18

Music on the edge (connector): demixing the sound of the NES and Famicom

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From consoles to control decks

The story of the transformation of Nintendo’s Family Computer (or Famicom) into the international Nintendo Entertainment System (or NES) is an oft-told one, although, more often than not, it is oversimplified and based on apocrypha and a number of well-rehearsed inaccuracies. The barest version of the narrative centers around a US market decimated by the release of low-quality games and the resulting indifference and even hostility of consumers unwilling to buy and retailers unable to sell, into which Nintendo triumphantly released the rebadged version of its console that had been so wildly successful. Such was the quality of the console and its roster of games – including, among others, the much-celebrated *Super Mario Bros.* (Nintendo, 1985) – that the newly monikered NES resuscitated and resurrected the entire industry and propelled videogames to their rightful place as a global entertainment medium. Of course, the reality of the situation is rather more complex and recognizes, for instance, the comparatively slow start the Famicom experienced in Japan which, combined with technical recalls to fix faulty chips and crashing units, meant that its mass popularity came a over year after its initial release in 1983 (Uemura et al 2013, Kent 2001). Add in the myriad reasons for the beleaguered state of the US market which are typically, and rather unfairly, laid at the feet of just a few games such as Atari’s now-infamous *ET* (Fassone 2014, Penn 2014, also

Guins 2009) but which could be attributed to a slew of putatively poor titles as well as retail practices that allowed the returning and refunding of unwanted games. Couple this with a piece of sheer good fortune that could so easily have seen the NES disappear without trace in the US market crash, had a deal with Atari to license the system proceeded as originally planned (Altice 2015), and we begin get a sense of how much intriguing detail is elided in the popular account.

One aspect of the Famicom's metamorphosis into the NES that is hard to overlook, however, is the rebadging and rebranding of the device itself. With its redesigned case intended to mimic the respectability of a VHS recorder, the grey, almost austere NES is self-evidently and self-consciously different from its altogether more colorful, playful and even playable Japanese counterpart. That the Famicom's design included a functionally unnecessary cartridge eject switch following a suggestion from Nintendo's Game & Watch designer Gunpei Yokoi that children might enjoy playing with it, is a case in point. And if 'videogame' had become so tarnished a term in the post-crash US marketplace then a whole new nomenclature was called for. And so, videogame cartridges became 'Game Paks' and, crucially, where the Famicom was unabashedly a videogame console, the heart of Nintendo's 'Entertainment System' was an altogether more serious and future-facing (if not almost meaninglessly imprecise) 'Control Deck.'

What is particularly interesting then is that, while there is a recognition of the impact and even the rationale of the alterations to the Famicom's exterior casing and the sobriety of the renamed and refocused NES, it remains commonplace to find popular and scholarly discussion conflating the two devices as a single 'platform' as though the transformations were limited just to matters of industrial design and marketing terminology. In this chapter, I wish to delve beneath the surface in order to reveal some of the technical and functional differences between the two systems and how Nintendo's 'beneath-the-hood' alterations materially impact how games can be designed, and even how what might seem to be ostensibly the same game manifests differently depending upon which device it is developed for, ported to, and played on. While these technical and operational differences certainly make a demonstrable and important impact on the reproduction of graphics and even the hardware interfaces with which players interact and exert control, my particular focus here is on the markedly different sonic potential of games developed for the Famicom and NES. In this way, in addition to highlighting the importance of sound and music in what has been an often eerily silent world of scholarly game studies (see Collins 2008; Fritsch and Summers 2021), the discussion here continues my earlier work on the illusory nature of 'platforms' and the impact of technological, temporal and geographical plasticity (or 'instability') on videogames and gaming systems as coherent objects of study (see Newman 2012, also Apperley and Parikka 2018). Accordingly, the discussion draws on Altice's (2015: 7) definition of the Famicom and NES 'as a holistic network of objects and texts, including cartridges, controllers, peripherals, marketing materials, play environments, and emulators.'

