Data Access Arrangement Design for Low Speed Modems

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Preface

The following report is the result of a research project at Softart Microsystems Inc. This report was written to provide information and guidance for the development of data access arrangements and assumes the reader has some prior knowledge of modems and electronics. Although the appropriate tests have been conducted, the design presented in this report has not been formally certified. Softart Microsystems Inc. takes no responsibility as to the use of the information herein. Any end design must be formally certified before being offered for sale in a product.

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Summary

The purpose of this report is to investigate the data access arrangement design of a low speed, low cost modem. Since these devices are common in systems such as set-top boxes and credit card terminals, data access arrangement design remains important. The data access arrangement must be as cost effective as possible while retaining the ability to meet the standards of the target market. The DAA design presented in this report was derived from one presented in an application note published by Midcom Inc. [11]. Several improvements to the data access arrangement are suggested. The designer will also need to investigate all aspects of modem design in order to implement a successful design.

After a brief introduction to the layout of a modem, the data access arrangement will be explained. Each of the three main areas, the line interface, the important features, and the transformer will be investigated for areas of improvement. All changes are verified by the test results that follow the investigation.

The investigation and testing leads to several conclusions and recommendations:

- Data access arrangements based on wet transformers, with the help of additional circuitry, can now be designed to meet both FCC part 68 and CTR 21, and provide the most cost-effective solution.

- A much cheaper RC network can replace the relay often used for caller ID signal reception.

- Finally, the mechanical relay could be replaced with an optical device.

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1 Introduction

The field of telecommunications is laden with new technologies. Better and faster solutions keep emerging. In this rapidly developing field, it would seem that older technologies would quickly become obsolete and rendered useless. This is not the case. Older and slower technologies have advantages over the newer methods of data transfer. Modem technology is a good example of a situation where it is not always the best choice to go with the newest and fastest technology available. Low speed modems can connect faster than then high-speed modems due to their simpler protocols. This is important in devices such as credit card terminals or set-top boxes where there is not a lot of data to transmit. Overall transmission speed is not as important as the time it takes for the device to connect with another modem. Another advantage to using mature solutions is that this technology tends to be more cost effective. Since many devices such as credit card terminals and set-top boxes are produced in large numbers with small profit margins, any costs that can be reduced are translated into greater profits.

Since cost reduction is important, examining and evaluating the designs of mature technology is important. For this reason, this report will evaluate and suggest a Data Access Arrangement (DAA) that can be implemented on low speed, cost efficient modems.

2 Modem Structure

To further introduce the DAA, the makeup of a modem will be presented. A modem can be divided into 4 distinct parts the DAA, the DSP, the microcontroller, and the host interface as shown in figure 1, below.

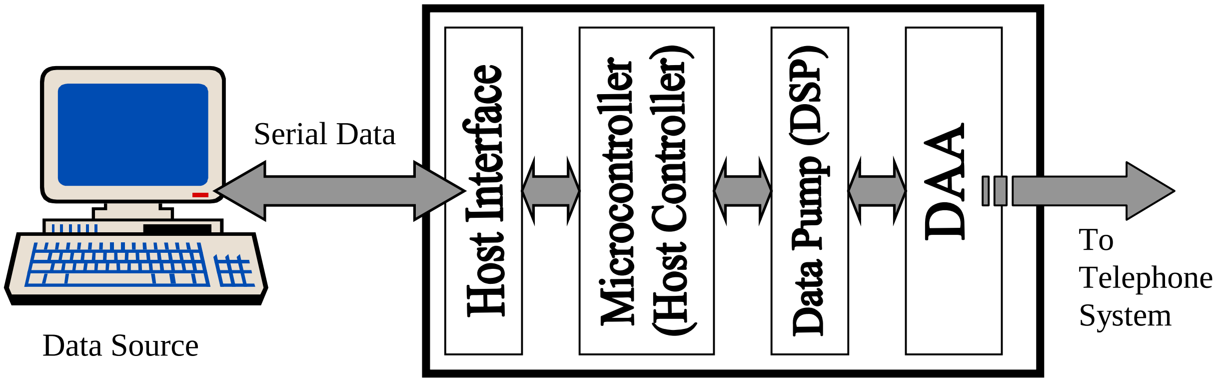

Figure 1: Typical Layout of a Modem

The host interface is the circuitry used to connect the source of the data with the modem. In a typical computer, the computer interfaces to the modem through a serial port. Data is sent and received through this interface by the microcontroller. Incoming data from the computer is received by the microcontroller and is processed. The microcontroller creates packets from the data, according to the protocol it is using, and sends the data to the DSP. In the other direction, the microcontroller receives packets of data from the DSP, extracts the data, and sends it to the computer. The DSP coverts the packets bit by bit into analog signals to be sent over the telephone lines. It also converts incoming analog signals to digital form to be processed by the microcontroller. Finally, the DAA is used to interface with the telephone lines. All analog signals are sent and received through the DAA. It provides electrical isolation between the DSP and the outside lines. The design of the

DAA must meet various governmental and safety standards. In North America, FCC Part 68 specifies the standards a modem must conform to, while in Europe ETSI CTR 21 is used.

