This user manual assumes that the reader has sufficient working knowledge on the operation of RS-485 in 2-wire mode, its grounding as well as Modbus RTU.

## 2. Description

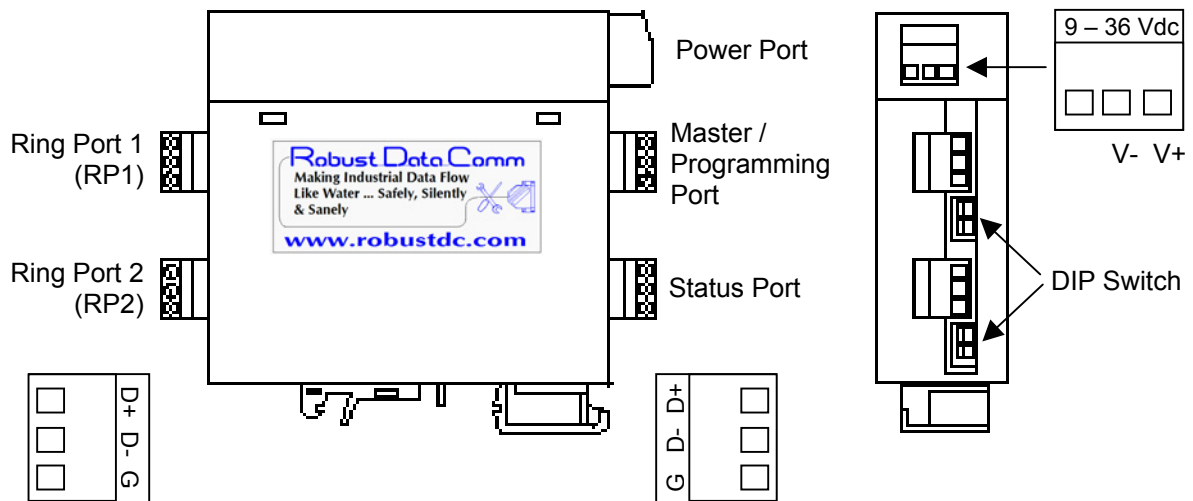


Figure 1 : Description of the rdcRM

As shown in Figure 1 above, there are 5 connectable ports on the rdcRM. One of them is a Power Port that draws 9 to 36 Vdc from a DC power supply while the remaining four are RS-485 ports that operate on 2-wire mode only. There are also 4 DIP switches that can be used to enable / disable the biasing of the RS-485 lines. These are enabled by default.

Note : although the 3-way screw terminals of the RS-485 ports are interchangeable, precaution must be taken against swapping the Ring Port connectors with those of the Master and Status Ports because they are labeled differently.



Figure 2 : Top label indicators

Figure 2 on the left shows the available indicators on the rdcRM for rapid troubleshooting.

The Power LED will remain a solid green when power to the rdcRM is stable.

All “RX” indicators (yellow) imply that there is data entering the port.

The Program button is used to tell the rdcRM to run in “Program Mode”.

The Fault LED (red), when solid red, implies that a ring fault has occurred. If it flashes instead, a bad Modbus packet has been received from one of the “RX” ports.

The State LED (yellow) operates differently between Normal Mode and Arbitration Mode and is dependent on the number of Modbus Masters (MM) that will be accessing the ring.

In Normal Mode, there can be 1 or 2 rdcRMs. But for Arbitration Mode, there must be 2 rdcRMs. Whenever 2 rdcRMs are used, one of them must be configured as a Ring Master while the other must be configured as a Ring Assistant.

If there is going to be 1 MM only, then either Mode is fine. For redundancy however, use 2 rdcRMs in Normal Mode.

If 2 MMs are required to access the ring, then Arbitration Mode is required.

See Table 1 below for the various blinking rates of the State LED in different operating Modes.