Chipsound

In this age dominated by gaming systems that stream pre-recorded orchestral soundtracks or the spoken word dialogue of characters from hard disks, CDs or Blu-Rays, it is important to remember that the Famicom, just like every other home computer or console of its era, created all of its sounds using its own built-in sound generating hardware. The Famicom's audio circuit, known as the 2A03, was manufactured by Ricoh to Nintendo's specification, and is an example of an Audio Processing Unit or APU (though it is very often referred to as a sound chip as we will see below). The APU is responsible for lightening the load from the Central Processing Unit (CPU) by taking responsibility for all of the sound and musical elements in a game which are generated in real time by the APU. By way of analogy, we could think of the contemporary situation in which pre-recorded game music streamed from an optical disc is the equivalent of playing back music from the audio CD player in a domestic Hi-Fi or in-car entertainment system. The source material has already been created and committed to disc using whatever technologies and special effects are available to the individuals, bands, producers and performers involved in the creation process. At its simplest, a contemporary videogame audio engine could be considered to be pressing 'play' on the

CD player at the appropriate time in order to initiate the correct track to accompany the level or sequence of gameplay. By way of contrast, the audio hardware components in consoles and computers from the 1980s and early 1990s, do not play back pre-recorded sounds but operate in response to data that are interpreted in real time and transformed into sound. In this sense, we might perhaps think of the APU as the equivalent of a group of musicians reading a score and giving a live performance, although here the score is not musical notation but rather a stream of data forming the instructions for what and when to play. In place of staves, time signatures, crotchets and quavers, the videogame console music 'score' comprises bytes upon bytes of hexadecimal data that are dutifully interpreted and output as musical sounds. In such circumstances, the composer is both musician and programmer (or at least works alongside a programmer transcribing their music into machine-readable code). As Manami Matsumae, who composed the soundtrack for the first *Rockman* (Capcom, 1987 – known as *Mega Man* outside Japan) game, explains, the process of creation could be a laborious and possibly alien task for the musician:

> [N]owadays it's a lot simpler to get the data that you want to create, and if you need to make any changes, it's not that difficult. Back then, in order to put the musical data into the ROMs, you had to convert the musical notes into numbers . . . there were times when you'd have to put the entire game into ROM and test it, but there are also times when only the music had to go in (Parish 2016).

And just like any group of musicians playing live, there is a limited scope to this kind of performance. Whether it is a four-piece band comprising vocals, drums, rhythm and bass guitars or a 90-piece orchestra and 60-person choir, there are a necessarily limited number of voices, hands and instruments that can play simultaneously; a limitation that can only be overcome by adding more personnel (or augmenting the live performance with subsequent post-production, recording and overdubbing). The computer/videogame console APU/soundchip is no different from the live performer in being limited in the type and number of simultaneous sounds it can play, although, as we will see, it tends to operate more towards the gigging band than the symphony orchestra in terms of scope. But just like the band, orchestra or choir, the soundchip has its own distinctive sound. A Famicom APU does not sound like a Game Boy, a Nintendo 64 or a PC Engine, Commodore 64 or Sega Mega Drive, not just because of the work of different composers writing music for them but because each system has a different means of generating audio - a different APU/soundchip - that generates a different palette of tones, a different number of simultaneous sounds, all of which are, crucially, generated using different audio synthesis technologies.

It is useful to note here that the particular set of qualities and capabilities contained within any given console audio system constitute a large part of what might be thought of as the distinctive sonic dimension of a platform. As Altice (2015) notes, while audiophiles will doubtless debate the characteristics imparted by different components in a Hi-Fi system, in principle there is nothing to distinguish the playback of a pre-recorded piece of music on a Yamaha or Sony CD player. It follows that, all other things being equal, there is no distinctive audible difference between a piece of pre-recorded music played back on an Xbox or a PlayStation. In this way, we could argue that the PlayStation, Xbox or any other console playing back the pre-recorded/streamed music that is so prevalent in contemporary game systems and audio engines, do not impart an identifiable ‘sound’ any more than any given brand of CD player. Any specific APU or soundchip, however, can be seen as utterly integral to the formation and definition of a ‘platform’ precisely because of its distinctive abilities to make - or not be able to make - certain sounds, just as the graphics chip imparts a distinctive suite of possibilities by virtue of the number of objects that can be simultaneously displayed onscreen, the resolution of the display, or the specific range of colors from which an artist can draw (see Newman 2021).

Famisound

Even for connoisseurs of 2A03 music, the specification of this Audio Processing Unit (APU) makes for surprising reading, making available to the composer a maximum of just five simultaneous sounds. And let us be clear what we mean by a 'sound' here. This is not a drumkit, piano, bass and a couple of guitars playing rhythm and solos. That would be five instruments each capable of playing somewhere between one and 88 notes simultaneously. The 2A03 is certainly capable of playing five separate sounds (though the degree to which they sound like drums and guitars is something to return to) but each is capable of playing just one note at a time. So, that is five notes. The entire chip comprises, in audio synthesis terms, five monophonic voices or channels. At the risk of laboring the point, that is less than the number of individual percussion pieces in a drumkit. To play a five-note chord such as could be played with a single hand on a piano keyboard would require the full sonic potential of the 2A03 with a sixth note being simply impossible. In reality, the actual maximum number of simultaneous notes available for musical performance was often just four and sometimes considerably less, as music is typically not the only element in a game's soundscape. Background and synchronized sound effects would also have to be generated in real time by the 2A03, as this was the only component capable of generating sound in the console.