3 DAA Design

3.1 Introduction to DAA Design

An important aspect of low cost, low speed modem design is the design of the DAA. The DAA is the interface between the modem's DSP and the phone line. It is used to isolate the telephone system and the modem, as well as providing additional features such as such as CID and ring detection. A DAA must be designed to conform to the standards of its target market, such as CTR 21 or FCC Part 68. To meet these standards and remain cost effective, the DAA must be properly designed.

There are two main approaches to DAA design, using a transformer-based design or using an optical-based design. Both methods are used to provide isolation between the modem and the telephone equipment. The older and more widely used approach is to use a transformer-based design. Optical DAAs use newer, silicon-based products that use optical coupling techniques to provide electrical isolation between the telephone lines and the modem. An example of an optical DAA is CP Clare's LITELINK^{TM} chipset.

A transformer-based DAA can either be designed around a wet or a dry transformer. The type of transformer will determine the rest of the DAA design, and to what specifications it will meet. Wet and dry transformers have one significant difference; a wet transformer is designed to carry DC current while a dry transformer cannot allow DC current to pass. Due to a wet transformer's ability to carry DC current, a DAA based on wet transformer is much easier to implement. A dry transformer requires additional circuitry to facilitate the flow of current. This is called a loop holding coil.

While designing a DAA based on optical components provides improved isolation over transformers, as well as consuming less space on a printed circuit board (PCB), the cost of such a solution still limits its use. Transformers, such as those from Midcom, still provide the most cost effective design, and can pass standards such as CTR 21 and FCC Part 68 if properly designed. For example, in quantities of 10k, CP Clare's CPC5600A CP Clare's LITELINK^{TM} DAA costs \$4.86 in US dollars. This price is much more than the cost of Midcom's 82107 transformer in quantities of 10k, which is \$0.67 in US dollars. Both solutions require additional components, but for each solution the supporting components tend to have a similar total cost. Since cost is the important driving factor in low speed modem design, a transformer-based DAA will be investigated, as opposed to the more expensive optical DAA. The design of a DAA can be grouped into several key areas. First, the DAA must provide the ability for the modem to be connected to the telephone line through a standard connector. Along with this connection comes the requirement for the DAA to protect itself and the rest of the modem against electrical surges and other transients. Following the line interface is where features such as ring detection and CID are included. After the special features, the transformer is placed in the circuit to provide isolation between the phone lines and the modem equipment. In conjunction with the transformer, components are required between the transformer and the data pump, or digital signal processor (DSP), to produce the required impedance on the line and, if required, a hybrid circuit to separate the transmit and receive signals. All of these components make up the DAA that allows the modem to transmit and receive signals to and from the data pump over the telephone lines. These three areas, which will be dealt with in more depth below, are outlined in figure 2 [1].

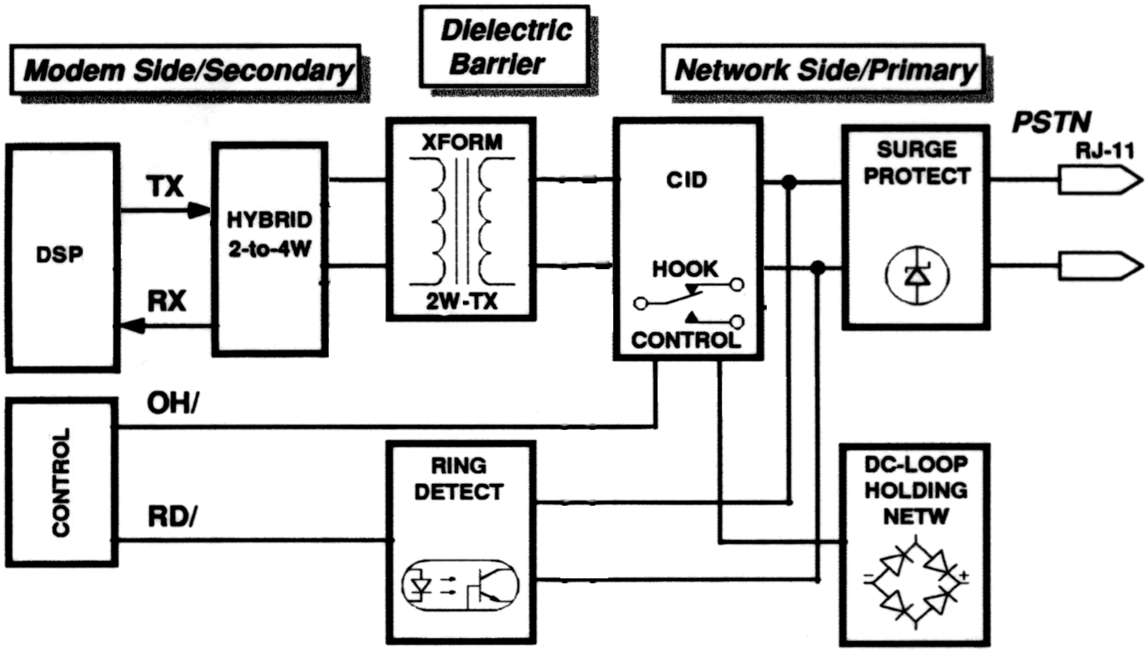

Figure 2: The Layout of a Data Access Arrangement

3.2 <u>The Line Interface</u>

To allow the modem to connect to the telephone system, the DAA must have a line interface. The schematic in figure 3 shows a typical line interface for a DAA.