Mode	Single rdcRM	Dual rdcRM		
		RM & RA Operational	Only RM Operational	Only RA Operational
Normal	Blinks twice per sec	RM State LED always On. RA LED State blinks once every 1.5 secs	Blinks twice per sec	Blinks twice per sec
Arbitration	Always On	When both MMs are accessing the ring, the RM’s and RA’s State LEDs will alternate with each other.  (i.e. when the State LED of a rdcRM is On, it means that rdcRM is accessing the ring)	Always On	Always On

Table 1 : State LED indication

More details on configuring the rdcRM as a Ring Master / Assistant as well as the operating modes (Normal or Arbitration) will be given in Section 6.

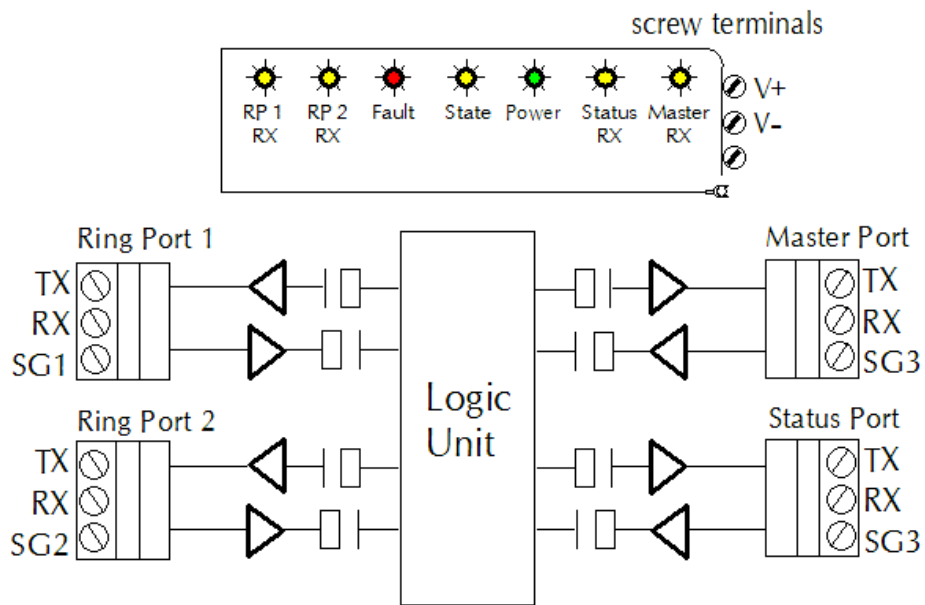


Figure 3 : Isolation within the rdcRM

The rdcRM is built with a 4-way isolation design, hence there are 4 isolated grounds :

- a) V- for power ground
- b) SG1 for Ring Port 1 (RP1) ground
- c) SG2 for Ring Port 2 (RP2) ground
- d) SG3 for Master Port and Status Port ground

There is 1 KV of isolation between all 4 grounds.

For proper operation,

1. Ensure that between 9 to 36 Vdc are supplied to the power port's V+ and V- terminals.
2. Ensure that the start of the ring begins at RP1 and ends at RP2.
3. Ensure that the Master Port is connected to a MM.
4. Ensure that the Status port is connected to the other rdcRM if more than 1 rdcRM is used.
5. Ensure that the ring ports RP1 and RP2 are multi-dropped to the other rdcRM if more than 1 rdcRM is used. (i.e. RP1 to RP1, RP2 to RP2)
6. Add terminating resistors (not provided) at the start and end of the RS-485 line (which should be at RP1 and RP2) to reduce signal reflections. (Normally 120  $\Omega$  to 150  $\Omega$ .)

From a communication standpoint, the rdcRM is a Modbus addressable device. Internally, there are 18 word-sized registers that can be polled for diagnostic purposes as shown in Table 2 below.

Address	Description	Explanation	Remarks
1	Ring Break Start	First Slave ID where ring fault is detected. "0" implies no fault in the ring.	Not writable.
2	Ring Break End	Second Slave ID where ring fault is detected. "0" implies no fault in the ring.	Not writable.
3	Master Available	"1" implies Ring Master is detected, "0" otherwise.  This implies the Ring Master is operational in both Normal and Arbitration modes.	Not writable.
4	Assistant Available	"1" implies Ring Assistant is detected, "0" otherwise.  In Normal mode, this implies the Ring Assistant is on hot-standby.  In Arbitration mode, this implies the Ring Assistant is also operational.	Not writable.
5	Major Firmware Version	Not used in Normal mode. In Arbitration mode, it implies that the Ring Master has the "right to access the ring."	Not writable.
6	Minor Firmware Version	Not used in Normal mode. In Arbitration mode, it implies that the Ring Assistant has the "right to access the ring."	Not writable.