And, lest we think that the number of simultaneous sounds is the only limiting factor facing the 2A03 composer, it is worth noting that the range of sounds is rather restricted, too. The four main voices or channels are each capable of playing back one synthesized waveform. There is a triangle wave, two pulse waves, and a noise generator. The fifth voice or channel is able to play back very short snippets of pre-recorded audio (otherwise known as samples). Technically, this voice is a 1-bit DMC Delta Modulation Channel (DMC) and it plays back samples with a very low data rate and a comparatively high cost to overall computational power of the system. Nonetheless, despite these factors which, among other things can lead to rather indistinct and muffled playback, samples are used in many Famicom and NES games, including the percussion sounds in Nintendo's own *Super Mario Bros. 3* (1988), for instance. As we might imagine from the layout of the 2A03's voices, the bulk of the music even in games like *Super Mario Bros. 3* where DMC samples are utilized, still derives from the four synthesized waveform channels.

Each of the four main channel's waveforms has its own distinctive sonic characteristic. The triangle wave is quite soft, although possessing a decidedly digital edge. Played in its lower registers through the kinds of speakers built into the average portable TV set into which a Famicom or NES might be connected, its softness makes it very often near-inaudible. The same cannot be said for the two pulse waves which could charitably be said to be 'raspy.' The duty cycle of these waveforms can be modulated (changed) between 12.5%, 25%, 50% and 75% (the latter being mathematically different but audibly identical to 25%) which, in practice, results in a fuller tone at 50% (a square wave) and a progressively thinner or more reed-like tone at 12.5 or 25/75%. As we shall see below, musical duties are generally spread across these three channels with the triangle often playing a baseline while the two pulse channels take lead and countermelody duties. The noise channel is actually a simple linear feedback shift register (LFSR) circuit that can generate noise, which is useful (and typically used for) percussion sounds or sound effects such as whistling wind or explosions.

Among the most celebrated composers of music for the 2A03 is Kōji Kondō whose work includes *The Legend of Zelda* (Nintendo, 1986) to which we will return later, and *Super Mario Bros.* (Schartmann 2015). Kondō's 2A03 themes are, broadly speaking, rather stripped back. By no means could they be considered bare or minimalistic, but they are not brimming with the kind of flourishes or baroque style ornamentation that Guay and Arsenault (2012) identify in much chip-based composition. In many ways, Kondō's work can be seen to be informed by the implied musical layout of the 2A03 and replicate a four-piece group of bass (triangle), melody and countermelody (pulses) and percussion (noise). Moreover, although it shifts into a higher tempo as the in-game timer approaches zero, thereby adding further tension while simultaneously playing with the notion of diegesis (Collins 2007), the background music in *Super Mario Bros.* plays on regardless of where the player is in a level. As such, the musical accompaniment is not dynamic and does not respond to the position or action of the player. Of course, this does not mean that there is interactive sound in Mario's world because there remains the small matter of sound effects. Every time Mario jumps, collects a coin or acquires (or loses) a power-up, a perfectly-timed sound effect underscores and reinforces the action. And, it goes without saying that those characteristically springy 'boings,' metallic clangs and ascending or descending power-up (and down) effects have to come from the 2A03 which means, if we are already using all of its available voices for music, something has to give.

The handling of music and effects reveals much about the priorities understood by the game development team as a whole in creating the experience of play. In the case of the first *Super Mario Bros.* game, we might expect the countermelody to be momentarily replaced by the jumping sound effect, thereby leaving the integrity of the piece relatively unaffected. However, the perhaps unexpected decision was taken to the drop out the lead melody line instead, leading to an altogether more jarring interruption. One explanation, offered by McAlpine (2018), connects the pitch of the jump sound effect to the key of Kondō's soundtrack which might serve to preserve the overall harmonic integrity of the soundscape even in the absence of the melody. Alternatively, we could argue that the removal of the most putatively important part of the musical composition serves to underline the primacy of the ludic as the player and their movement in the game literally takes precedence in the experiential whole. Regardless of implementation, this 'voice stealing' as it is typically termed in electronic music parlance, reminds us of the limited resources available to the 2A03 game composer. This equally applies to composers working with any number of other similarly specified soundchips and APUs.