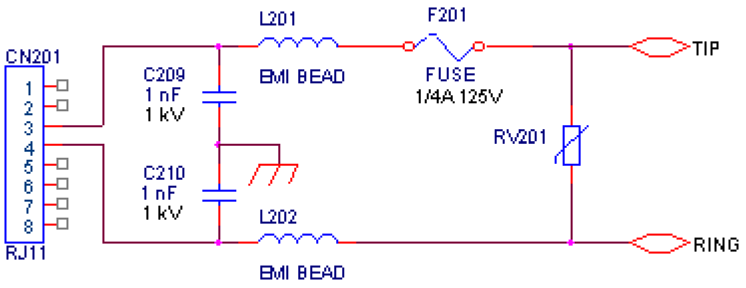

Figure 3: Typical Line Interface

This line interface begins with a standard RJ-11 jack. This requirement is outlined further in CTR 21, section 4.2 [2] or in FCC Part 68.500 [3]. This type of connector will allow the equipment to be connected through standard wiring.

Ferrite beads are inserted on tip and ring, immediately following the connector. These are used to prevent EMI noise from leaving the device and being sent over the phone cables. The value of the ferrite beads must be chosen to block the radiation being emitted by the device, which will often depend on clock signals and other rapidly changing signals.

Protection circuitry must also be added to the line interface of the DAA. Often a fuse will be inserted before one of the ferrite beads. This fuse will provide over-current protection, and insure an off-hook state if the fuse should blow. Other components should also be inserted to protect the device from surges and transient signals. As shown in figure 3, across tip and ring, a transient/surge absorber, or varistor is inserted to protect the device from differential surges. The value of this device must be chosen carefully though so that it does not affect the normal operation of the device. Under FCC 68.312, the maximum voltage used to test the device will be no greater than a 150 Vrms wave superimposed on

56.5 Vdc or approximate peak voltage of 269 V [4]. Under CTR 21, the maximum voltage that is applied during testing is 90 Vrms superimposed on 60 Vdc or a peak voltage of approximately 187 V [5]. Therefore any device that clamps during spikes must not activate at or below this voltage. The two 1 nf capacitors shown in figure 3 are used to guard against common mode surges. The capacitors are used to ensure product safety, earth ground routing and shock prevention. [6]

3.3 Important Features

Between the line interface and the isolation transformer is where the modem designer can add functionality to the modem. The feature set of a basic, low speed, low cost modem is usually limited to save costs, but several features are important. An essential feature is providing the modem with the ability to go off-hook to place and answer calls. Another important feature is the ability to detect incoming ring signals. Furthermore, circuitry can be added to allow the modem to detect and receive CID signals. The following schematic in figure 4 shows how these three features are implemented.