Table 2 : Internal registers of the rdcRM (Continued on next page)

Address	Description	Explanation	Remarks
7	Ring Timeout	Maximum time (ms) for the Ring Master to wait for a response in the ring before timing out and sending the Modbus Query in the opposite direction.	Recommended to set to 2 times of the slave that takes the longest to respond. Minimum value is 250 ms.
8	Master Fail Count	Cumulative failures on the Ring Master.	Recommended to clear this registers to 0 after a fault has been rectified.
9	Assistant Fail Count	Cumulative failures on the Ring Assistant.	
10	Ring Break Count	Cumulative ring faults.	
11	RM Master Side Error Count	Cumulative error packets received on the Master port of the Ring Master.	
12	RM Last Master Side Error	Last type of error that occurred on the Master port of the Ring Master. (See Table 2 for error codes)	
13	RM Ring Side Error Count	Cumulative error packets received on the Ring port of the Ring Master.	
14	RM Last Ring Side Error	Last type of error that occurred on the Ring port Ring Master. (See Table 2 for error codes)	
15	RA Master Side Error Count	Same as memory locations 11 to 14 but applied to the Ring Assistant	
16	RA Last Master Side Error		
17	RA Ring Side Error Count		
18	RA Last Ring Side Error		

Table 2 : Internal registers of the rdcRM (Continued)

No	Description	Error Codes		Remarks
		Hex	Decimal	
1	RESPONSETIMEOUT	0xC3	195	No response from any slave. (Ring side)
2	CRCFAILED	0xC4	196	Bad CRC received on any RS-485 port.
3	MESSAGELENGTHISSUE	0xC6	198	Partial loss of bytes in packets received on any RS-485 port.
4	UNKNOWNSLAVEID	0xCA	202	ID in query packet received via Master Port is not pre-programmed in the rdcRM.

Table 3 : Error codes in the rdcRM internal registers

Out of 18 internal registers, the first 6 are read-only while the remaining 12 are readable/writable.

Only Modbus function codes 0x03 (Register Read), 0x06 (Single Register Write) and 0x10 (Multiple Register Writes) are supported when accessing the internal memory of the rdcRM.

### 3. Basic Setup and Operation

As previously mentioned, the rdcRM allows a traditional Modbus network to be wired up as a Ring. Consider the example RS-485 network in Figure 4 below.