As we noted above, the 2A03's triangle waveform is very often used by composers to take on bassline duties, as is the case with Kondō's *Super Mario Bros.* 'Overworld' theme. At least part of the reason for this derives from the lack of control the composer has over its amplitude (thereby offering fewer, if any, opportunities for dynamics) and its pitch range extends down to 27.3 Hz, unlike the two pulse voices that reach down only as far as 54.6 Hz. Perhaps unsurprisingly, some composers challenged compositional convention by using the triangle wave in different ways. With some creative programming, rapidly altering the pitch of the triangle wave ekes out more musical value, and single voice can effectively do double duty as it alternates between what is heard as the simultaneous playback of a pitched bass note and a kick drum. When the drum note is further reinforced with a blast from the 2A03's noise channel, the result is heard as a mix of bass, kick and percussion. Tim and Geoff Follin's soundtrack to *Silver Surfer* (Arcadia Systems, 1990) and Neil Baldwin's composition for the unreleased *Hero Quest* showcase this effect extensively.

Given what we have learned above, and notwithstanding the creativity and virtuosity of particular composers and/or programmers who managed to find new sonic potential from the same piece of silicon, it would be reasonable to assume that the sound of the Famicom is in large part defined by the sound of its 2A03 APU. However innovative those 2A03 composers might be, surely they are ultimately limited by the capability, scope and tonality of the instrument with which they work. It should also follow that, as the cosmetic and marketing differences that distinguish the Famicom and NES have no bearing on the internal workings of the systems, the two consoles/incarnations of the same console should sound the same. Therefore, the sound of the Famicom and NES should ultimately be defined by the sound of the 2A03. That would certainly be convenient if we were to try to sustain the notion of the Famicom and NES constituting a single, coherent platform. However, a few points are worthy of note here.

Marching to the beat of a different refresh rate

First, and most minor, there is an argument to be made that the 2A03 inside the Famicom is not actually an APU at all and certainly not a soundchip even though, in popular parlance, that is the sobriquet most commonly used to describe it, along with any of a variety of different sound generating hardware in general computing and gaming systems. To be strictly accurate, we would term 2A03 a 'pseudo APU' or pAPU as it actually resides on the same physical chip as the Central Processing Unit in the Famicom. Essentially, while it can be addressed independently at a programmatic level, it is considered a pseudo APU because it is not an architecturally discrete component. More significant, however, are the changes made to the Famicom's APU as it travelled out of Japan because, while there are only very small differences between the 2A03 as it appears in the Japanese Famicom and US NES, if we cast our net further afield, we see and hear some altogether more meaningful adaptations made to accommodate the system's journey to Europe.

One of the defining features of the 2A03, like numerous other APUs and soundchips found in computers and videogame consoles of its ilk, is that its timing source – the clock that governs all of its operation – is derived from the system's CPU which is, in turn, tied to local television standards. Specifically, this means the 2A03's operation is linked to the rate at which the TV image is drawn and, in particular, to the amount of time between the drawing of each of the horizontal lines that comprise the full image on screen. While delving into the history of international television formats or their differential spread and standardization across different parts of the world is beyond the scope of this chapter, it is useful for our purposes here to note that the refresh rate of the NTSC TV system utilized across Japan and the US is 60Hz. By contrast, across much of Europe where the PAL broadcast system defines the technical specifications for TV sets and broadcasts, that picture refresh rate is 50Hz. Setting aside any discussions over the perceived quality or smoothness of graphical 50/60Hz reproduction and frame rates (Phillips 2013), what is important to our analysis here is that the NTSC and PAL standards employ different timings that require alterations to the hardware. As such, the APU at the heart of the European NES, renamed the 2A07, is tweaked to operate at a clock rate of 50 rather than 60Hz. Of course, this alteration alone is not all that is required, and game code must also be modified in order to properly accommodate for the new hardware, different timings and clock speeds. In cases where these code adaptations were undertaken by programmers, games played in Europe, Japan and North America might look and sound indistinguishable. However, where code was imperfectly modified to compensate for the timing differences between international TV standards, a European conversion or port of a Japanese or US game might run significantly slower. Where the code was not modified at all, the European port would run 17.5% slower.