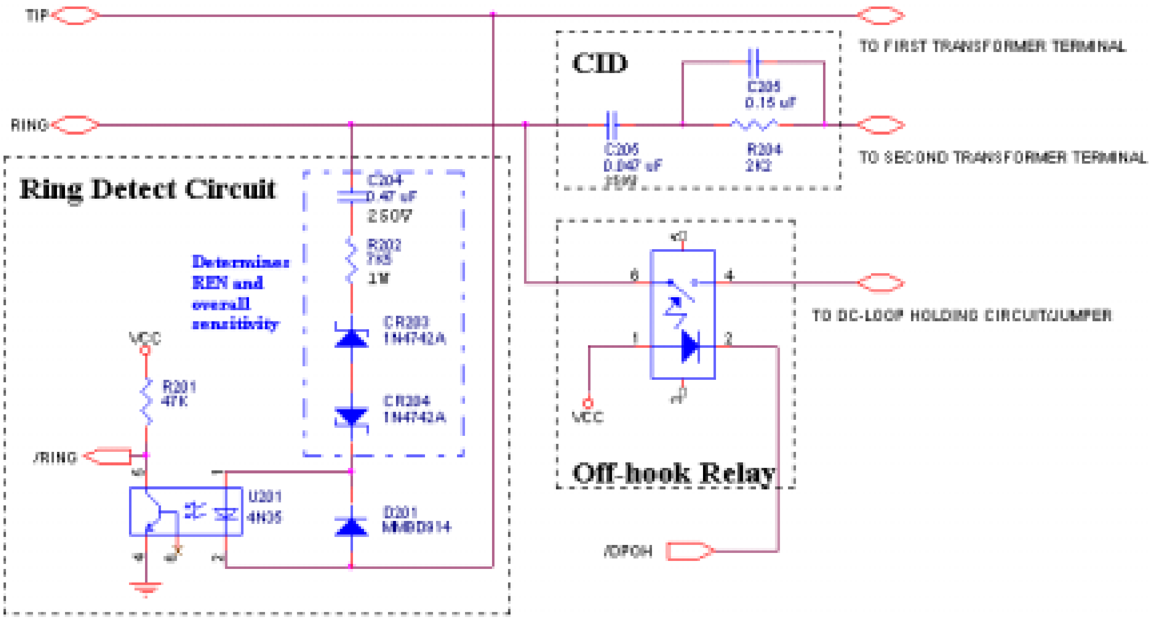

Figure 4: Schematic of a Modem's Features

The simplest way to allow a modem to be taken off hook is to use a mechanical relay. This relay is controlled by the modem's microcontroller and either is an open circuit when the modem is on-hook or a short-circuit when off-hook. Using a relay allows the DAA to easily meet minimum on-hook impedance requirements, since it is an open circuit. The relay is a good choice when the modem is off-hook since it presents very little resistance to the incoming signals. The main disadvantage of a mechanical relay is its high cost, which contributes a major portion to the overall cost of the DAA. Therefore, a cheaper alternative, such as a solid-state relay or a darlington photocoupler, can be used. The problem with this approach is that these devices provide less than ideal results with regard to their impedance. For this reason, more care is needed during design to insure that the impedance specifications of CTR 21 and FCC part 68 are met.

Another important feature is the ability for the modem to detect a ring signal. The ring detect circuit is connected across the incoming phone line. Due to this, the ring detect circuit must not cause the impedance of DAA to drop below acceptable limits during ringing. Capacitors are inserted in the circuit to prevent DC current from passing through the circuit. It is important that DC current does not pass, since this would indicate to the telephone system that the device has connected to the line. The goal of the ring detect circuit is to send a signal to microcontroller indicating that an incoming ringing signal is being received. The microcontroller then has the option of taking the modem off-hook and answering the call. The circuit that was shown in figure 4 will produce a series of pulses as the ringing signal, a sinusoidal AC source between 25Hz and 50Hz for CTR 21 or 15.3Hz and 68Hz for FCC part 68, is received. An optoisolator is used to isolate the microcontroller from the incoming line. To insure proper isolation, a 4N35 optoisolator with a rated isolation voltage of 3550 V is recommended. To insure balanced loading of the Telco ring generator, back-to-back zener diodes are used. The resistor, capacitor, and back-to-back zener diodes, in series, will determine the overall sensitivity of the ring detect circuit, as well as the Ring Equivalence Number (REN) as outlined by FCC Part 68.312(d) [4]. As shown by figure 4, the resistor used has a high power rating and the capacitor has a high voltage rating to account for the range of possible ringing voltages and frequencies. A diode positioned in the opposite direction as the internal diode of the optoisolator is used to allow the AC current, traveling in the reverse direction, to pass without damaging the optoisolator. Therefore, the combination of the optoisolator and the diode will create a series of pulses that will be sent to the microcontroller to indicate ringing. The frequency of the pulses will be the same frequency as the ring signal.

Another common feature is CID detection. In the U.S. CID signals are made using Bell 202 FSK signaling transmitted at –13 dB, using 1200 Hz and 2200 Hz signals for marks and spaces respectively sent between the first and second rings. These signals can be received by using another relay, either mechanical or optical. Again, it is important to restrict DC current flow. Therefore, one approach would be to ‘borrow’ the capacitor from the ring detect circuitry, by connecting on terminal of the relay between the capacitor and the resistor. The other terminal is connected to the transformer, around the off-hook relay. Thus, between rings, the controller can close the relay and receive the CID signals through the normal receive path to the DSP. The problem with this method is that another relay, whether it is mechanical or optical, is required. Instead, a circuit to receive the CID signal can be designed using an RC network or filter to allow CID signals to pass, but still provide a high impedance during ringing. This means that the RC network must provide high attenuation to the low frequency ringing signal, while allowing the CID signals, at 1200Hz and 2400Hz, to pass. This RC network is shown in figure 4, across the off-hook relay. This position insures that the RC network will not affect the operation of the modem when it is off-hook because the relay will place a short circuit around the components. Therefore, the impedance of the network is important when the modem is on-hook, at ringing frequencies and at CID frequencies. Since FCC Part 68 requires the impedance between tip and ring to be between 1.6 kΩ and 40 kΩ [4] and CTR 21, section 4.4.2.1, requires the impedance to exceed 4 kΩ [7], while the Canadian DOC CS-03 regulation requires a minimum resistance of 2 kΩ at 1660 Hz, a resistor of at least 2.2K is required. This resistor then causes problems at CID frequencies, since the combination of it and the series shunt capacitor forms a low pass RC filter. To remove this resistance, a second capacitor is placed in parallel with the resistor. This capacitor will have high impedance at low frequencies and thus the resistor will dominate the value of the impedance. At higher frequencies, the value of the capacitor should be chosen such that the impedance of the capacitor reduces quickly, and thus lowers the combined impedance of the resistor and capacitor. This will allow the CID signals to be sent to the DSP with very little attenuation, which is important since the modem should be able to receive incoming CID signals down to –30 dBm.