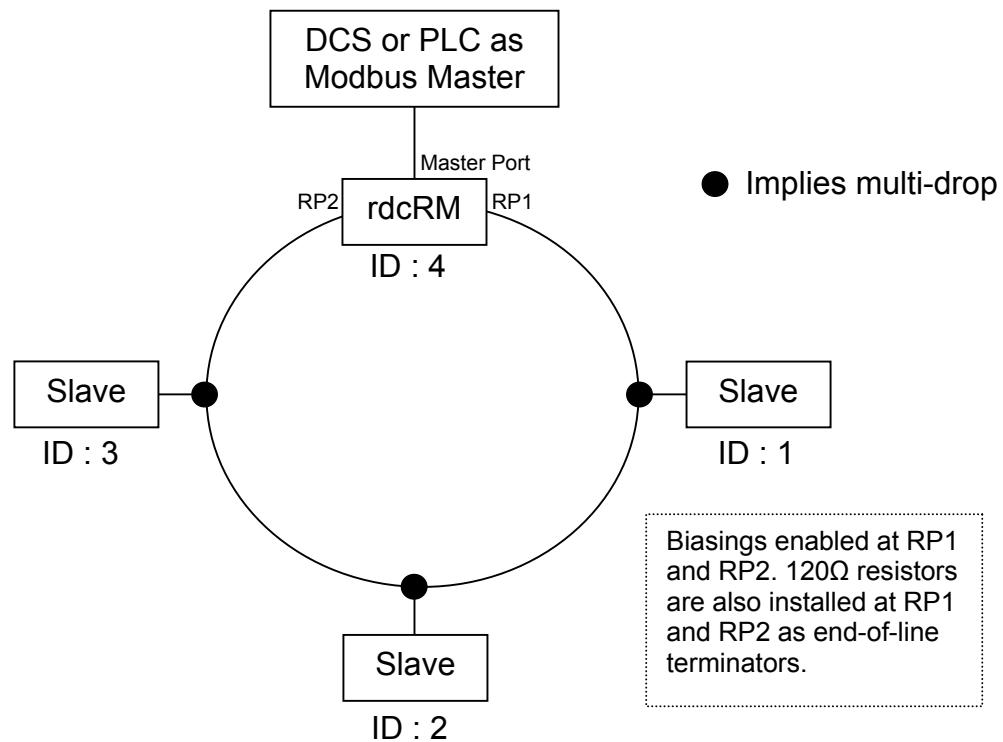


Figure 4 : Basic Setup (Example)

The rdcRM must be pre-programmed with the actual number of slaves, their corresponding IDs as well as their positions in the ring, in addition to the serial port parameters. More details on configuring the rdcRM will be described in Section 6.

The main function of the rdcRM is to divert the flow of a Modbus query should a line fault occur in the ring. Note that the RM does not initiate any polling at all. All polls must be initiated by a device that acts as a Modbus Master (MM).

So, let us assume that the DCS polls in the following sequence : ID-1 to ID-4 then back to ID-1 and so on.

When the rdcRM (ID-4) is being polled, it will respond accordingly when the supported function codes are used. Otherwise, a Modbus Error Exception (0x81) will be returned to the MM.

When a packet containing a slave ID other than the rdcRM's own is being received from its Master Port, then the rdcRM will determine if that slave ID is in its pre-programmed list. The packet will be allowed to pass through if and only if, the slave ID in the packet is in the rdcRM's pre-programmed list. Otherwise, the "RM Master Side Error Count" will be increased by 1 and the last error would be UNKNOWNSLAVEID (0xCA). The MM would not get back any response and the result would be a timeout to the MM.

The rdcRM will always send out a query packet via RP1 (Ring Port 1) first. Only when it fails to get a response via RP1 (i.e. RP1 times out) will it try RP2 (Ring Port 2). By then, it will stick to RP2 until the ring is fixed. Obviously, when no response is received via both RP1 and RP2, the MM would timeout. The rdcRM would also increase its "RM Master Side Error Count" by 1 and the last error would be RESPONSETIMEOUT (0xC3). Thereby indicating that there could be more than 1 fault in the ring, the slave is offline, or the ring timeout setting is too short.

The advantages of this setup are :

- a) Line Redundancy  
When a line break occurs along any part of the ring, the rdcRM will re-send the Modbus query in the opposite direction, thereby ensuring that all slaves can still be polled.
- b) Fault Identification  
If a line fault occurs between 2 slaves, the rdcRM is able to identify that segment providing the ID of the 2 slaves.
- c) Self-healing Ring  
When a line fault is fixed, the rdcRM automatically resumes the forwarding of query packets via RP1. Thereby making sure that the ring redundancy is still available when needed.

Note : The ring status will be updated if the MM polls the slaves continuously. If the polling stops for any reason, some of the status registers (Master / Assistant available, Ring Break Start / End etc) will not be updated.

With this basic setup, it is recommended to configure the rdcRM as a Ring Master. Hence, any register pertaining to the Ring Assistant has no meaning.



#### 4. Advanced Setup and Operation : Normal Mode

Although the basic setup as previously shown in Figure 3 provides line redundancy, the rdcRM can still be considered a potential single point of failure when accessing the ring. To eliminate this problem, a second rdcRM can be added to the ring as shown in Figure 4 below.