I have noted elsewhere (Newman 2019) the impact of imperfect and overlooked NTSC/PAL conversions on high profile games such as Sega's 1991 *Sonic the Hedgehog* (Sega, 1991), transformed into a plodding version of its former self as our spiky blue hero slows down by nearly 20% and the soundtrack to Green Hill Zone becomes an almost funeral dirge. We might be tempted to write this off as an oversight on Sega's part, albeit a rather remarkable one given how seriously it impacted one of their flagship titles. Yet, of course, Sega were far from the only developer who failed to optimize their PAL releases. Nintendo's own European NES releases of games such as *Balloon Fight* (1984) and its flagship *Donkey Kong* (1981) similarly suffered from being unoptimized and ran at 5/6 speed. The irony is inescapable. Just as Sega would go on to release a dramatically decelerated version of a game it had defined by the speed of its gameplay, delivering an arcade perfect home conversion of *Donkey Kong* had been the *raison d'être* of the Famicom and a cornerstone in its design specification. It achieved that in Japan and the US, but *Donkey Kong* in PAL territories enjoyed an altogether slower climb to the top of the tower accompanied by a downtempo rendition of music and sound effects.

It is important to remember that such ready availability of information for comparison has not always been within the grasp of even the avid gamer. With no reference point available in the gaming magazines of the 1980s, there were few opportunities for comparison nor any reason to consider that such a comparison would be necessary. Why would a European player encountering the release of *Donkey Kong* assume that this was not the speed at which carpenters ran? Besides, with mainstream retailers carrying only hardware and software released through the official European distribution channels and a TV set designed for 50Hz PAL playback, what could a player do even if they did suspect there was a faster version to be had?

Of course, websites such as The Cutting Room Floor (https://tcrf.net/) and Clyde Mandelin's exhaustive *Legends of Localization* (legendsoflocalization.com), as well as book projects (e.g. Mandelin 2015a, 2016), offer today's players the most in-depth analyses of the minutiae of graphical, auditory and gameplay performance of videogames released on different platforms, leading to significantly increased awareness of the vagaries of international conversions. Similarly, the availability of illegally-obtainable ROMs has broadened access to a plethora of versions of games from across the world and, in providing what is essentially a universal machine, has effectively erased the region specificity of PAL/NTSC incarnations of the NES such that a player in Europe is no longer restricted to a PAL version of *Donkey Kong*, for instance. That said, the existence of these regional differences is remarkably durable in some contexts. Indeed, *Balloon Fight* was once again the focus of discussion over a quarter of a century after its initial release after Nintendo re-released it on the European Wii U Virtual Console running in 50Hz with slowed down music and effects. The titles of Phillips' (2013) article for Eurogamer, 'Nintendo using inferior 50Hz mode for European Wii U Virtual Console,' and Biggs' (2013) piece for Nintendo Today, 'Wii U, Virtual Console and 50Hz: Why Is It Still A Thing?' are particularly revealing and speak to the increased information about these international speed differences and palpable dissonance that many players experience in returning to this 5/6 speed version after having become accustomed to the faster NTSC NES game.

And so, what we find in these examples is a salient reminder that, while the US NES might sound like the Famicom thanks to the comparatively seamless transition of hardware and software between US and Japanese versions of the NTSC television standard with their shared refresh rate and timing signal, the PAL NES and its modified 2A07 APU, could sound like a very different, and altogether more lethargic, beast without the necessary optimizations to raise its tempo. Moreover, we are reminded of the importance of studies such as Navarro-Remesal and Pérez-Latorre's (2022) collection on European gaming that seek to diversify and broaden the scope of historical videogame studies to account for the distinctive nature of regional markets, development, and even the operation of technologies.

Importantly, a distinctive feature of the European NES component of the global Famicom/NES ’platform’ arises, let us not forget, because of the need for a game console and code to accommodate the already-existing regional infrastructures and standards governing televisual broadcasting and domestic audiovisual appliance design. A console might therefore be defined as much in terms of what it subsequently has to plug into as by what its designers had intended. A holistic network, without doubt! And yet one whose complexities and contours we have still only begun to scratch the surface of because further investigation reveals that the Famicom has two more facets that add to its instability as a single, coherent device.

Expanding audio

Perhaps the most obvious way in which our idea about what constitutes ‘the Famicom’ is confounded arises with the addition of the Family Computer Disk System, more commonly known as the Famicom Disk System or simply FDS. Released in Japan at the beginning of 1986, the FDS is a peripheral device whose primary function is to add a disk drive to the base Famicom system. Where standard Famicom games were delivered on comparatively expensive cartridges, the FDS brought cheaper floppy disk storage media to the console. Of particular note was that, unlike cartridges which contained Read Only Memory (ROM) chips filled with game data, the FDS was a read/write device. This meant that, as well as loading data from what initially seemed like generously capacious, inexpensive floppy disks, the console could also write information to them, thereby allowing scores and even progress through a game to be saved (McFerran 2010).