3.4 The Transformer

Another major design decision is whether to use a dry or wet transformer. As previously mentioned, the difference between a dry transformer and a wet transformer is that a dry transformer can not allow DC current to pass, while DC current may pass through a wet transformer. Since DC current must flow so that the telephone system knows that the modem is in the off-hook state, a DAA design using a dry transformer requires additional components, called a DC-loop holding circuit, to facilitate the flow of DC current. The purpose of the circuit is to appear as very high impedance to AC current and as low impedance to DC current. These additional components make a dry transformer solution more difficult and costly to implement. Additionally, a dry transformer costs more than a wet transformer, further increasing the cost of a dry transformer design. For these reasons, most modems destined for the North American market use wet transformers. Historically, the reason dry transformer designs have been used was to pass the many different standards used by European countries. Many of these standards specify return loss limits and current requirements that cannot be met by a wet transformer. With the introduction of CTR 21, a unified standard for European countries, combined with new transformer technology, it is now possible to use a wet transformer in a DAA design and meet CTR 21. Additional components are still required to meet the minimum current requirement specified in CTR 21, but the ability to use a wet transformer reduces cost. On top of this, it is very easy to design a DAA that can be used to meet CTR 21 and then use the same design, without populating the additional components, to meet FCC 68 requirements. Using a single design can reduce costs and simplify the manufacturing process. Figure 5 shows the wet transformer and its associated circuitry.

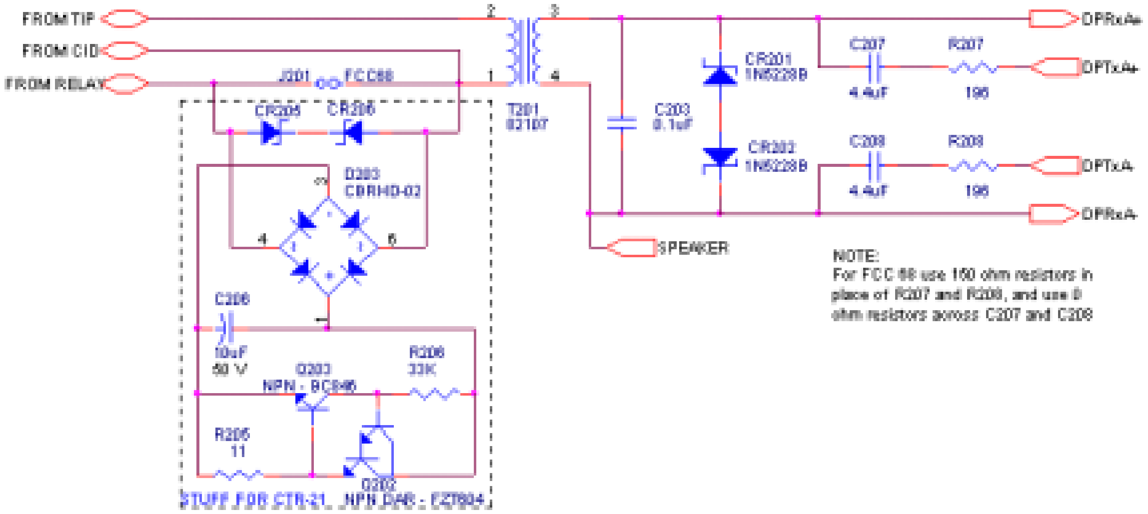

Figure 5: Wet Transformer with Additional Components to Meet CTR 21.

The dotted box shows the additional components needed to meet the minimum current draw requirement of CTR 21. These components are all located on the primary side of the transformer. The transformer used in this setup is Midcom's 82107 wet transformer, which is well suited for this type of circuit. This transformer was developed to make it possible to pass CTR 21 with a wet transformer. The additional circuit is similar to the DC-loop holding circuits used in dry transformer designs. Therefore, the advantage of this circuit is from the cost savings of using a wet transformer, and the ability to use the same board, populated differently, for FCC Part 68 compliant designs.

On the secondary side of the transformer a linearizing capacitor is added in parallel across the transformer's secondary terminals. This capacitor is used to counter-balance the some of the effects of the transformer such as insertion loss and leakage inductance differences. Following this capacitor, two back-to-back zener diodes are used as protection against surges. Depending on the DSP used, these diodes should be used to limit the voltage to between 3.1 and 5.1 volts.

