Understanding Duo-Art expression

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For someone who has spent 30 years listening mainly to Ampico rolls, it seems ironic, even impossible that this same person would dare put pen to paper about that most strange of all things, Duo-Art expression. So I will start by saying that I do not regard myself as any sort of expert on Duo-Art expression coding and the operation of the Duo-Art expression box. But I am learning, and rather rapidly, thanks to my roll reader and the generosity of collectors allowing me to record their Duo-Art rolls into computer. One collector (Tony Hilton) has what I regard as a most interesting collection of rolls, which are arranged in order of roll number. Some of Tony's rolls are UK issues, and therefore possibly rarer in Australia than the US issues.

When Tony offered me access to his collection, I decided to start at the lowest roll numbers and to record his entire collection. This has meant I started recording rolls issued in 1914, progressively moving forward in time as the roll numbers increase. An advantage of this is being able to see how Aeolian editors handled the expression coding, and how the techniques changed over the years. My aim in this article is to give my impression of how the expression box works, based on a range of tests I devised, and how the editors used their skills and tricks to create some incredibly good piano roll recordings.

Expression box principles

While those reading this article probably understand the basic operation of the Duo-Art expression box, it's worthwhile reviewing the operating principles before getting into its complexities. There are two suction regulators, called the accompaniment and theme regulators. They work in the same way, except the theme side operates at a slightly higher suction level than the accompaniment side. There are four accordions in each regulator that are arranged to pull a lever that opens the knife valve in the regulator. The resulting increase in suction causes the regulator pneumatic to close the knife valve, so the final position of the knife valve, and therefore the suction level is a combination of these two actions.

The four accordions operate over different distances, ranging from 1/16 inch to half an inch. There are 16 possible combinations of the four accordions, from all open (zero setting) to all closed (maximum suction). These are often called powers, such as power zero, power 1 to power 15. When a static vacuum reading is taken at each level, you get 16 readings that progressively increase from the minimum suction level to maximum. Because the theme side is always slightly higher than the accompaniment side, there are in effect 32 discrete levels of suction.

The stack is divided into two sides, bass and treble, with E above middle C the first note in the treble side. Under normal operation, the accompaniment regulator provides suction to both sides of the stack. This means that any group of notes playing at the same time will give the same playing volume. The theme regulator has two valves, (bass and treble) operated by primary valves that are controlled by the two theme holes in the tracker bar.

If the treble side theme hole is uncovered, its primary valve operates, causing the treble theme valve in the box to open. The resulting increase in suction in this part of the box causes a flap valve to open, directing theme suction to the treble side of the stack. Notes in this side of the stack are now louder than in the bass side, which is still under accompaniment suction.

When the bass side theme hole in the tracker bar is uncovered, a similar action occurs in which theme suction is directed via another flap valve to the bass side of the stack. The treble side remains controlled by the accompaniment regulator. If both theme holes in the bar are uncovered, the entire stack is controlled by the theme regulator. Therefore the Duo-Art requires five expression ‘tracks’ on each side of the roll, four to operate the accordions (numbered 1, 2, 4 and 8), and one to operate the theme valve for that side of the stack.

Another aspect is the spill valve in the expression box, which is moved by either set of accordions, such that it’s fully closed at power 10. Its purpose is to increase the box suction level as the accordions close, which gives a sort of amplifying effect by increasing the box suction in tandem with opening a regulator’s knife valve. The only other means of controlling expression is judicious use of the damper and soft pedals.

Tests

It is probably true to say that the Duo-Art expression box is a wonder of steam age mechanics. It is the most entertaining thing to watch while it's in action, with accordions and regulator pneumatics flapping up and down, a spill valve flipping back and forth, all accompanied by lots of hissing and huffing. That it works at all is often a point of wonderment amongst those with an engineering bent. And yet it does, and sometimes with magical results. This aspect of the Duo-Art has intrigued me for many years, so it's been an interesting journey of discovery over the last few months as I probe the mystery I refer to as the black art of the Duo-Art.

It appears that the expression system relies on its shortcomings to produce a much wider range of suction levels than the 32 static levels. Unlike most regulating systems, the Duo-Art expression regulator has substantial inherent delays. It takes quite a while for the suction level in either the theme or accompaniment regulators to increase from one level to another, and an even longer time for the suction to decrease from one level to another. The number of notes being played affects the delay time, which further complicates the issue.

Delays are inherent in all regulating systems, but not usually to the extent of the Duo-Art. To gain a better understanding of this, I prepared a MIDI file in the form of a Duo-Art roll, bearing in mind I can play this MIDI file on my Weber Duo-Art, now that it's fitted with a "Virtual valve" system. I produced the file in a MIDI editor program called Cakewalk, then I played it on the Duo-Art so I could evaluate the expression by ear.

The first test had a series of 32 slowly repeating notes, grouped so two notes would play at each of the 16 possible accompaniment expression levels. See Figure 1. The first note of a pair was positioned to play a short time after the expression level had changed from its previous, lower value. The second note was positioned to play after the expression level had stabilised. In all cases, the first note of a pair was softer than the next, showing how slowly the regulator was operating.