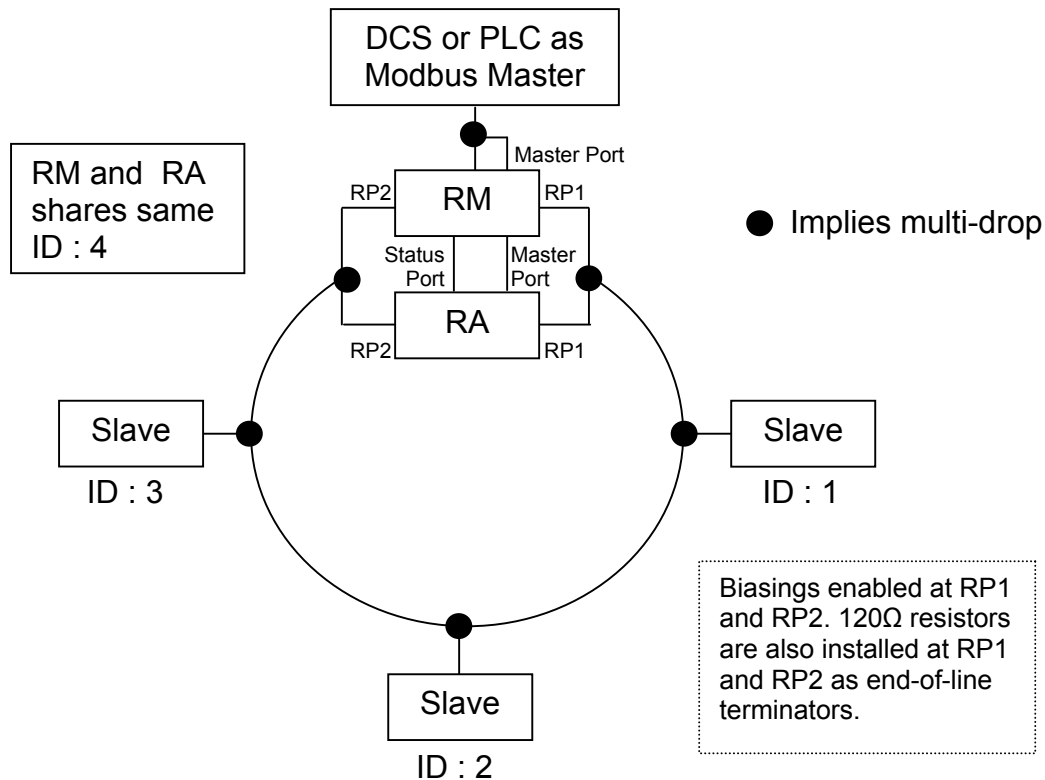


Figure 4 : Advanced Setup with redundant rdcRM in Normal Mode (Example)

In this setup, all communication ports of both rdcRMs are in use. With 2 rdcRMs, one of them must be configured as a Ring Master while the other, as a Ring Assistant. The Status Ports of both rdcRMs must be connected to each other for “syncing” purposes. Both Master Ports of the rdcRMs are multi-dropped to the MM.

Now, all 18 registers in Table 2 would apply to both rdcRMs and the single point of failure from accessing the ring is eliminated.

Note : Failure to connect the Status Ports would cause both rdcRMs to access the ring simultaneously and will cause numerous communication faults in the ring.

## 5. Advanced Setup and Operation : Arbitration Mode

In some cases, dual MMs need to be updated with information from the ring. Therefore, the rdcRMs can be configured as shown in Figure 5 below.