Following the diodes are components used to attain the required impedance of the DAA, as specified by either FCC 68 or CTR 21. There is also the possibility of using an active hybrid network, using op-amps, to separate transmit and receive signals. For low cost, low speed modem designs, it is more cost effective to use a DSP that does not require an active hybrid network, such as Zilog's series of modem data pumps. Therefore, all that is required is the circuitry to match the impedance to its required value. For CTR-21 a 4.4µF capacitor and a 196Ω resistor in series will meet the requirement. For FCC Part

68, the capacitors can be replaced with 0Ω resistors, to short the pads, and 150Ω resistors should be used in place of the 196Ω resistors. Alternatively, a different combination of 2 resistors in series could be used, as long as they accurately add up to the required 150Ω value on both sides.

At this point, the DSP's transmit and receive lines are connected to the DAA, and the other control lines such as ring detect and the off-hook relay control are either connected to the DSP or the microcontroller depending on how these two components are implemented. Therefore, the DAA design, from the line to the DSP, is complete.

4 Testing the DAA

4.1 Overview of the Tests

Testing is an important part of completing a modem's DAA. The DAA must be tested while on-hook, during ringing, during the transition from the on-hook to the off-hook state, and while off-hook. The following results will demonstrate the measurements that should be expected from a DAA based on the design that has been developed and explained. Further tests will have to be performed on the modem as a whole to pass the complete CTR 21 or FCC Part 68 specifications. The tests included in this section are meant as a way to quickly verify the important properties of the DAA.

4.2 Testing Impedance

CTR 21 requires that the equipment cannot draw more current than a 1MΩ resistor. When using a 50 Vdc power supply connected to tip and ring, this translates to 50µA. Testing the CTR 21 DAA shows that only 5µA is drawn at 50V, easily within acceptable limits. FCC Part 68 requires at least 5 MΩ, which the 5µA measurement also meets.

During ringing the effects of the ring detect circuit and the CID circuit will become more predominant, since during DC current tests, the capacitors block DC current. CTR 21 requires that during ringing frequencies between 25Hz and 50Hz that the impedance of the device cannot drop below 4kΩ. As well, during ringing, the DC current should not exceed 0.6mA. The maximum DC current measured during ringing was 0.06mA, which is well below the maximum of 0.6mA. Table 1 shows the results of the AC impedance test. These results were obtained using the test as outlined in A.4.4.2.1 of CTR 21 [8].

Table 1: AC Impedance Test Results for CTR 21

Ringing Frequency	AC Current (ITE)	RMS Voltage (UTE)	Impedance (|ZRi|)
25 Hz	1.5 mA	28.1 V	18.7 kΩ
50 Hz	1.93 mA	27.2 V	14.1 kΩ

These results show that the DAA is easily above the 4kΩ minimum for impedance. As expected, at higher frequencies, the impedance of the DAA begins to drop. FCC Part 68 requires an impedance between 1.6kΩ and 40kΩ for ringing frequencies between 15.3Hz and 68Hz. Again, as table 2 demonstrates, the DAA passes the requirements.

Table 2: AC Impedance Test Results for FCC Part 68

Ringing Frequency	AC Current (ITE)	RMS Voltage (UTE)	Impedance (|ZRi|)
15.3 Hz	1.2 mA	28.8 V	24.0 kΩ
68.0 Hz	2.1 mA	27.1 V	12.9 kΩ

4.3 Testing Current and Voltage Characteristics

The next important tests investigate the current characteristics of the modem, as it makes the transition from the on-hook state to the off-hook state. Table 3 shows the measured and required values for CTR 21, section 4.6.2.

Table 3: Current Characteristics for CTR 21.

Feeding Voltage (Vf)	Feeding Resistance (Rf)	Current Measured	Minimum Current Required
50 Vdc	150 kΩ	0.32 mA	0.30 mA
50 Vdc	36 kΩ	1.32 mA	1.25 mA
50 Vdc	24 kΩ	1.95 mA	1.86 mA
50 Vdc	8 kΩ	5.82 mA	5.00 mA

Therefore, the DAA passes the requirements of section 4.6.2. The test procedure is outlined in CTR 21 A.4.6.2. Further voltage and current characteristics are outlined by section 4.7.1 of CTR 21. As mentioned before, additional circuitry is required for CTR 21 so that the DAA can pass the current and voltage requirements. The design of current limiting circuit added for the CTR 21 DAA will determine how the DAA performs in this test. By altering the values of the resistances in the circuit, specifically R205, different voltage/current curves can be obtained. By using the values recommended in figure 5, the circuit produces the following results.

Table 4: Current/Voltage Characteristics in Loop State

Feeding Resistor (Ω)	Volts (V)	Current (mA)
230 Ω	38.3 V	52.0 mA
850 Ω	12.3 V	45.0 mA
2050 Ω	6.44 V	21.2 mA
3200 Ω	5.08 V	14.0 mA
8000 Ω	3.46 V	5.86 mA

Taking these results and graphing them against the required values gives a clearer picture of how the DAA is performing. Figure 6, shown below, demonstrates the behavior of the DAA with respect to the current and voltage requirements specified by CTR 21. The values measured are within the enclosed area indicated by the acceptable limit line.