While the potential cost savings to consumers were, without doubt, an important factor and the FDS is typically understood as being part of Nintendo’s response to retailers requesting cheaper games as well as an attempt to alleviate the pressures of fluctuating costs and the supply chain issues associated with ROM chips and other cartridge circuitry (Linneman 2019), it is the ability to save player data that is usually taken to represent the FDS' most significant transformation to the Famicom system and to game design potential. Among the first games to take advantage of the FDS and its save game functionality was Nintendo's *The Legend of Zelda*. The creation of celebrated designer Miyamoto Shigeru, *The Legend of Zelda* is a sprawling, open world game that combines action-adventure and role-playing elements and was designed to be played over multiple sessions that would see players return to pick up from the position they left off by recalling their save state from the disk. Of course, many games had implemented progress saving mechanisms before, but these had typically been somewhat awkward arrangements that involved the recording and re-entry of passwords, as with titles such as *Metroid* (Nintendo, 1986) and *Metal Gear* (Konami, 1987) for instance. The FDS integrated saving and recalling into the system – into the game itself – and *The Legend of Zelda*, released only on FDS, was a perfect exemplar of the transformative nature of this futuristic peripheral.

There is, however, much more to this peripheral than the introduction of re-writable storage media because the FDS was more than a disk drive. The device also augmented the Famicom's audio capabilities by adding another channel of sound playback. Joining the four channels of synthesized waveforms and the DMC sample channel was a sixth voice, and a very capable voice it was. Even if it had simply added another pulse, triangle or noise channel, this would have been a significant expansion, but the FDS's additional voice actually made use of a different synthesis technology that allowed composers to effectively draw their own unique waveforms. By setting the values of 64 amplitude levels, the FDS sound channel could generate rich sawtooth, sine waves as well as a host of esoteric and unusual wave shapes. In this way, the FDS not only increased the Famicom's overall voice count but also broadened the sonic palette of the console by adding sounds incapable of synthesis or reproduction on the base unit alone.

Just as *The Legend of Zelda* was a shining example of the FDS' data storage feature, so too was it a showcase for the expanded audio capabilities. Kondō's compositions make extensive use of the FDS channel in not only adding extra texture but a greater tonal range as the custom waveforms are put into play from the very opening bars of the title music. In fact, Kondō makes use of numerous new waveforms throughout the soundtrack that includes, among other sonic inventions, bell and chime sounds that would have been impossible to achieve with the unexpanded Famicom 2A03 APU. Other titles made even more extensive use of the sound design options with Iwai Toshio's *Otocky* (ASCII Corporation, 1987), a side-scrolling shooting game based around generative music creation, being a key example. Perhaps not unexpectedly given the centrality of music in the game, the player's shooting/sonic inputs are all generated using the FDS' additional channel and make extensive use of its ability to offer a more imitative approach to synthesis that seeks to replicate pianos and orchestral instruments in a way that is hard to imagine attempting with the 2A03 alone.

As if the presence of the optional FDS peripheral and its expanded audio capabilities did not already complicate the stability of the Famicom as a gaming platform, we must also factor in that it met with a relatively swift demise and was taken out of production by Nintendo several years prior to the discontinuation of the Famicom itself. Although the capacity/cost ratio of the FDS' proprietary Quick Disks appeared to offer a substantial boon over the higher-priced equivalent in ROM chips at the peripheral's inception, the situation soon changed. Larger and cheaper ROM chips soon made the FDS' disks seem small, while the FDS' often agonizingly slow load times compared extremely unfavourably with the near instantaneity of the retrieval of data from cartridges. The FDS' anti-piracy measures were easily circumvented, meaning that unauthorized duplication was rife (Plunkett 2012). Retailers, although initially buoyed by cheaper games and plentiful inventory, soon found that the media and the in-store re-writing Disk Writer kiosks that allowed players to load new games onto their blank disks, were troublesome and unreliable (Eisenbeis 2014). Even the transformative re-writability of the FDS' disks was eventually replicated through the addition of a small amount of battery-backed RAM alongside the ROM chips so that progress data and scores could be stored right on the cartridge. In just a few years, the FDS was essentially rendered obsolete by developments in cartridge technology that duplicated the best of its functionality while reaffirming the centrality of copy protection and accelerating loading times.