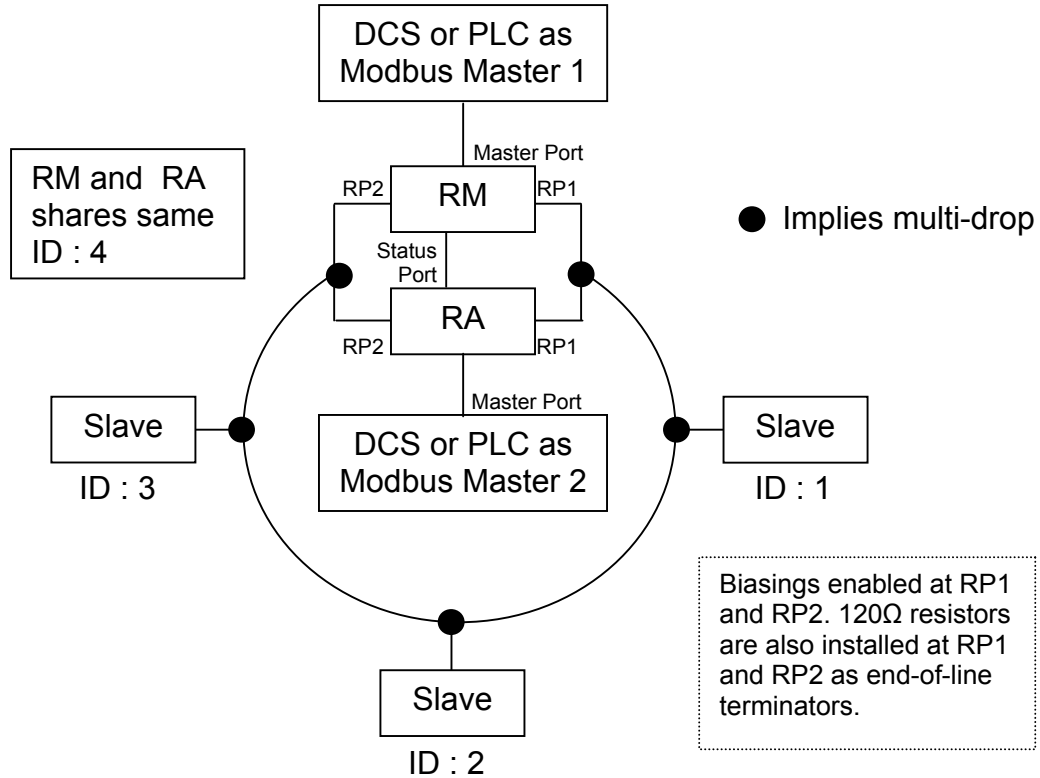


Figure 5 : Advanced Setup with redundant rdcRM in Arbitration Mode (Example)

The physical connection for 2 rdcRMs is almost identical between Normal and Arbitration Mode except that the Master Ports of the rdcRMs are connected to their individual MMs. This way, both MMs will take turns to access the ring.

Note : Failure to connect the Status Ports would cause both rdcRMs to access the ring simultaneously and will cause numerous communication faults in the ring.

## 6. Configuration

In order for the Ring Master to manage the ring effectively, it needs to know how the slaves are connected as shown in Figure 6 below.