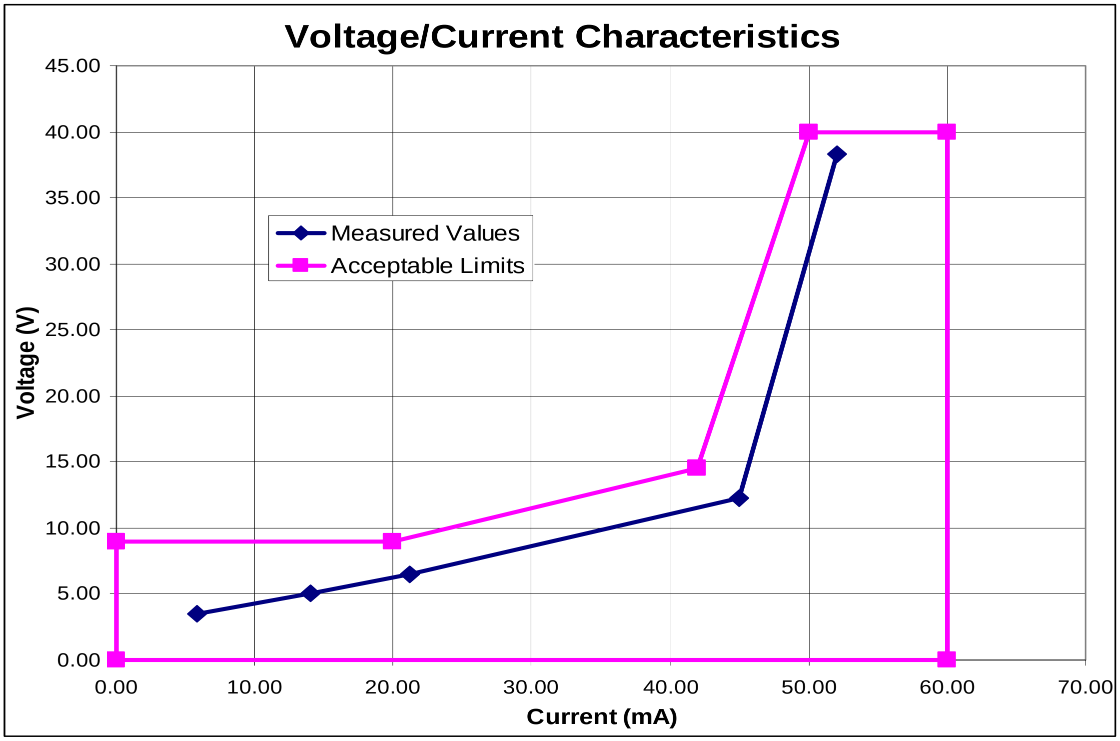

Figure 6: Graphical Representation of Current/Voltage Characteristics

4.4 Testing Return Loss

Return loss is an important consideration when designing a DAA. Section 4.7.2 outlines the return loss requirements for CTR 21. For FCC, Part 68.308(b)-6 specifies the return loss requirements. To make the testing process easier, technical note #34 by Midcom can be used [9]. Once the test setup outlined by the document is implemented, it is very easy to test a modem's DAA. The setup facilitates easy testing of the return loss, with respect to both FCC Part 68 and CTR 21 requirements. An important point to remember is that a modem will often need to be forced to go off-hook during the testing. Table 5 shows the successful results of the return loss tests using the Midcom setup and the DAA setup for CTR 21. The DAA passes the return loss requirements between the ranges of frequencies that are applicable. Note that for frequencies of 300 Hz or greater, the return loss cannot be greater than –8 dB, while for frequencies less than 300 Hz, values less than –6 dB are acceptable.

Table 5: Return Loss Measurements for CTR 21

Frequency (Hz)	Measured Return Loss (dB)	Maximum Return Loss (dB)
200 Hz	-7.8 dB	-6 dB
300 Hz	-10.6 dB	-8 dB
500 Hz	-12.0 dB	-8 dB
1000 Hz	-11.8 dB	-8 dB
4000 Hz	-8.6 dB	-8 dB

Since FCC Part 68 has different impedance requirements, the Midcom setup must be reconfigured. Table 6 shows the results when the DAA and the Midcom setup are configured for FCC Part 68. Again the DAA meets the requirements specified by 68.308

[3]. Note that 68.308 specifies a formula for maximum return loss from 200Hz to 500Hz, but for values 500Hz and above –6.0dB is the maximum.

Table 6: Return Loss Measurements for FCC Part 68

Frequency (Hz)	Measured Return Loss (dB)	Maximum Return Loss (dB)
200 Hz	-10.4 dB	-9.0 dB
250 Hz	-11.8 dB	-8.2 dB
300 Hz	-13.0 dB	-7.7 dB
500 Hz	-16.6 dB	-6.0 dB
1000 Hz	-21.5 dB	-6.0 dB

4.5 Summary of Testing

By performing the tests outlined above, the results indicate that the DAA, in both configurations, is able to meet the required specifications. As previously mentioned, the modem will require complete testing of all the requirements indicated by the respective specification before it can be used in the respective area. The partial results given above are meant to assist in DAA design only.