The most dramatic effect was the change between power 7 (has top three accordions on) and power 8 (bottom accordion on only). The time taken for the top three accordions to open while the bottom accordion is closing caused the first note under power 8 to be softer than the preceding notes at power 7.

But there are other variables to consider. Returning to the test file, the next test I developed was a repeat of the first, except notes were now controlled by the theme regulator. As shown in Figure 1, this test was positioned so it follows the first, such that the repeating notes continued without interruption. Again each note was played twice at each of the 16 possible theme levels. The first note of this part of the test was coded to play at theme power zero, and would be played after a note playing at power 15 from the accompaniment regulator. To my surprise, instead of this first note playing softly, it played at about power 8 level.

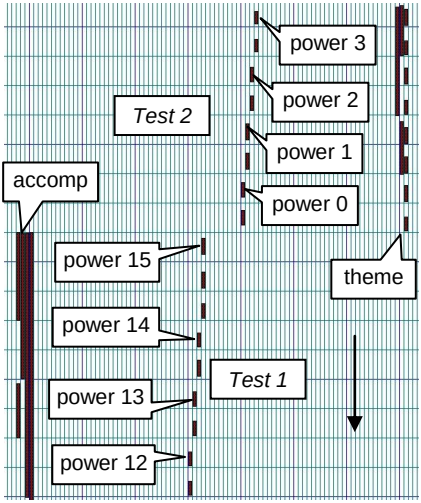

Figure 1: Section of test file where a note at theme power 0 follows a note at accompaniment power 15

The reason is the accompaniment suction was still falling towards its zero level when the note played. Because this suction was higher than the theme suction, the theme flap valve was sucked shut, causing the stack to be supplied from the accompaniment regulator. This is a case that does seem to be mentioned in the literature about the Duo-Art, where the theme suction level is lower than the accompaniment suction, which prevents the theme suction from having any effect. Another complication the Aeolian editors either used, or needed to be aware of.

By now I could see that the inherent delays in the expression box were part of its very design, whether intended or not. Without them the box would not work properly and anyone trying to make a more efficient Duo-Art regulator would be disappointed at the results. By taking advantage of the relatively slow operation of the box, a roll editor could create subtle changes in the expression.

For example, as my tests show, coding the roll to operate an accordion just before playing a note means the note plays more softly than a later note, when the accordion has been on for some time. Notes playing not long after an accordion has been turned off will play more loudly than following notes.

What it all adds up to

At first glance, Duo-Art expression coding appears easy to read. The more accordions there are on at a time, the higher the volume, that sort of thing. But when you look at a roll while it's playing you are not seeing what the player action is seeing. Nor are you inside the expression box to see what is going on. At best, you can approximate the loudness of the notes due to the coding you are seeing. But after a while you begin to realise that for the apparently same coding, notes are playing at a higher or lower volume.

But does this mean that a typical Duo-Art roll incorporates a large number of expression levels? The answer is yes and no. The expression system has the potential to achieve an almost infinite number of levels, but in practice I have found this does not often occur. At least not in early rolls, say up to 1918. After that time, editors seemed to be more skilled in coding the expression, and the number of discrete expression levels is higher.

My way of determining this is through computer 'emulations' of Ampico and Duo-Art erolls. I promise not to go on about this, but a brief explanation might help. When I record a Duo-Art roll on the roll reader, I end up with a MIDI file I can play on the Duo-Art. That's all it can do. To make that MIDI file play my Disklavier requires the file to be passed through a program called an expression *emulator*. This program reads the Duo-Art expression coding and converts it to information the Disklavier can respond to. This is a number, called a velocity value, between 1 and 127, with 127 the loudest. Each note is given a velocity value which, ideally, causes that note to play at much the same volume on a Disklavier as it would on a Duo-Art.

It was to take me some time before I was happy with the Duo-Art emulations I am now achieving. I spent a lot of time making critical adjustments to the emulator settings and I also wanted to prove the emulator was capable of doing an acceptable job. Hence all the tests mentioned above. In the end, my findings convinced me the emulator is pretty accurate, sufficiently so for me to enjoy the results on my Disklavier. It also allows me to analyse the operation of the Duo-Art expression system in a way I could not otherwise have done.

Example

To give you an idea of how difficult it is to read the expression of a Duo-Art roll, here's an example taken from a roll issued in 1920, called *The Dark Rose*, played by Felix Arndt. By looking at the photo of the roll in Figure 2 (b), you might like to determine the playing level of notes 1 to 5. For example, you would expect note 1 to play at theme zero, wouldn't you? But notice that not long before, the theme accordions have gone from power 12 to zero. As a result, note 1 plays quite loudly. Note 2 appears to also be at theme zero, but definitely not so.