That the entire lifespan of the FDS existed within that of its host console is notable in itself but it also raises a number of important issues. First, it meant that some games that had initially been FDS exclusives were remade in cartridge format, necessitating the reworking of their musical soundtracks and effects to accommodate the absence of the FDS' expanded audio capabilities. Second, the relative failure of the FDS in Japan meant that, despite plans and even formal announcements of its release in the US, the FDS was never launched outside Japan which, similarly, meant that FDS exclusives had to be reworked for international NES consoles. Reworking the soundtracks of FDS games for the Famicom and NES might seem like identical tasks but, in fact, a further difference between the two consoles reveals itself to complicate the issue yet further.

Music on the edge connector

The ability to expand the Famicom's audio system was made possible by a particularly forward-thinking decision taken during the design phases of the console itself and long before the invention of the FDS that would first put it to use. Compared with other contemporary (and current) console and computing systems that route the output of their soundchips and APUs directly to the device's audio outputs (typically an RF modulator for direct connection to a TV set in the case of devices contemporary with the Famicom), the design of the Famicom saw the output of the 2A03 routed back to the cartridge through an audio-in pin on the cartridge itself. From there, the 2A03 audio could be combined with other signals, mixed and then sent to the system's audio outputs. This is precisely how the FDS's expanded audio works. The output of the 2A03's five channels of sound is fed to the FDS where it is summed with the additional voice before the entire six channel mix is directed to the TV via the console's outputs. This unusual and seemingly circuitous audio path not only presaged the development of the FDS but also made possible a subsequent and undoubtedly even more impactful innovation.

Because the Famicom's 2A03 output is always routed via the audio in pin on the edge connector, the sound signal always enters and exits the system via the cartridge. In many cases, this simply means that the audio is looped around the circuit, passing in and out of the cartridge before it arrives at the console's TV connector completely unaltered and unaffected by its largely fruitless journey. Of course, as we have seen, where there is an FDS connected, an extra channel can be mixed in via the cartridge connector. But, while it was the first device to make use of this internal audio loopback feature, the FDS was by no means the last and soon Nintendo, along with a number of other developers, began adding audio chips to their cartridges in order to augment the 2A03 and add richer, more varied soundtracks to their games.

In fact, the Famicom's architecture and cartridge input/output design meant that these additional chips, or 'mappers' as they are commonly called (especially within the emulation community), are not limited to augmenting audio and might also impact on graphics or perform other co-processing tasks. Here, however, our focus is on those mappers that provide sound generation and audio processing functions. Collectively referred to as 'Famicom expansion audio,' their development and deployment is as intriguing as it is baffling.

In all, six companies produced Famicom cartridges that included mappers with expansion audio capabilities. In addition to mappers created by Jaleco and Bandai, the most notable of these came from Nintendo who produced the 'MMC5' that added three further audio channels (two pulse channels largely identical to those of the 2A03 along with rudimentary PCM sample playback); Namcot's 163 boosted the channel count by up to eight voices of synthesized waveforms, although using more voices led to a trade-off in processing; Sunsoft used a cut-down derivative of the well-known and widely used AY3 soundchip in their '5B' mapper; while Konami produced two mappers, the VRC6 and VRC7, the former adding three voices (two pulses and sawtooth wave) and the latter bringing six channel Frequency Modulation (FM) to the Famicom. Among the most well-known and much-celebrated uses of the VRC6 is found in the energetic melodrama of the soundtrack for *Akumajō Densetsu* (Konami, 1989). The VRC7 is, for reasons we shall see below, synonymous with the 1991 Konami game *Lagrange Point*, released exclusively in Japan, and its soundtrack is quite unlike any other Famicom game has to offer. Regardless of taste or musical preference, it is unarguably the case that *Lagrange Point*'s soundscape is unique, as its basis in FM synthesis is not repeatable using either the 2A03 stock capability or any other Famicom expansion audio.

It might surprise us to learn that the design of the Famicom's cartridge's 'edge' connector (the exposed row of contacts that protrude from the bottom of the plastic cartridge case) meant that it was not simply a means of transferring data to the console. Rather, the edge connector plays host to inputs and outputs and allows communication between the console and the various chips and processors that could be embedded into a Famicom cartridge.