5 Conclusions

Low speed, low cost modems are often used in devices that are produced in large quantities. In this situation any cost savings is important since it will translate into increased profits. For this reason the following points should be kept in mind during the design process.

Mechanical relays should be avoided where possible. Cheaper, optical devices are the component of choice. In place of a second relay to detect caller ID signals, an RC network should be used. The network provides high impedance to DC and ringing signals, while imposing very little impedance to caller ID signals.

Transformers are still the best method to implement electrical isolation. Data access arrangements designed around new wet transformers can be designed to pass either FCC part 68 or CTR 21. Using a wet transformer provides a cost savings over dry transformers or optical solutions, while still maintaining adequate performance. To implement a CTR 21 compliant data access arrangement using a wet transformer additional circuitry will be required. The additional circuit is similar to a DC-loop holding circuit found in dry transformer designs but serves to limit the current drawn from the line.

Designers can implement the above modifications to cut costs. Testing shows that a data access arrangement based on these changes can meet the requirements of FCC part 68 or CTR 21.

6 Recommendations

The suggested data access arrangement design provides basic functionality and will meet FCC part 68 or CTR 21 if properly implemented. Additional investigation can be done to further improve the functionality of the data access arrangement, as well as the entire modem.

It is recommended that a wet transformer based design should be used so cut costs. Relays should be replaced with cheaper optical components, and caller ID should be implemented using a simple RC network.

For additional functionality, a feature such as the ability for the device to detect when a phone connected in parallel goes off-hook could be implemented. This would give the phone the option to hang-up if desired.

Furthermore, while it is important to implement cost savings in the data access arrangement, the remaining sections of the modem cannot be forgotten. The designer must consider all areas of the device when attempting to create an effective and efficient design.

Finally, to meet FCC part 68 and CTR 21, more than just the data access arrangement must be tested. When designing a device to implement modem functionality, it is important to have a complete test plan. Developing a plan will involve carefully studying the target specification to understand what is required.

7 References

[1] “Desktop Modem DAA”, AT&T Microelectronics, July 1993, pp. 2.

[2] “TBR 21”, European Telecommunications Standards Institute, France, January 1998, pp. 14.

[3] “Code of Federal Regulations: Parts 40 to 69”, The Office of the Federal Register National Archives and Records Administration, Washington, 1996, pp. 277-323.

[4] “Code of Federal Regulations: Parts 40 to 69”, The Office of the Federal Register National Archives and Records Administration, Washington, 1996, pp. 259-323.

[5] “TBR 21”, European Telecommunications Standards Institute, France, January 1998, pp. 14.

[6] “Desktop Modem DAA”, AT&T Microelectronics, July 1993, pp. 5.

[7] “TBR 21”, European Telecommunications Standards Institute, France, January 1998, pp. 15.

[8] “TBR 21”, European Telecommunications Standards Institute, France, January 1998, pp. 32.

[9] “TN #34 – Return Loss Test Method using 671-0023”, Midcom Inc., Watertown, USA, pp. 1-5.

[10] “Code of Federal Regulations: Parts 40 to 69”, The Office of the Federal Register National Archives and Records Administration, Washington, 1996, pp. 239.

[11] “TN #88 - Low Cost, CTR 21 Compliant DAA For Europe”, Midcom Inc., Watertown, USA

8 Glossary

CID	*Caller Id*. A service provided by the telephone company to identify the calling party's telephone number. The information is sent as a burst of Bell 202 FSK signals between the first and second ring.
CTR 21	*Common Technical Regulation 21*. CTR 21 is a telecommunications standard published by the European Telecommunications Standards Institute (ETSI). It specifies the attachment requirements for pan-European approval for connection to the analogue Public Switched Telephone Networks (PSTNs).
DAA	*Data Access Arrangement*. A data access arrangement is the interface between a modem and the public telephone line. The DAA isolates the device from the higher voltage on the telephone line. The DAA must conform to the telephone standards of the area in which it will be used.
DSP	*Digital Signal Processor*. A specialized CPU used for digital signal processing.
EMI	*Electromagnetic Interference.* The phenomenon when a device generates an electromagnetic field in the radio-frequency spectrum

	that could disrupt other electronic devices, systems and components in close proximity.
FCC Part 68	*Federal Communications Commission part 68*. The FCC is an independent US government agency that regulates interstate and international communications by radio, television, wire, satellite and cable. Part 68 regulates the connection of terminal equipment to the telephone network.
FSK	*Frequency Shift Keying*. FSK is a method of transmitting digital signals by representing logic 1 and 0s as analog waves at different frequencies.
Return Loss	Return loss is the dB value of the absolute reflection coefficient, the ratio of the reflected wave to the incident wave at the point of reflection. A return loss value of 0 indicates 100% reflection and is infinite (negative) for an ideal connection.
Vdc	*Voltage, Direct Current.* The portion of voltage that is a result of direct current.
Vrms	*Root Mean Square Voltage*. The root mean square of the effective voltage that is a result of alternating current wave.