How the player action 'reads' the roll is shown in Figure 2 (a), which is the time a tracker bar hole is open. Here you can see that note 2 is playing at power 6, with accordions 2 and 4 having been operated a short time before. The emulator reports that note 1 has a velocity of 68 and note 2 a velocity of 72. The notes playing prior to note 1 have a velocity of 83, so the theme regulator suction level is changing quite slowly towards zero, and is still giving note 1 a playing volume around that of power 5. Not the power zero you would have expected.

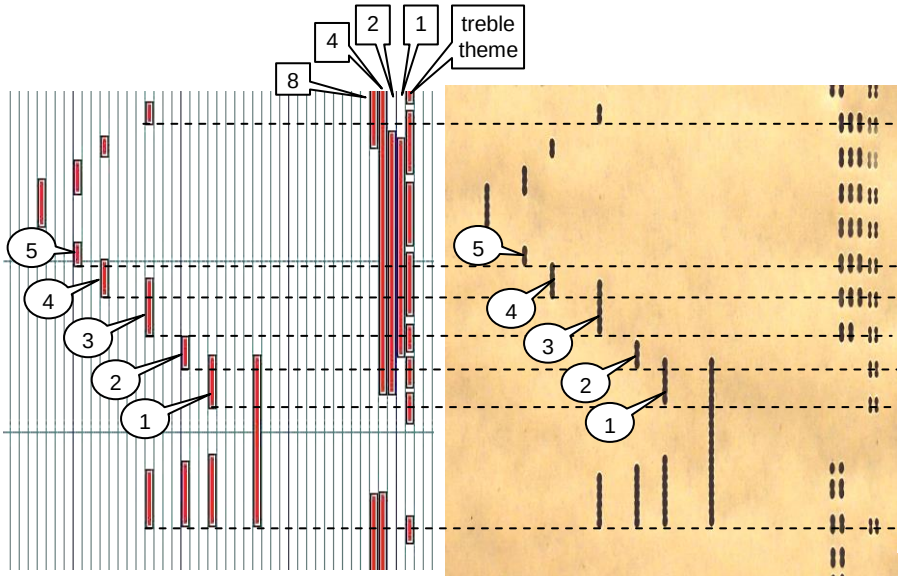

Figure 2: (a) What the player action sees *(b) What the piano roll shows you*

Note 3 on the roll might be assumed to be at power 6, in fact, as the player action sees it, power 7 is on, so note 3 plays at a higher level than note 2, at a velocity of 78. You will probably pick that note 4 plays at power 7, but the theme regulator suction has increased slightly since note 3 as it reaches its static value, giving note 4 a velocity of 79. Note 5 also sees a stable power 7, and it too plays at a velocity of 79. The result is a subtle crescendo over five notes. Tricky, isn't it.

Conclusion

The best kept secret is how Aeolian recorded the expression of a piano performance. A generally accepted theory is that someone operated two knobs in a console that were connected to some sort of recording device, by twisting them one way for loud, the other for soft. A more intriguing question is how did the editors convert this expression information into coding on the roll, given the many vagaries of the expression box. My guess is practice and experience, that slowly improved as new ways to achieve certain effects were developed. Some early rolls (1914) have swathes of expression perforations, but the volume seems to remain almost unaltered, and routinely loud. Note theming is sometimes ridiculously loud, and crescendos are very bumpy. Later rolls, such as those in the 6000 series, have better expression, often giving very delicate soft playing.

While I've pointed out some of the complexities of the expression system, there are others, such as the number of notes being played at a time. Because the regulators have such a slow response time, when several notes are played at power zero, the suction level falls below the static level you took so long to adjust. Subsequent notes will then play at this lower level, which may be ok if your zero setting is not too low. The editors probably took advantage of this effect to create colour in the soft playing. But it's a hazardous effect, as we know when notes don't play, even though the zero has been carefully set using the test roll and your best judgement.

My conclusion is that it is impossible to adjust a Duo-Art to play all rolls perfectly. Over the last six months I have listened to some 400 Duo-Art rolls, deciding at times that I need to adjust the theme regulator, as themed notes are sometimes too loud. Other rolls I listen to suggest I need to increase the accompaniment zero to prevent notes dropping out. Then along comes those rolls that have convinced me I should not touch a thing. This is often true of rolls made after 1920.

In fact, after listening to all these rolls, I have decided not to change the expression settings, as it's rather like a dog chasing its tail. I accept that some rolls will not sound as I would like, knowing that other rolls will. Fortunately, the quality of the expression coding is somewhat related to the quality of the pianist. For example, Busoni rolls, although issued in 1915, are excellent, while rolls by Felix Arndt issued around the same time are usually quite dreadful.

In my opinion, because the Duo-Art expression system is indeed a black art, it took the editors a lot of experience and time before the real gems started to appear. Even then, rookie editors would have the same learning curve. This means there are some quite ordinary Duo-Art roll recordings, regardless of issue date, but it also means there are some fantastic rolls. In fact, my other conclusion is that Duo-Art roll performances often exceed those on the Ampico, a fact I am slowly discovering as I record more and more Duo-Art rolls on the roll reader. It may be a black art, but I now have a lot of respect for the outcomes.