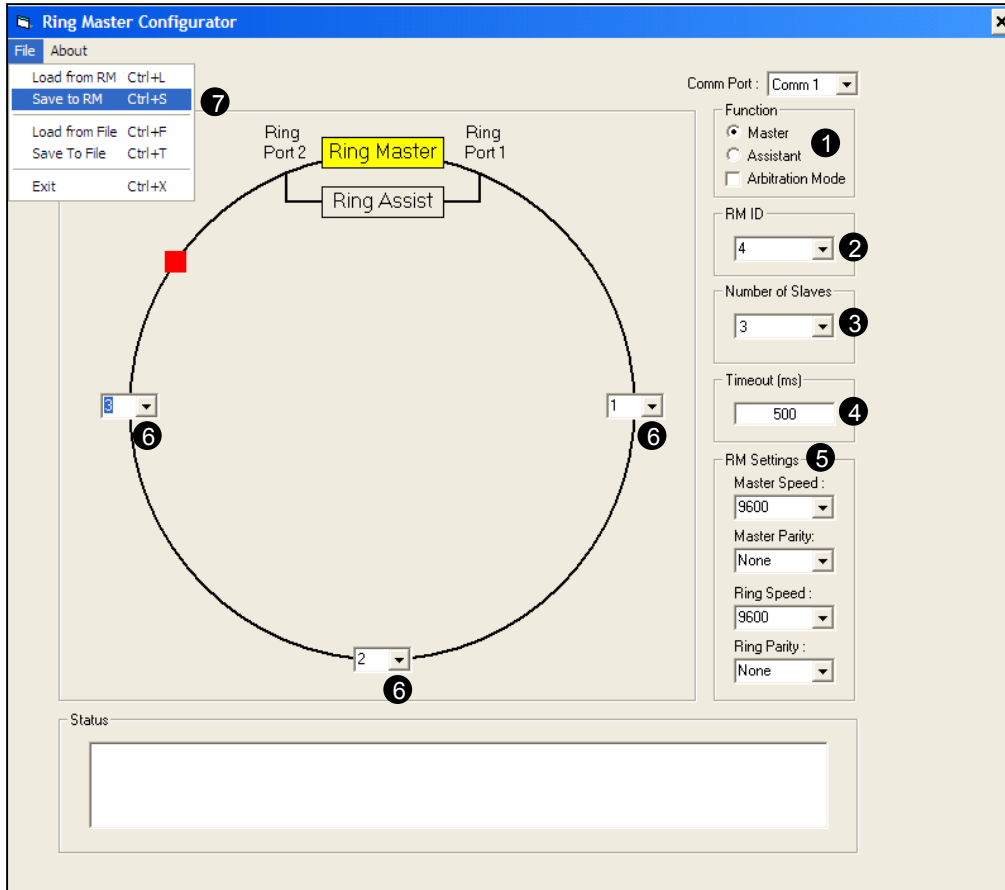


Figure 6 : Configuring the Ring Master

The rdcRM must be “forced” into Program Mode before it can be configured. To do that, power cycle the rdcRM, wait for the Fault LED to turn on (red) and press (and release) the Program button. By then, the Fault LED should be flashing once per second to show that the rdcRM is in “Program Mode”.

Make sure there is an available comm port for the Ring Master Configurator Program on the PC and connect it to the programming port of the rdcRM.

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After running the Ring Master Configurator program,

1. Select Function of Ring Master – either Ring Master or Ring Assistant and whether Arbitration Mode is required (Default = not required).
2. Select a unique ID for Ring Master / Assistant.
3. Select the number of slaves to be managed in the ring.
4. Select the response timeout. The rdcRM will wait this long before resending a Modbus via RP2.
5. Configure the rdcRM's serial parameters on both the Master Port side as well as the Ring side.
6. Set the IDs of the slaves in the ring. These IDs must be unique and must not be the same as the rdcRM's ID.
7. Save the settings to the Ring Master. (Remember to select the correct comm port that is connecting the PC to the rdcRM.)

For convenience, the settings of the rdcRM can be saved / retrieved to / from a file as well.

After the settings are saved, the rdcRM must be power cycled so that it can be returned to a Running Mode.

Note : The RM and RA must share the same ID. If a RM and RA is required, it is recommended to configure and program the RM first. Then change setting number 1 to "Assistant" and program the RA. This way, both RM and RA will definitely be properly paired with each other. Failure to do so would cause unpredictable results.

## 7. Performance of the rdcRM

RDC has the following definitions :

Ring Fault Detection Time - Measured from the time the fault has occurred, to the time it takes for the rdcRM to be updated.

Ring Recovery Time - Measured from the time the fault has been rectified, to the time it takes for the rdcRM to be updated.

Ring Fault Indication Time - Measured from the time the fault has occurred, to the time it takes for the rdcRM to pinpoint the fault segment in the ring.

With the above 2 definitions in mind, the prominence of the ring timeout setting in the rdcRM's internal registers (See Table 2 for details) can be emphasized.

The ring timeout is defined as the maximum amount of time that the rdcRM will wait for a response to come back from a slave device. When that time is exceeded, the rdcRM will re-send the Modbus query using RP2 and again, will wait for the same amount of time for the response.

So clearly, the Ring Fault Detection time is equal to the ring timeout setting.

The Ring Recovery Time is typically less than 100 ms and is independent of the number of slave devices.

Due RDC's proprietary algorithm, the Ring Fault Indication Time (RFIT) is dependent on the ring timeout setting as well as the number of slaves in the ring. Therefore,

$$\text{RFIT}_{(\text{worst case})} = (\text{Number of slaves}) \times (\text{ring timeout in ms}) \times 2 \dots \dots \dots (\text{Eq. 1})$$

Although it is tempting to set the ring timeout to a smaller value, it all depends on the response time of the slave devices. Normally, it is a good practice to set the ring timeout to twice that of the slave that takes the longest time to respond, and to set the timeout of the MM to twice the ring timeout. This is done to prevent recurring timeouts when using a single MM.