Two things will surely immediately strike those investigating the deployment of Famicom expansion audio mappers. First is just how rarely some of these expansion chipsets were utilized. Given the time and cost that must have accompanied their development, debugging and implementation, one might reasonably expect to see them used more than a handful of times. Aside from the FDS expansion audio which augments the 2A03 on around 70 titles, the Namco 163 leads the cartridge-based pack having been used in ten games including *Mappy Kids* (Namco, 1989) and *Final Lap* (Namcot, 1988), while Konami's FM tour-de-force, the VRC7, and Sunsoft's 5B found their way into just one cartridge each, powering the respective soundtracks of *Lagrange Point* (Konami 1991) and *Gimmick!* (Sunsoft 1992).

Second, one is struck by the fact that each of these chips are referred to as 'Famicom expansion audio mappers' rather than NES or Famicom/NES. The simple reason for this is that there are no expansion audio mappers available for any international NES consoles. Expansion audio is unique to the Famicom. In pondering why, perhaps we might be tempted to concoct theories based around initiatives aimed at reducing the cost of manufacture or international distribution, but the altogether more uncomplicated truth is that the Famicom's cartridge edge connector audio loop feature was removed in the NES. And so, even if a cartridge were to contain a VRC7 and the game code was authored to make use of it, the 2A03 audio would not – could not – be routed to it, as the necessary inputs and outputs on the connector are simply not present.

And so, we encounter in this alteration to the edge connector design yet another under-the-hood difference between the Famicom and NES that further complicates any attempt to conflate the two devices as a single platform. Beyond this, however, our attentions must surely turn to those games released in Japan with Famicom expansion audio. What becomes of their NES releases? The simple answer is that they sound different. But, unlike the differences that arise from the 5/6 slower playback speed of PAL and NTSC NES consoles, here the difference arises from the fact that soundtracks are very often rewritten for the reduced palette of the stock, unembellished 2A03. Of course, examples abound and it almost stands to reason that high-profile Famicom releases would include audio mappers that would not make their way into their NES ports. As such, the removal of the FDS expansion audio leaves Kondō's reworked NES *The Legend of Zelda* melodies rather flat by comparison and lacking the subtle, shimmering vibrato in its opening bars and lacking the textural richness that another voice brings (Mandelin 2015b). Similarly, with the loss of the VRC6, the NES *Castlevania 3* themes are transformed into comparatively thin and lifeless cover versions of the original Famicom *Akumajō Densetsu* soundtrack. To be clear, these are not simply the same pieces with elements missing, these are tunes rewritten for a less capable instrument.

In fact, it is possible to reinstate the ability of the NES to play back expansion audio but only by digging into the guts of the machine and hot-wiring the expansion port which retains the audio loopback capability. However, even without this hybrid, hacked-together NES expansion audio capability, it is abundantly clear that any investigation of the sonic dimensions of the Famicom and NES consoles reveals a wealth of sometimes small but often hugely impactful changes that mark out a web of similarities and differences.

Viewed in this light, the Famicom and NES become fascinating and complex classes of digital object that are sometimes notable for the extent of their differences and sometimes by their apparent indivisibility, but which remain constant elements in that unstable constellation of related materials sometimes orbiting and occasionally colliding with one another. In sonic terms, we might summarize by noting that the presence of extensions to the Famicom such as the FDS and the various cartridge-based audio expansions we have explored, makes it near-impossible to talk definitively or uncomplicatedly about the sound of the Famicom. The N163 adds more than doubles the voice count of the stock APU while the VRC7 transforms it into a FM-based synthesizer whose output would not sound out of place in Mega Drive game or even a budget Yamaha DX synthesizer. By contrast, we can say with a little more certainty that, with the removal of the audio loop from its edge connector, the sound of the NES is very much the sound of the unexpanded 2A03, because it could be nothing more.

As such, what we see, or rather hear, in these examples reminds us that the transformation of the Japanese Famicom into the international NES was an altogether more complex one than is often portrayed in scholarly and popular histories. Indeed, we might well argue that the nature and impact of alterations such as the presence and absence of expanded audio capabilities through the cartridge connector or the availability of the FDS peripheral might lead us to think about these devices as different platforms, or at the very least as distinctive objects in the broader Famicom/NES constellation.

Dedication

Writing this piece is tinged with sadness as, in December 2021, Uemura Masayuki passed away. As the head of Nintendo's R&D2 division, Uemura-sensei was responsible for the design of many of the company's most important and influential gaming systems including the Famicom. It was my great pleasure to have had the opportunity to work with Uemura-sensei on a number of projects over the years and I am grateful to have learned so much from his approach to the past, present and

future of games and play. There are very few people who can claim to have changed the face of contemporary popular culture, and while Uemura-sensei would have been too humble to have even thought such a thing about himself, I say without hesitation that he ranks among that number.

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