In Arbitration Mode, MMs take turns to access the ring. Therefore it is advisable to further double the timeout value on both MMs.

TIP : The ring timeout value can be changed on the fly. So as not to compromise the ring's fault detection / indication performance, this value can be increased when performing writes to the slaves, and reduced to its original value when writes are no longer required.

## 8. Troubleshooting

Table 4 below describes some of the common issues that could occur after the rdcRM is configured for the first time.

No	Problems	Possible Cause(s)	Solution(s)
1.	Modbus queries are not being forwarded to the ring.	<ul style="list-style-type: none"> <li>The ID of the slave device in the ring has not been programmed in the rdcRM.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Use the rdcRM Configurator program to add that slave ID to the rdcRM's list of slaves in the ring.</li> </ul>
		<ul style="list-style-type: none"> <li>The serial settings of the MM and the rdcRM are not identical.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Use the rdcRM Configurator program to match the serial settings of the rdcRM to that of the MM's.</li> </ul>
		<ul style="list-style-type: none"> <li>Only the ring status registers are being polled thus these queries will not be forwarded into the ring.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Make the MM poll a slave device in the ring</li> </ul>
2.	The Fault LED is always On.	<ul style="list-style-type: none"> <li>The ring is broken; there is a line break in the ring.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Ensure that the RS-485 lines are multi-dropped from RP1 and end at RP2.</li> </ul>
3.	The ring break start and end registers fluctuate between slave IDs when a ring fault occurs.	<ul style="list-style-type: none"> <li>The rdcRM is still in the process of pinpointing the faulty line segment.</li> </ul>	<ul style="list-style-type: none"> <li>✓ The rdcRM requires a certain amount of time to determine the faulty segment as calculated in (Eq.1) in Section 7.</li> </ul>
4.	2 rdcRMs cannot seem to work with each other. They can work individually but not together.	<ul style="list-style-type: none"> <li>The RM and RA settings are not correctly set.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Use the rdcRM Configurator program to ensure that the settings of the RM and RA are identical, except for the part that states their function (i.e. Master or Assistant)</li> </ul>
		<ul style="list-style-type: none"> <li>The Status Ports of the RM and RA are not connected or not correctly wired to each other.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Ensure that the Status Ports of the RM and RA are correctly wired to each other at all times.</li> </ul>
		<ul style="list-style-type: none"> <li>The ring ports of the RM and RA are not correctly wired to each other.</li> </ul>	<ul style="list-style-type: none"> <li>✓ Ensure that the ports on the ring side are correctly multi-dropped to each other. (i.e. RP1 to RP1, RP2 to RP2)</li> </ul>

Table 4 : Common issues with the rdcRM

## 9. Technical Specifications

Interface : 2-wire RS-485 (D+, D-, SG)

Connectors : 3-way removable screw terminals

### Power Supply

Operating Voltage : 9 to 36 Vdc

Max Power : 2.4 W Max (24 Vdc @ 100 mA)

User Indications : Green LED for main power supply

### Isolation

Between all ports : 1 KV except Master and Status Port

### Communication

Maximum Speed : Up to 115 kbps

Character Setting : 8,N,1

User Indications : Yellow LED indicators for RS-485 ports

: Yellow LED for State indication

: Red LED for Fault indication

Practical Distance : 2 km with good quality cable (Cap < 50 pF/m)

### Environmental

Operating Temp : -40C to +65C

Storage Temp : -40C to +100C

Relative Humidity : 10-90%, non condensing

Casing : nylon polyimide, fungus and termite resistant

: self-extinguishing per UL 94 V2

### Mechanical Dimensions

Height, Width, Depth : (See drawing)

Weight : Approx.: 130g

Terminal Capacity : 2.5mm(12AWG)

Mounting Rail : DIN EN 50022 (35mm sym)

: DIN EN 50025 (32mm sym)

: Note: removal from a DIN EN50025 rail is difficult.

